

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

IBG LLC and INTERACTIVE BROKERS LLC,

Petitioner

v.

TRADING TECHNOLOGIES INTERNATIONAL, INC.

Patent Owner

Case CBM2016-00009
U.S. Patent No. 7,685,055

DECLARATION OF DAN R. OLSEN, JR.

I. Qualifications

1. I, Dan R. Olsen Jr., Ph.D., am a resident of Orem, Utah and have more than 35 years of experience in computer science and human-computer interaction (HCI). I hold a doctorate in Computing and Information from the University of Pennsylvania. For 3 ½ years I was an Assistant Professor of Computer Science at Arizona State University. I then served for 30 years on the faculty of Brigham Young University retiring as a full professor in 2015. During that time at BYU, I also served as the chair of the Department of Computer Science. I took leave from BYU in 1996 to become the founding director of the Human Computer Interaction Institute in the School of Computer Science at Carnegie Mellon University. I returned to BYU in 1998. I am currently the CEO of a software startup in educational technology (SparxTeq, Inc).

2. During the course of my academic career, I authored over 70 papers in the field of computer science. The topics on which I have published papers are:

- User Interface Management Systems
- Syntactic representations of user interfaces
- Multi-user interaction across networks
- Induction of interaction behavior from pictures
- Novel interaction techniques using speech and laser pointers
- Interactive machine learning

- Interactive robotics
- Interactive television

3. I currently hold 4 patents in human-computer interaction. I have authored 3 textbooks on the techniques of software design for human-computer interaction.

4. I have had extensive involvement in professional societies, such as the Association for Computing Machinery (ACM), the premiere society in computing. I have served in many offices of ACM's Special Interest Group on Computer Human Interaction (SIGCHI) and currently serve as its treasurer. I have been conference chair of CHI, which is the premier conference in Computer Human Interaction. I was the founding editor of ACM's Transactions on Computer Human Interaction. I was a co-founder and active leader for the conference on User Interface Software and Technology (UIST) for the past 29 years. I have also served at the governor's request on the Utah Science, Technology and Research (USTAR) board, which oversees and funds state economic development efforts in technology.

5. I twice received best paper awards in intelligent user interfaces. In 2004, I was appointed to the CHI Academy for international excellence in Computer Human Interaction research. In 2007, I was recognized as one of ACM's

Fellows for research in computer science and in 2012 received the CHI Lifetime Research Award, which is the highest award in Computer Human Interaction.

II. Graphical User Interfaces and the '055 Patent

6. Attorneys for the Patent Holder have explained to me that U.S. Patent No. 7,685,055 (“the ‘055 patent”) has been challenged as a Covered Business Method (CBM) patent. I have been asked to review the nature of the invention in the ‘055 patent. As explained below, it is my opinion that the ‘055 patent claims a technological invention because the claimed invention provides a technical improvement to prior graphical user interfaces.

III. Historical context

7. In discussing how graphical user interfaces are a technology with specific technical problems, I would first like to refer to two very old patents involving earlier mechanical technologies. I will use these two patents to illustrate two key pieces of technical knowledge that are used widely in graphical user interface (GUI) technology.

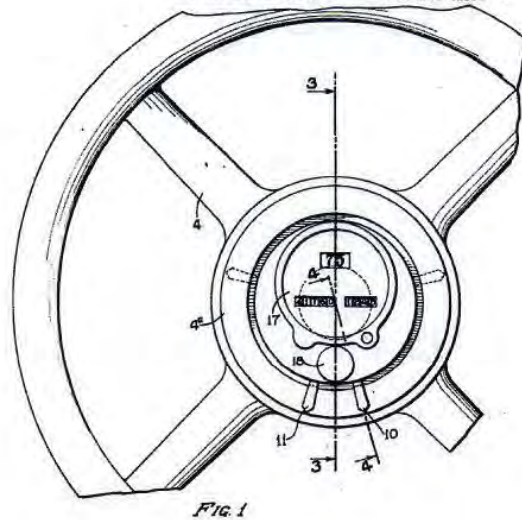


Figure 1 – Speedometer in the Steering Wheel.

IV. Simplification of perception – US patent 1,692,601

8. In 1928, U.S. patent 1,692,601 was issued for an automobile speedometer that was mounted in the center of the steering wheel. This patent claims the ability to perceive an automobile's speed. It was not for the sensor for measuring speed (which was well known at the time). It was not for the concept of displaying speed in a meter (which was also well known). The key claim was as follows:

first, to provide a steering control means -for vehicles on which is mounted a speedometer whereby the speed of the vehicle may be readily determined by merely dropping the vision slightly to the middle portion of the steering wheel which is substantially in line with the line of vision of the driver and as close to the eyes of the driver as

possible, thus determining the speed of the vehicle with least danger to the driver and other occupants ...

9. This patent's key contribution was that it placed the speedometer in the center of the steering wheel where it was easier for the driver to perceive. This was not awarded for the esthetics or appearance of that speedometer placement. It was the arrangement of the components of the technology for easiest human perception that was the key to this patent. It will be shown in this report that the '055 patent claims constructing a GUI to display information in particular locations to improve the interface between man and machine by improving the user's perception of the relevant information, with bits and pixels comprising the GUI elements rather than cables, shafts and gears.

V. Reduction of human effort - US 714,878

10. In 1902, U.S. patent 714,878 was issued for a new steering mechanism. The claim was not for steering, which was well known, and not for the gears, shafts and motive power that were used. The essential claim of this patent is as follows:

This invention relates to improvements in motor-vehicles or automobiles, and more particularly to the class of such vehicles wherein the front Wheels are both the driven and the steering wheels; and the invent-ion more especially pertains to the mechanisms and

controlling appliances whereby the motor may be made available for the propulsion of the vehicle through the front steering wheels, whereby the motor may be employed to swing the steering-wheels to steer, whereby the motor may be simultaneously caused to both drive and steer, and whereby the motor may only drive the steering-wheels, the steering being operated manually.

The improved mechanism is especially useful on large and heavy motor wagons or trucks in which, especially at the time of starting the same, considerable power is necessary to change the relative position of the wheels under the body.

11. By this time the steering of vehicles was well known. The specific technical problem that was addressed was that with very heavy vehicles the power required to turn the steering wheels was beyond the capacity of normal human beings. They were simply not strong enough. In this patent, a mechanism is described for using power from the motor to perform the task that a human could not do. As explained in this report, the '055 patent, rather than using a motor to reduce human effort, describes a way of constructing a GUI to increase speed, efficiency and usability. Bits and pixels comprising GUI components have replaced gears, motors and shafts but again human capacity to control and interface with a machine has still been enhanced in a novel way.

VI. Graphical User Interface Technology

12. One of the questions at issue in the Petitioner's arguments is whether or not GUIs constitute a technology. User interface technology is the subject of study at institutions such as MIT-Media Lab, CMU-HCI Institute in their School of Computer Science, Stanford, UC-Berkeley, University of Washington and Georgia Tech. All of these highly technical institutions have strong research faculty and educational programs in human-computer interaction. The goals of HCI research are to invent new ways for people to interact with computers. This is not a new field of study, but rather a subset of man-machine interface design. Indeed, HCI has adopted a number of terms from its mechanical parent. For example, buttons, sliders, exist in both fields for study, and just as changes to these features may provide an improvement in a mechanical device, improving the equivalent features in a GUI allows a computer to function better or even in ways that were not previously conceived. For example, the various GUIs on the iPhone transform it into a phone, compass, calculator, and so on. Without these GUIs, the iPhone is a useless handheld computer. Indeed, the iPhone itself uses HCI design, for example, by using slide to unlock to access the phone to replace a mechanical lock.

13. Two common measures of success in HCI research are speed and accuracy. Learnability is also a common success metric. The ease with which someone can master a user interface is very important. Although esthetics do come

into play when marketing some types of products (e.g., retail products), HCI researchers generally ignore this aspect and focus on making a user interface more effective rather than just prettier.

14. Merriam-Webster dictionary defines technology as “the practical application of knowledge, especially in a particular area.” At issue then is the knowledge, or scientific principles, that cause the invention claimed in the ‘055 patent to work better than previous solutions. In my opinion, at least two basic GUI principles cause users to perceive the claimed GUI as an improvement over prior GUIs, namely: human visual search, and optimizing human effort. This section of the report includes a light introduction to these principles so that they can be understood with respect to the claims of the ‘055 patent.

VII. GUI Architecture

15. In the case of the ‘055 patent, the claims identify the specific architecture/make-up, functionality, and structural components, including a dynamic display aligned with a static price axis providing information about the particular commodity market in which trades are occurring. The ‘055 patent particularly describes a mechanism whereby the user can more easily control the display as it adapts to changes in the market. The design of this GUI, including its claimed adjusting and repositioning features are critical to the user’s ability to correctly perceive the state of the interaction information. There are many

possibilities for the design of the GUI architecture and they will vary widely in how rapidly and accurately the user can perceive information the user is trying to perceive. The claims of the '055 patent describe how to construct a GUI with a very specific and concrete arrangement and repositioning of the presentation of the market information aligned with a static price axis so as to facilitate the user's (trader) perception of the market. With this static price axis comes a need to adapt to the changes of market pricing in a way that is effective for the user with very little effort.

16. The '055 patent claims provide a GUI that a user can see, feel and interact with no differently than a mechanical device. The '055 claims provide technical solutions to the technical problems of user's perception of market data. For example, the '055 patent claims provide an innovative mechanism for adapting that display to market changes by providing the claimed adjusting and repositioning of the static price axis.

17. Innovation in human control of processes has a long patent history. US Patent 3,018,661 issued in 1957 is for an aviation display. The goal of this display is as follows:

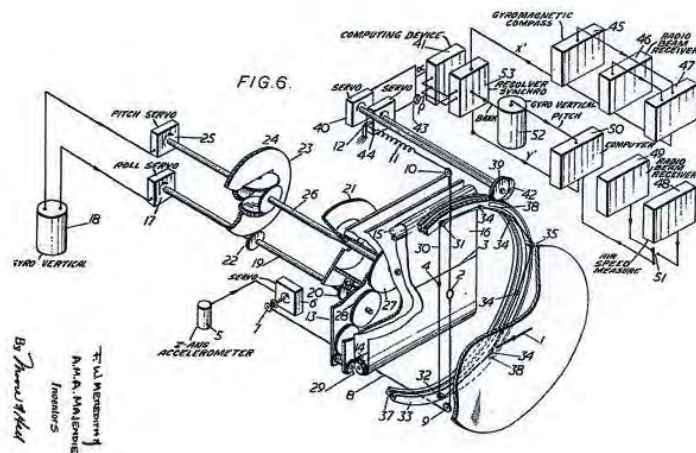
It is an object of the present invention to provide an aircraft instrument constructed to facilitate the control of an aircraft simultaneously in pitch and roll by a human

pilot and which preferably is combined with means to display the pitch and roll attitude of the aircraft to give a readily appreciated indication of the actual attitude of the aircraft and the action which is required to attain the desired flight path.

And the patent claimed providing that particular way of presenting information as follows:

1. An aircraft instrument comprising means to define a viewing aperture, a first index supported for movement within the aperture, means within the aperture to define a datum position for the first index, driving means connected to the first index, means to control the driving means in accordance with the component of the normal plane absolute acceleration of the aircraft in direction of its Z axis so that the displacement of the first index from the said datum position is proportional to the said component of the normal plane absolute acceleration of the aircraft, a further index supported for movement within the aperture and means to displace the further index in relation to the said datum position in accordance

with a demanded value, both as to magnitude and direction of the normal plane absolute acceleration, said demanded value being that required if some desired flight path is to be achieved and a maneuver of the aircraft in bank and pitch to superpose the first index and further index thus resulting in the attainment of the demanded normal plane acceleration and the desired flight path, neglecting any components of the normal plane absolute acceleration in the direction of the transverse axis of the aircraft.



18. The innovation in this aviation patent relies upon the pilot's ability to perceive his current flight state in a way that will more easily allow him to control

the plane. The '055 patent innovates in a similar way using the claimed structure, makeup and functionality of a GUI rather than gears and dials.

VIII. Human factors

19. This is not the place for a complete discussion of the human factors principles that impact the design of interfaces between man and machine. However, there are three that are instructive in this case. They are: short term memory, foveated perception and expressive leverage.

A. Seven +/- two

20. A great deal of what we do when we work depends upon our short-term memory. Short term memory consists of the knowledge we need right now for the task at hand. It has been shown that the number of concepts that can be held in short term memory is between 5 and 9, which is described as the “seven plus or minus two” rule. When the amount of information required for a task exceeds these limits we forget something to make room for a new piece of information. This is why talking with someone will cause us to forget a phone number that we just looked up. The new information from talking pushes out the phone number we just saw. In commodity trading, driving a car, or piloting aircraft there are many pieces of information that must be considered rapidly and simultaneously to perform successfully.

B. Foveated perception

21. When information is displayed on the screen, the speed and accuracy with which a user can interact is heavily influenced by their ability to find desired information on the screen. The visual search for information is largely controlled by the anatomy of the eye and specifically the retina. Figure 3 shows the anatomy of the eye. Most of the retina is the periphery with a small spot near the center called the macula or the fovea. The periphery has a lot of sensors but they are quite spread out and can only sense gray, not color. This means that most of the image that we see at any one time is gray and quite blurry. The sensors at the fovea are densely packed so that we see in high resolution and they also can sense color.

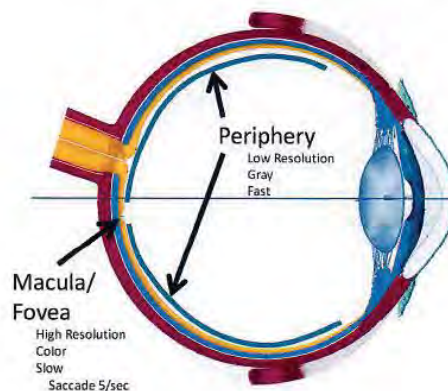


Figure 3 – Eye anatomy

22. At first most people do not believe that their eye works this way because they think they see everything in high resolution and in color. In actuality that is your visual memory that is supplying the information as well as the fact that

your eye can move very rapidly. As soon as you think about wanting to see something, your eye moves to look at it and it appears in high resolution. This effect can be understood by a simple experiment. Pick a line of text in the middle of this paragraph. Hold your eyes still and without moving them, attempt to read the lines above and below. With double-spaced text you will not be able to see anything but a blur outside of the line you are looking at.

23. Because only the fovea can pick up high resolution information, it relies upon the eye's ability to move very rapidly (5 times per second) and on the periphery to identify important locations to look. However, the periphery is limited in its ability to identify where to look because of its low resolution (blurry images). Good interface design will organize information so that it is easy for the periphery to identify where the eye should look for the desired information. For example, this is why warning lights in a car are displayed around a car's more frequently viewed speedometer. The claims of the '055 patent describe a particular way of constructing a GUI with a specific set of visual relationships to simplify visual search for the information.

C. Expressive leverage

24. The process of visual search is only part of the technical problem of creating an efficient interactive solution. We also need to minimize the human effort to interact with the GUI. One principle of such interactivity is called

“expressive leverage” [OLSE 07]. Expressive leverage is the ratio between the amount of information to be expressed and the amount of human effort required in such expression. High expressive leverage creates very efficient user interfaces. Natural languages such as English are attractive due to their high expressive leverage.

25. A very common way to measure human effort in an interaction is the keystroke-level model (KLM) [CARD 08]. This simply counts the number of key or button entries required to accomplish a task. This measure has many limitations but it will serve here as a simple measure of expressive leverage in this discussion.

Use Previous	
Name:	George Mendenhall
Street Address:	1450 Sonoma Blvd
City:	Pig Creek
State:	CA
Zip:	98765

Figure 4 – Form Filling

26. In one application a user may be required to enter a shipping address using the form shown in figure 4. To enter the address shown in the figure requires 49 key presses plus 5 mouse clicks for a KLM measure of 54. If the user enters this address many times, the designers can introduce the “Use Previous” button that

requires only 1 click (expressive leverage of 54/1) to accomplish the task. This is the technique used by Amazon in US Patent 5,960,411. These examples are modern instances of the same kind of innovation found in the power steering patent. Again bits and pixels have replaced shafts, wheels and gears but the concept of magnifying the power of humans to effect desired actions is the same.

IX. The '055 patent analysis

27. The preceding discussion has laid out some of the knowledge and principles found in the field of interface design. We have shown that improvements to interfaces have long been the subject of patentable technologies and provide specific benefits. In particular, the '055 patent addresses the technical problem of GUIs with a static price axis, such as the one in the '132 patent, where the display of information can be adjusted and repositioned so that it is responsive to market changes while retaining the benefits of displaying bid/ask indicators relative to a static price axis. It is not the nature of commodity trading that is claimed in the '055 patent but rather the technology of a new mechanism that improves usability, speed and efficiency.

SYCOM FGBL DEC99						
	E/W	10:48:44	BidQ	AskQ	Prc	LTQ
1009	L	3		104	99	
1010	R	5		24	98	
1011		720		33	97	
1012	X	10		115	96	
1013		0				
1014		10 1H		32	95	
		50 3H		27	94	
1007	S 0 W 24	1K 5H		63	93	
	S 0 W 7	CLR		45	92	
1015	X	10		28	91	
1016		17		20	90	10
1008	B 0 W 15	CXL	18		89	
	B 0 W 13	+ -	97		88	
1017		NET 0	30		87	
1018	B 0 W 17	NET REAL	43		86	
1019			110		85	
			23		84	
			31		83	
1021			125		82	
			21		81	

Figure 5 – [Figure 3] from the '055 patent

28. The claim 1¹ recites the following “adjusting” feature:
 in response to an input command received via an input device associated with the computing device, adjusting the first plurality price levels among a range of price levels to an adjusted plurality of price levels including the first plurality of price levels;

¹ Claim 17 includes a similar feature. Ex. 1001, 36:14-25.

displaying a bid and ask display region on the graphical user interface, the bid and ask display region comprising a plurality of locations corresponding to the first plurality of price levels displayed along the static price axis, wherein each location corresponds to one of the first plurality of price levels, and wherein a number of the plurality of locations changes according to adjusting the first plurality of price levels;

29. This adjusting allows the user to extend the visible range of the market the price axis can remain static (simplifying perception and interaction) relative to a wider range of market prices. This size is always a tradeoff with other information on the screen. This element empowers the user to make that tradeoff decision.

30. The claim 1² recites the following “repositioning” feature:
receiving the reposition command to reposition the static price axis when a designated price is within a designated number of price levels from the lowest value or the highest value along the static price axis; and
responsive to receiving the reposition command,
automatically repositioning the static price axis on the

² Claim 17 includes a similar feature. Ex. 1001, 36: 45-52.

graphical user interface such that a current inside market price is displayed at a new desired location.

31. This repositioning provides the ability to keep relevant information on the interface. Unlike a speedometer example, market prices have no natural limit. In a rising market, for example, the price could rise beyond the limited range of the static price axis. When this happens, the static price axis needs to be reset so that the current market status is visible. These two elements engage three principles of GUI design. The first is simplification of visual search. These elements do not continuously move the price axis because that would make visual search confusing. Holding the price axis static until “a designated price is within a designated number of price levels” maintains the static presentation that is beneficial for visual search.

32. Because the repositioning is performed automatically, the user does not need to think about maintaining the price axis in an appropriate range. This engages the “seven plus or minus two” rule. Because the user does not need to consider repositioning of the price axis, short term memory is conserved for tasks related to trading commodities rather than managing the user interface.

33. Because the user need only rarely issue the reposition command that sets the parameters for repositioning, these elements provide expressive leverage.

The parameters of the reposition command are reused continually in repositioning without additional effort on the part of the user.

34. The whole of the language of claim 1 is not about executing commodity trades. The claim provides the structure, make-up, and functionality to address technical problems with the usability, speed and efficiency of an interface with a static price axis. The inventors have applied GUI design knowledge to the particular area of commodities trading to achieve a practical solution of providing a more efficient interface for doing commodity trading for some users. Thus, they have applied technical knowledge to a technical problem.

X. References

[CARD 80] Card, Stuart K; Moran, Thomas P; Allen, Newell (1980). "The keystroke-level model for user performance time with interactive systems".
Communications of the ACM 23 (7): 396–410.

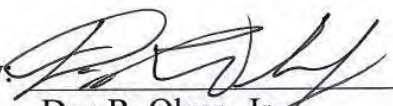
[OLSE 07] Olsen, D. R. "Evaluating User Interface Systems Research,"
UIST 2007, ACM (2007)

I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Date:

7/20/16

By:


Dan R. Olsen, Jr.

APPENDIX A

[CARD 80]

The Keystroke-Level Model for User Performance Time with Interactive Systems

Stuart K. Card and Thomas P. Moran
Xerox Palo Alto Research Center

Allen Newell
Carnegie-Mellon University

There are several aspects of user-computer performance that system designers should systematically consider. This article proposes a simple model, the Keystroke-Level Model, for predicting one aspect of performance: the time it takes an expert user to perform a given task on a given computer system. The model is based on counting keystrokes and other low-level operations, including the user's mental preparations and the system's responses. Performance is coded in terms of these operations and operator times summed to give predictions. Heuristic rules are given for predicting where mental preparations occur. When tested against data on 10 different systems, the model's prediction error is 21 percent for individual tasks. An example is given to illustrate how the model can be used to produce parametric predictions and how sensitivity analysis can be used to redeem conclusions in the face of uncertain assumptions. Finally, the model is compared to several simpler versions. The potential role for the Keystroke-Level Model in system design is discussed.

Key Words and Phrases: human-computer interface, human-computer interaction, user model, user performance, cognitive psychology, ergonomics, human factors, systems design

CR Categories: 3.36, 4.6, 8.1

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© 1980 ACM 0001-0782/80/0700-0396 \$00.75.

1. Introduction

The design and evaluation of interactive computer systems should take into account the total performance of the combined user-computer system. Such an account would reflect the psychological characteristics of users and their interaction with the task and the computer. This rarely occurs in any systematic and explicit way. The causes of this failure may lie partly in attitudes toward the possibility of dealing successfully with psychological factors, such as the belief that intuition, subjective experience, and anecdote form the only possible bases for dealing with them. Whatever may be true of these more global issues, one major cause is the absence of good analysis tools for assessing combined user-computer performance.

There exists quite a bit of research relevant to the area of user-computer performance, but most of it is preliminary in nature. Pew et al. [14], in a review of 40 potentially relevant human-system performance models, conclude "that integrative models of human performance compatible with the requirements for representing command and control system performance do not exist at the present time." Ramsey and Atwood [15], after reviewing the human factors literature pertinent to computer systems, conclude that while there exists enough material to develop a qualitative "human factors design guide," there is insufficient material for a "quantitative reference handbook."

This paper presents one specific quantitative analysis tool: a simple model for the time it takes a user to perform a task with a given method on an interactive computer system. This model appears to us to be simple enough, accurate enough, and flexible enough to be applied in practical design and evaluation situations.

The model addresses only a single aspect of performance. To put this aspect into perspective, note that there are many different dimensions to the performance of a user-computer system:

- *Time*. How long does it take a user to accomplish a given set of tasks using the system?
- *Errors*. How many errors does a user make and how serious are they?
- *Learning*. How long does it take a novice user to learn how to use the system to do a given set of tasks?
- *Functionality*. What range of tasks can a user do in practice with the system?
- *Recall*. How easy is it for a user to recall how to use the system on a task that he has not done for some time?

The authors of this report are listed in alphabetical order. A. Newell is a consultant to Xerox PARC. This paper is a revised version of [3]. For a view of the larger research program of which the study described in this paper is a part, see [5].

Concentration. How many things does a user have to keep in mind while using the system?

Fatigue. How tired do users get when they use the system for extended periods?

Acceptability. How do users subjectively evaluate the system?

Next, note that there is *no single kind of user*. Users vary along many dimensions:

- Their *extent of knowledge* of the different tasks.
- Their *knowledge of other systems*, which may have positive or negative effects on the performance in the system of interest.
- Their *motor skills* on various input devices (e.g., typing speed).
- Their general *technical ability* in using systems (e.g., programmers vs. nonprogrammers).
- Their *experience* with the system, i.e., whether they are *novice users*, who know little about the system; *casual users*, who know a moderate amount about the system and use it at irregular intervals; or *expert users*, who know the system intimately and use it frequently.

Finally, note that there is *no single kind of task*. This is especially true in interactive systems, which are expressly built around a command language to permit a wide diversity of tasks to be accomplished. The number of qualitatively different tasks performable by a modern text editor, for instance, runs to the hundreds.

All aspects of performance, all types of users, and all kinds of tasks are important. However, no uniform approach to modeling the entire range of factors in a simple way appears possible at this time. Thus, of necessity, the model to be presented is specific to one aspect of the total user-computer system: *How long it takes expert users to perform routine tasks.*

The model we present here is simple, yet effective. The central idea behind the model is that the time for an expert to do a task on an interactive system is determined by the time it takes to do the keystrokes. Therefore, just write down the method for the task, count the number of keystrokes required, and multiply by the time per keystroke to get the total time. This idea is a little too simplistic. Operations other than keystrokes must be added to the model. Since these other operations are at about the same level (time grain) as keystrokes, we dub it the "Keystroke-Level Model." (The only other similar proposal we know of is that of Embley et al. [9], which we discuss in Section 6.1.)

The structure of this paper is as follows: Section 2 formulates the time prediction problem more precisely. Section 3 lays out the Keystroke-Level Model. Section 4 provides some empirical validation for the model. Section 5 illustrates how the model can be applied in practice. And Section 6 analyzes some simpler versions of the model.

2. The Time Prediction Problem

The prediction problem that we will address is as follows:

Given: A task (possibly involving several subtasks); the command language of a system; the motor skill parameters of the user; the response time parameters of the system; the method used for the task.

Predict: The time an expert user will take to execute the task using the system, providing he uses the method without error.

Several aspects of this formulation need explication, especially the stipulations about execution, methods, and the absence of error.

2.1 Unit Tasks and Execution Time

Given a large task, such as editing a large document, a user will break it into a series of small, cognitively manageable, quasi-independent tasks, which we call *unit tasks* [4; 5, ch. 11]. The task and the interactive system influence the structure of these unit tasks, but unit tasks appear to owe their existence primarily to the memory limits on human cognition. The importance of unit tasks for our analysis is that they permit the time to do a large task to be decomposed into the sum of the times to do its constituent unit tasks. Note that not all tasks have a unit-task substructure. For example, inputting an entire manuscript by typing permits a continuous throughput organization.

For our purposes here, a unit task has two parts: (1) *acquisition* of the task and (2) *execution* of the task acquired. During acquisition the user builds a mental representation of the task, and during execution the user calls on the system facilities to accomplish the task. The total time to do a unit task is the sum of the time for these two parts:

$$T_{\text{task}} = T_{\text{acquire}} + T_{\text{execute}}$$

The acquisition time for a unit task depends on the characteristics of the larger task situation in which it occurs. In a manuscript interpretation situation, in which unit tasks are read from a marked-up page or from written instructions, it takes about 2 to 3 seconds to acquire each unit task. In a routine design situation, in which unit tasks are generated in the user's mind, it takes about 5 to 30 seconds to acquire each unit task. In a creative composition situation, it can take even longer.

The execution of a unit task involves calling the appropriate system commands. This rarely takes over 20 seconds (assuming the system has a reasonably efficient command syntax). If a task requires a longer execution time, the user will likely break it into smaller unit tasks.

We have formulated the prediction problem to predict only the execution time of unit tasks, not the acquisition time. This is the part of the task over which the system designer has most direct control (i.e., by manipulating the system's command language), so its prediction suffices for many practical purposes. Task acquisi-

tion times are highly variable, except in special situations (such as the manuscript interpretation situation); and we can say little yet about predicting them.

Two important assumptions underlie our treatment of execution time. First, execution time is the same no matter how a task is acquired. Second, acquisition time and execution time are independent (e.g., reducing execution time by making the command language more efficient does not affect acquisition time). These assumptions are no doubt false at a fine level of detail, but the error they produce is probably well below the threshold of concern in practical work.

2.2 Methods

A *method* is a sequence of system commands for executing a unit task that forms a well-integrated ("compiled") segment of a user's behavior. It is characteristic of an expert user that he has one or more methods for each type of unit task that he encounters and that he can quickly (in about a second) choose the appropriate method in any instance. This is what makes expert user behavior routine, as opposed to novice user behavior, which is distinctly nonroutine.

Methods can be specified at several levels. A user actually knows a method at all its levels, from a general system-independent functional specification, down through the commands in the language of the computer system, to the keystrokes and device manipulations that actually communicate the method to the system. Models can deal with methods defined at any of these levels [4, 11]. The Keystroke-Level Model adopts one specific level—the keystroke level—to formalize the notion of a method, leaving all the other levels to be treated informally.

Many methods that achieve a given task can exist. In general such methods bear no systematic relationship to each other (except that of attaining the same end). Each can take a different amount of time to execute, and the differences can be large. Thus, in general, if the method is unknown, reasonable predictions of execution time are not possible. For this reason, the proper prediction problem is the one posed at the beginning of the section: Predict the time given the method.

2.3 Error-Free Execution

The Keystroke-Level Model assumes that the user faithfully executes the given method. The user deviates from a postulated method when he makes an error. Up to a fourth of an expert's time can be spent correcting errors, though users vary in their trade-off between speed and errors. We are simply ignoring the tasks containing errors and only predicting the error-free tasks, for we do not know how to predict where and how often errors occur. But, if the method for correcting an error is given, the model can be used to predict how long it will take to make the correction. Indeed, experts handle most errors in routine ways, i.e., according to fixed, available methods.

3. The Keystroke-Level Model

We lay out the primitive operators for the Keystroke-Level Model and give a set of heuristics for coding methods in terms of these operators. Then we present a few examples of method encoding.

3.1 Operators

The Keystroke-Level Model asserts that the execution part of a task can be described in terms of four different physical-motor operators: **K** (keystroking), **P** (pointing), **H** (homing), and **D** (drawing), and one mental operator, **M**, by the user, plus a response operator, **R**, by the system. These operators are listed in Figure 1. Execution time is simply the sum of the time for each of the operators.

$$T_{\text{execute}} = T_K + T_P + T_H + T_D + T_M + T_R. \quad (1)$$

Most operators are assumed to take a constant time for each occurrence, e.g., $T_K = n_K t_K$, where n_K is the number of keystrokes and t_K is the time per keystroke. (Operators **D** and **R** are treated somewhat differently.)

The most frequently used operator is **K**, which represents a keystroke or a button push (on a typewriter keyboard or any other button device). **K** refers to keys, not characters (e.g., hitting the **SHIFT** key counts as a separate **K**). The average time for **K**, t_K , will be taken to be the standard typing rate, as determined by standard one-minute typing tests. This is an approximation in two respects. First, keying time is different for different keys and key devices. Second, the time for immediately caught typing errors (involving **BACKSPACE** and rekeying) should be folded into t_K . Thus, the preferred way to calculate t_K from a typing test is to divide the total time taken in the test by the total number of nonerror keystrokes, which gives the *effective* keying time. We accept both these approximations in the interest of simplicity.

Users can differ in their typing rates by as much as a factor of 15. The range of typing speeds is given in Figure 1. Given a population of users, an appropriate t_K can be selected from this range. If a user population has users with large t_K differences, then the population should be partitioned and analyzed separately, since the different classes of users will be likely to use different methods.

The operator **P** represents pointing to a target on a display with a "mouse," a wheeled device that is rolled around on a table to guide the display's cursor. Pointing time for the mouse varies as a function of the distance to the target, d , and the size of the target, s , according to Fitts's Law [2]:

$$t_P = .8 + .1 \log_2 (d/s + .5) \text{ sec.}$$

The fastest time according to this equation is .8 sec, and the longest likely time ($d/s = 128$) is 1.5 sec. Again, to keep the model simple, we will use a constant time of 1.1 sec for t_P . Often, pointing with the mouse is followed by pressing one of the buttons on the mouse. This key press is not part of **P**; it is represented by a **K** following the **P**.

Fig. 1 The Operators of the Keystroke Model.

Operator	Description and Remarks	Time (sec)
K	Keystroke or button press. Pressing the SHIFT or CONTROL key counts as a separate K operation. Time varies with the typing skill of the user; the following shows the range of typical values:	
	Best typist (135 wpm)	.08 ^a
	Good typist (90 wpm)	.12 ^a
	Average skilled typist (55 wpm)	.20 ^a
	Average non-secretary typist (40 wpm)	.28 ^b
	Typing random letters	.50 ^a
	Typing complex codes	.75 ^a
Worst typist (unfamiliar with keyboard)	1.20 ^a	
P	Pointing to a target on a display with a mouse. The time to point varies with distance and target size according to Fitts's Law. The time ranges from .8 to 1.5 sec, with 1.1 being an average time. This operator does not include the button press that often follows (.2 sec).	1.10 ^c
H	Homing the hand(s) on the keyboard or other device.	.40 ^d
D(n_D, l_D)	Drawing (manually) n_D straight-line segments having a total length of l_D cm. This is a very restricted operator; it assumes that drawing is done with the mouse on a system that constrains all lines to fall on a square .56 cm grid. Users vary in their drawing skill; the time given is an average value.	$.9n_D + .16l_D^e$
M	Mentally preparing for executing physical actions.	1.35 ^f
R(t)	Response of t sec by the system. This takes different times for different commands in the system. These times must be input to the model. The response time counts only if it causes the user to wait.	t

^a See [8].

^b This is the average typing rate of the nonsecretary subjects in the experiment described in Section 4.1.

^c See [2].

^d See [2, 4].

^e The drawing time function and the coefficients were derived from least squares fits on the drawing test data from the four MARKUP subjects. See Sections 3.1 and 4.1.

^f The time for M was estimated from the data from experiment described in Section 4.1. See Section 4.2.1.

The mouse is an optimal pointing device as far as time is concerned; but the t_P is about the same for other analog pointing devices, such as lightpens and some joysticks [2].

When there are different physical devices for the user to operate, he will move his hands between them as needed. This hand movement, including the fine positioning adjustment of the hand on the device, is represented by the H ("homing") operator. From previous studies [2, 4], we assume a constant t_H of .4 sec for movement between any two devices.

The D operator represents manually drawing a set of straight-line segments using the mouse. D takes two parameters, the number of segments (n_D) and the total length of all segments (l_D). $t_D(n_D, l_D)$ is a linear function of these two parameters. The coefficients of this function are different for different users; Figure 1 gives an average value for them. Note that this is a very specialized operator. Not only is it restricted to the mouse, but also it assumes that the drawing system constrains the cursor to lie on a .56 cm grid. This allows the user to draw

straight lines fairly easily, but we would expect t_D to be different for different grid sizes. We make no claim for the generality of these times or for the form of the drawing time function. However, inclusion of one instance of a drawing operator serves to indicate the wide scope of the model.

The user spends some time "mentally preparing" to execute many of the physical operators just described; e.g., he decides which command to call or whether to terminate an argument string. These mental preparations are represented by the M operator, which we estimate to take 1.35 sec on the average (see Section 4.2.1). The use of a single mental operator is, again, a deliberate simplification.

Finally, the Keystroke-Level Model represents the system response time by the R operator. This operator has one parameter, t , which is just the response time in seconds. Response times are different for different systems, for different commands within a system, and for different contexts of a given command. The Keystroke-Level Model does not embody a theory of system re-

sponse time. The response times must be input to the model by giving specific values for the parameter t , which is a placeholder for these input times.

The **R** times are counted only when they require the user to *wait for the system*. For example, a system response counts as an **R** when it is followed by a **K** and the system does *not* allow type-ahead, and the user must wait until the response is complete. However, when an **M** operation follows a response, the response time is not counted unless it is over 1.35 sec, since the expert user can completely overlap the **M** operation with the response time. Response times can also overlap with task acquisition. When a response is counted as an **R**, only the nonoverlapping portion of the response time is given as the parameter to **R**.

3.2 Encoding Methods

Methods are represented as sequences of Keystroke-Level operations. We will introduce the notation with examples. Suppose that there is a command named **PUT** in some system and that the method for calling it is to type its name followed by the **RETURN** key. This method is coded by simply listing the operations in sequence: **MK[P] K[U] K[R] K[RETURN]**, which we abbreviate as **M 4K[P U T RETURN]**. In this notation we allow descriptive notes (such as key names) in square brackets. If, on the other hand, the method to call the **PUT** command is to point to its name in a menu and press the **RED** mouse button, we have: **H[mouse] MP[PUT] K[RED] H[keyboard]**.

As another example, consider the text editing task (called **T1**) of replacing a 5-letter word with another 5-letter word, where this replacement takes place one line below the previous modification. The method for executing task **T1** in a line-oriented editor called **POET** (see Section 4) can be described as follows:

Method for Task T1-Poet:

Jump to next line	MK[LINEFEED]
Call Substitute command	MK[S]
Specify new 5-digit word	5K[word]
Terminate argument	MK[RETURN]
Specify old 5-digit word	5K[word]
Terminate argument	MK[RETURN]
Terminate command	K[RETURN]

Using the operator times from Figure 1 and assuming the user is an average skilled typist (i.e., $t_K = .2$ sec), we can predict the time it will take to execute this method:

$$T_{execute} = 4t_M + 15t_K = 8.4 \text{ sec.}$$

This method can be compared to the method for executing task **T1** on another editor, a display-based system called **DISPED** (see Section 4):

Method for Task T1-Disped:

Reach for mouse	H[mouse]
Point to word	P[word]
Select word	K[YELLOW]
Home on keyboard	H[keyboard]
Call Replace command	MK[R]
Type new 5-digit word	5K[word]
Terminate type-in	MK[ESC]

$$T_{execute} = 2t_M + 8t_K + 2t_H + t_P = 6.2 \text{ sec.}$$

Fig. 2. Heuristic rules for placing the **M** operations.

Begin with a method encoding that includes all physical operations and response operations. Use Rule 0 to place candidate **M**s, and then cycle through Rules 1 to 4 for each **M** to see whether it should be deleted.

Rule 0. Insert **M**s in front of all **K**s that are not part of argument strings proper (e.g., text strings or numbers). Place **M**s in front of all **P**s that select commands (not arguments).

Rule 1. If an operator following an **M** is *fully anticipated* in the operator just previous to **M**, then delete the **M** (e.g., **PMK** → **PK**).

Rule 2. If a string of **MK**s *belongs to a cognitive unit* (e.g., the name of a command), then delete all **M**s but the first.

Rule 3. If a **K** is a *redundant terminator* (e.g., the terminator of a command immediately following the terminator of its argument), then delete the **M** in front of the **K**.

Rule 4. If a **K** *terminates a constant string* (e.g., a command name), then delete the **M** in front of the **K**; but if the **K** terminates a variable string (e.g., an argument string), then keep the **M**.

Thus, we predict that the task will take about two seconds longer on **POET** than on **DISPED**. The accuracy of such predictions is discussed in Section 4.

The methods above are simple unconditional sequences. More complex or more general tasks are likely to have multiple methods and/or conditionalities within methods for accomplishing different versions of the task. For example, in a **DISPED**-like system the user often has to "scroll" the text on the display before being able to point to the desired target. We can represent this method as follows:

.4(MP[SCROLL-ICON] K[RED] R(.5)) P[word] K[YELLOW].

Here we assume a specific situation where the average number of scroll jumps per selection is .4 and that the average system response time for a scroll jump is .5 sec. From this we can predict the average selection time:

$$T_{execute} = .4t_M + 1.4t_K + 1.4t_P + .4(.5) = 2.6 \text{ sec.}$$

For more complex contingencies, we can put the operations on a flowchart and label the paths with their frequencies.

When there are alternative methods for doing a specific task in a given system, we have found [4] that expert users will, in general, use the most efficient method, i.e., the method taking the least time. Thus, in making predictions we can use the model to compute the times for the alternative methods and predict that the fastest method will be used. (If the alternatives take about the same time, it does not matter which method we predict.) The optimality assumption holds, of course, only if the users are familiar with the alternatives, which is usually true of experts (excepting the more esoteric alternatives). This assumption is helped by the tendency of optimal methods to be the simplest.

3.3 Heuristics for the **M** Operator

M operations represent acts of mental preparation for applying subsequent physical operations. Their occurrence does not follow directly from the method as

defined by the command language of the system, but from the specific knowledge and skill of the user. The Keystroke-Level Model provides a set of rules (Figure 2) for placing M's in the method encodings. These rules embody psychological assumptions about the user and are necessarily heuristic, especially given the simplicity of the model. They should be viewed simply as guidelines.

The rules in Figure 2 define a procedure. The procedure begins with an encoding that contains only the physical operations (K, P, H, and D). First, all candidate M's are inserted into the encoding according to Rule 0, which is a heuristic for identifying all possible decision points in the method. Rules 1 to 4 are then applied to each candidate M to see if it should be deleted.

There is a single psychological principle behind all the deletion heuristics. Methods are composed of highly integrated submethods ("subroutines") that show up over and over again in different methods. We will call them *method chunks* or just *chunks*, a term common in cognitive psychology [17]. The user cognitively organizes his methods according to chunks, which usually reflect syntactic constituents of the system's command language. Hence, the user mentally prepares for the next chunk, not just the next operation. It follows that in executing methods the user is more likely to pause between chunks than within chunks. The rules attempt to identify method chunks.

Rule 1 asserts that when an operation is fully anticipated in another operation, they belong in a chunk. A common example is pointing with the mouse and then pressing the mouse button to indicate a selection. The button press is fully anticipated during the pointing operation, and there is no pause between them (i.e., PMK becomes PK according to Rule 1). This anticipation holds even if the selection indication is done on another device (e.g., the keyboard or a foot pedal). Rule 2 asserts that an obvious syntactic unit, such as a command name, constitutes a chunk when it must be typed out in full.

The last two heuristics deal with syntactic terminators. Rule 3 asserts that the user will bundle up redundant terminators into a single chunk. For example, in the POET example in Section 3.2, a RETURN is required to terminate the second argument and then another RETURN to terminate the command; but any user will quickly learn to simply hit a double RETURN after the second argument (i.e., MKMK becomes MKK according to Rule 3). Rule 4 asserts that a terminator of a constant-string chunk will be assimilated to that chunk. The most common example of this is in systems that require a terminator, such as RETURN, after each command name; the user learns to immediately follow the command name with RETURN.

It is clear that these heuristics do not capture the notion of method chunks precisely, but are only rough approximations. Further, their application is ambiguous in many situations, e.g., whether something is "fully

anticipated" or is a "cognitive unit." What can we do about this ambiguity? Better general heuristics will help in reducing this ambiguity. However, some of the variability in what are chunks stems from a corresponding variability in expertness. Individuals differ widely in their behavior; their categorization into *novice*, *casual*, and *expert* users provides only a crude separation and leaves wide variation within each category. One way that experts differ is in what chunks they have (see [6] for related evidence). Thus, some of the difficulties in placing M's is unavoidable because not enough is known (or can be known in practical work) about the experts involved. Part of the variability in expertness can be represented by the Keystroke-Level Model as encodings with different placements of M operations.

4. Empirical Validation of the Keystroke-Level Model

To determine how well the Keystroke-Level Model actually predicts performance times, we ran an experiment in which calculations from the model were compared against measured times for a number of different tasks, systems, and users.

4.1 Description of the Experiment

A total of 1,280 user-system-task interactions were observed, comprised of various combinations of 28 users, 10 systems, and 14 tasks.

Systems. The systems were all typical application programs available locally (at Xerox PARC) and widely used by both technical and nontechnical users. Some of the systems are also widely used nationally. Three of the systems were text editors, three were graphics editors, and five were executive subsystems. The systems are briefly described in Figure 3.

Together, these systems display a considerable diversity of user interface techniques. For example, POET, one of the text editors, is a typical line-oriented system, which uses first-letter mnemonics to specify commands and search strings to locate lines. In contrast, DRAW, one of the graphics systems, displays a menu of graphic icons on the CRT display to represent the commands, which the user selects by pointing with the mouse.

Tasks. The 14 tasks performed by the users (see Figure 4) were also diverse, but typical. Users of the editing systems were given tasks ranging from a simple word substitution to the more difficult task of moving a sentence from the middle to the end of a paragraph. Users of the graphics systems were given tasks such as adding a box to a diagram or deleting a box (but keeping a line which overlapped it). Users of the executive subsystems were given tasks such as transferring a file between computers or examining part of a file directory.

Task-system methods. In all there were 32 task-system combinations: $4 \times 3 = 12$ for the text editors, $5 \times 3 = 15$ for the graphics systems, and one task each for the five

executive subsystems. For each task-system combination, the most efficient "natural" method was determined (by consulting experts) and then coded in Keystroke-Level Model operations. For example, the methods for T1-POET and T1-DISPED are given in Section 3.2. (A complete listing of all the methods can be found in [3].)

Experimental design. The basic design of the experiment was to have ten versions of each task on each system done by four different users, giving 40 observed instances per task-system. No user was observed on more than one system to avoid transfer effects. Four tasks were observed for each of the text-editing systems, five tasks for each of the graphics systems, and one task for the executive subsystems.

Subjects. There were in all 28 different users (some technical, some secretarial): 12 for the editing systems, 12 for the graphics systems, and 4 for the executive subsystems. All were experts in that they had used the systems for months in their regular work and had used them recently.

Experimental procedure. Each user was first given five one-minute typing tests to determine his keystroke time, t_K . In addition, users of MARKUP (the only system requiring manual drawing) were given a series of drawing tasks to determine the parameters of their drawing rate (as discussed in Section 3.1).

After the preliminary tests, the user was given a small number of practice problems of the sort to be tested and was told the method to use (see above). In most cases, the methods presented were those users claimed they would have used anyway; in other cases, the method was easily adopted. Users practiced tasks until they were judged to be at ease with using the correct method; this was usually accomplished in three or four practice trials on each task type.

After practicing, the user proceeded to the main part of the experiment. The user was given a notebook containing several manuscript pages with the tasks to be done marked in red ink. Text-editing and graphics tasks appeared in randomized order. Executive subsystem tasks were always in the order T11, T12, T13, T14. All ten instances of task T10 were done in succession.

Each experimental session, lasting approximately 40 minutes, was videotaped and the user's keystrokes recorded automatically. Time stamps on the videotaped record and on each keystroke allowed protocols to be constructed in which the time of each event was known to within .033 sec. These protocols are the basic data from which the results below are derived.

4.2 Results of the Experiment

Each task instance in the protocols was divided into acquisition time and execution time (see Section 2.1) according to the following definitions. Acquisition time began when the user first looked over to the manuscript to get instructions for the next task and ended when the user started to perform the first operator of the method. Execution time began at that point and ended when the

Fig. 3. Systems measured in the experiment.

System	Description
<i>Text Editors</i>	
POET ^a	Line-oriented with relative line numbers.
SOS ^b	Line-oriented with "sticky" line-numbers.
DISPED ^a	Display-oriented; full-page; uses mouse for pointing.
<i>Graphics Systems</i>	
MARKUP ^c	Uses mouse to draw and erase lines on a bitmap display; commands selected from a hidden menu, which must be re-displayed each time.
DRAW ^e	Lines defined by pointing with mouse to end points; commands selected with mouse from a menu.
SIL ^d	Lines defined by pointing with mouse to end points; boxes defined by pointing to opposite vertices; commands selected by combinations of mouse buttons.
<i>Executive Subsystems</i>	
LOGIN ^d	TENEX command for logging in.
FTP ^e	Program for transferring files between computers.
CHAT ^e	Program for establishing a "teletype" connection between two computers.
DIR ^d	TENEX command for printing a file directory; has a subcommand mode.
DELVER ^d	TENEX command for deleting old versions of a file.

^a POET is a dialect of the QED editor [7].

^b See [16].

^c See [13, ch. 17].

^d See [12].

^e Experimental systems local to Xerox PARC, designed and implemented by many individuals, including: Roger Bates, Patrick Baudelaire, David Boggs, Butler Lampson, Charles Simonyi, Robert Sproull, Edward Taft, and Chuck Thacker.

Fig. 4. Tasks for the experiment.

Editing Tasks (used for POET, SOS, DISPED)

- T1. Replace one 5-letter word with another (one line from previous task).
- T2. Add a 5th character to a 4-letter word (one line from previous task).
- T3. Delete a line, all on one line (eight lines from previous task).
- T4. Move a 50-character sentence, spread over two lines, to the end of its paragraph (eight lines from previous task).

Graphics Tasks (used for MARKUP, DRAW, SIL)

- T5. Add a box to a diagram.
- T6. Add a 5-character label to a box.
- T7. Reconnect a 2-stroke line to a different box.
- T8. Delete a box, but keep an overlapped line.
- T9. Copy a box.

Executive Tasks

- T10. Phone computer and log in (4 char name, 6 char password).
- T11. Transfer a file to another computer, renaming it.
- T12. Connect to another computer.
- T13. Display a subset of the file directory with file lengths.
- T14. Delete old versions of a file.

user looked over to the notebook for the next task. (On the protocol the first measured time at the beginning of an execution is always the end of the first **K** of the method. Thus, operationally, the beginning of execution time was estimated by subtracting from this first **K** time the operator times for this first **K** plus all the operators that preceded it.)

Those tasks on which there were significant errors (i.e., other than typing errors) or in which the user did not use the prescribed method were excluded from further consideration. After this exclusion, 855 (69 percent) of the task instances remained as observations to be matched against the predictions. No analysis was made of the excluded tasks.

The resulting observed times for task acquisition and execution were stable over repetition. There was no statistical evidence for task times decreasing (learning) or increasing (fatigue) with repetition.

4.2.1 Calculation of execution time. Execution time was calculated using the method analysis for each task-system combination together with estimates of the times required for each operator. All times, except for the mental preparation time, were taken from sources outside of the experiment. Pointing time, t_P , and homing time, t_H , were taken from Figure 1. Typing time, t_K , and drawing time, $t_D(n_D, l_D)$, were estimated from the typing and drawing tests by averaging the times of the four users involved in each task-system. System response time, T_R , for each task-system was estimated from independent measurements of the response times for the various commands required in each method. For task T10, logging in to a computer, a telephone button-press was assumed to take time t_K . Moving the telephone receiver to the computer terminal modem was estimated to take .7 sec, using the MTM system of times for industrial operations [10].

Mental preparation time, t_M , was estimated from the experimental data itself. First, the total mental time for each method was estimated by removing the predicted time for all physical operations from the observed execution time. Then t_M was estimated by a least-squares fit of the estimated mental times as a function of the predicted number of **M** operations. The result was $t_M = 1.35$ sec ($R^2 = .84$, standard error of estimate = .11 sec, standard error about the regression line = 2.48 sec). A rough estimate of the SD of t_M is 1.1 sec, which indicates that the **M** operator has the characteristic variability of mental operators [4].

Execution times for each task-system combination were calculated by formula (1) in Section 3. The calculations of the execution times are summarized in Figure 5, which also gives the observed execution times from the experiment for comparison.

4.2.2 Execution time. The predicted execution times are quite accurate. This can be seen in Figure 6, which plots the predicted versus the observed data from Figure

5. The scales are logarithmic, since prediction error appears to be roughly proportional to duration. The root-mean-square (RMS) error is 21 percent of the average predicted execution time. This accuracy is about the best that can be expected from the Keystroke-Level Model, since the methods used by the subjects were controlled by the experimental procedure. The 21 percent RMS error is comparable to the 20–30 percent we have obtained in other studies on text-editing with more elaborate models that also predict the method [4].

The distribution of percentage prediction errors is fairly evenly spread, as an analysis of Figure 6 will show. No particular systems or tasks make excessively large contributions. Predictions are not consistently positive or negative for systems or tasks, except that all the executive subsystem tasks were overpredicted. Examination of the individual observations does not reveal any small set of outliers or particular users that inflate the prediction error.

Prediction accuracy is related to the duration of the attempted prediction. The results above are for individual unit tasks. Since unit tasks are essentially independent, prediction of the time to do a sequence of tasks will tend to be more accurate. This can be seen directly in the present data, since each user ran all the tasks for a given system. For example, consider predicting by the model how long it took to do *all four* editing tasks. The average RMS error is only 5 percent. The corresponding RMS error for the graphics editors over the five tasks is only 6 percent.

Ideally, all of the parameters of the model should be determined independently of the experimental situation. This was achieved for all the physical operation times, but not for the mental operation time, t_M . We did not have available an appropriate independent source of data from which to determine t_M . The accuracy of the model is somewhat inflated by the determination of one of its parameters from the data itself. The substantial variability of t_M indicates that this inflation is probably not too serious, which is to say that small changes in the value of t_M do not make much difference. For example, if a t_M as small as 1.2 sec or as large as 2.0 sec were used in the predictions, the RMS error for the Keystroke-Level Model would only increase from 21 to 23 percent. It should be noted that the t_M estimated from this experiment is now available as an independent estimate for use by others.

The variability of the observed task times is of interest per se, since user behavior is inherently variable. In our data the average coefficient of variation ($CV = SD/$ Mean) of the individual observations over each task is .31, which is the normal variability for behavior of this duration [4]. In comparing the predictions of the model against any actual behavior, the prediction error will always be confounded with some error from the process of sampling the behavior. The sampling error for each of our observed task times is indicated in the SE column of Figure 5. The average standard error is 9 percent.

Fig. 5. Calculated and Observed Execution Times in the Experiment.

Task-System	Calculated ^a										Observed	Pred. Error ^d
	t_A^b	η_M	η_K	η_{D1}	η_{D2}	η_{D3}	η_{D4}	η_{D5}	T_R	$T_{execute}$	$T_{execute}$	
	(sec)							(min)	(sec)	(sec)	$M \pm SE(N)^c$	(sec)
T1-POET	.23	4	15	...	...	...	...	...	...	8.8 ^e	7.8 ± 0.9(27)	11%
T1-SOS	.22	4	19	...	...	...	...	...	...	9.6	9.6 ± 0.8(31)	1%
T1-DISPED	.23	2	8	2	1	...	...	...	...	6.4 ^e	5.7 ± 0.3(31)	11%
T2-POET	.28	4	14	...	...	...	...	...	...	9.4	8.9 ± 0.7(17)	5%
T2-SOS	.23	4	18	...	...	...	...	...	...	9.5	9.7 ± 0.8(32)	-3%
T2-DISPED	.24	2	4	2	1	...	...	...	...	5.6	4.1 ± 0.3(32)	26%
T3-POET	.19	3	12	...	...	...	...	...	...	6.3	6.3 ± 0.4(24)	0%
T3-SOS	.23	2	7	...	...	...	...	...	...	4.3	4.0 ± 0.3(37)	8%
T3-DISPED	.23	1	2	1	1	...	...	...	...	3.3	3.5 ± 0.2(38)	-7%
T4-POET	.19	13	92	...	...	...	...	...	...	35.3	37.1 ± 4.3(20)	-6%
T4-SOS	.23	12	47	...	...	...	...	...	...	26.8	32.7 ± 1.8(16)	-22%
T4-DISPED	.24	2	6	1	3	...	...	3.8	11.8	11.8	14.3 ± 1.1(33)	-23%
T5-MARKUP	.25	...	3.2	...	2.5	4	24.9	...	...	11.1	10.5 ± 1.1(27)	6%
T5-DRAW	.25	7.6	12.6	...	5	...	...	...	...	18.9	12.5 ± 3.0(22)	34%
T5-SIL	.27	1	4	0.4	2	...	...	...	...	4.8	5.4 ± 0.7(32)	-12%
T6-MARKUP	.26	1	7	2	1	...	...	...	...	5.0	6.2 ± 0.4(34)	-23%
T6-DRAW	.25	1	7	1	1	...	...	...	...	4.6	5.9 ± 0.4(34)	-29%
T6-SIL	.27	...	6	1.4	1	...	...	...	...	3.3	3.6 ± 0.3(19)	-9%
T7-MARKUP	.24	...	8.6	...	4.8	6	13.6	...	...	15.1	15.0 ± 2.1(29)	2%
T7-DRAW	.19	5	13	...	8	...	...	...	...	18.0	18.2 ± 1.9(9)	-1%
T7-SIL	.28	1	8	...	5	...	...	...	...	9.1	12.3 ± 2.1(23)	-36%
T8-MARKUP	.26	...	8	...	8	1	4.0	...	...	12.3	9.3 ± 0.4(22)	24%
T8-DRAW	.21	1	5	...	3	...	...	...	...	5.7	5.3 ± 0.3(25)	7%
T8-SIL	.27	1	5	0.7	2	...	...	...	...	5.2	4.1 ± 0.2(33)	20%
T9-MARKUP	.25	2	8	...	6.5	...	...	3.5	15.4	15.4	13.0 ± 2.5(26)	15%
T9-DRAW	.22	...	5.7	...	5.7	...	...	...	...	7.5	10.5 ± 1.0(25)	-40%
T9-SIL	.28	...	5	0.3	3	...	...	...	...	4.8	6.0 ± 1.0(28)	-24%
T10-LOGIN	.29	2	28	...	...	...	...	15.9	27.4 ^f	27.4 ^f	25.1 ± 0.7(29)	9%
T11-FTP	.30	5	31	...	...	...	...	10.1	26.1	26.1	19.7 ± 0.7(29)	24%
T12-CHAT	.31	1	11	...	...	...	...	8.3	13.1	13.1	11.5 ± 0.6(36)	12%
T13-DIR	.30	2	20	...	...	...	...	0.5	9.2	9.2	6.6 ± 0.3(32)	28%
T14-DELVER	.32	2	20	...	...	...	...	0.4	9.4	9.4	7.5 ± 0.4(33)	20%

^a The calculations are done according to formula (1) using the operator times in Figure 1, except for t_A .

^b t_A is the average time from the typing tests for the subjects on a given system. Each subject's time is weighted by the correct number of instances for that subject on a given task (see Section 4.2.1).

^c SE is the standard error of estimation of the population mean for samples of size N .

^d The prediction error is given as a percentage of the calculated time, $T_{execute}$.

^e The calculated times for these tasks are different from the calculated times in the examples in Section 3.2, because different t_A are used.

^f The execute time for this task also includes .7 sec for the operation of moving the telephone receiver (see Section 4.2.1).

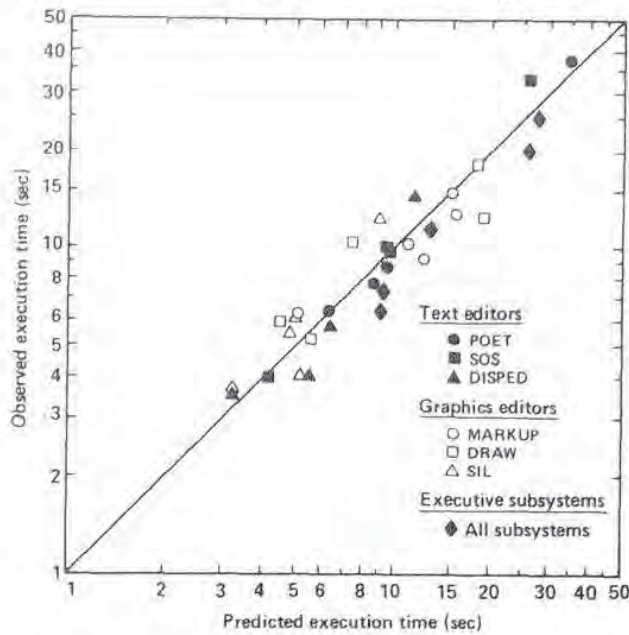
That the prediction error of the Keystroke-Level Model is over two times larger than this indicates that most of the prediction error is due to the inaccuracy of the model and not just unreliable observations.

4.2.3 Acquisition time. Turning from the execution part of the task to the acquisition part, the data shows that it took users 2 sec, on the average, to acquire a task from the manuscript. This number may be refined by breaking the tasks into three types: (a) those tasks that the user already had in memory (the executive subsystem tasks that were done each time in the same order); (b) those tasks for which the user had to look at the manuscript each time (all the graphics tasks, the POET and SOS tasks, and task T11); and (c) those tasks for which the

user had to look at the manuscript, then scan text on the CRT to locate the task. The times for these three types of acquisition are given in Figure 7. Users took only .5 sec when the task was in memory, 1.8 sec to get the task from the manuscript, and 4.0 sec to get the task from the manuscript and scan the CRT. These times are similar to results obtained in previous experiments [4]. It is interesting to note that, although display editors are generally faster to use, they impose a 2 sec penalty by requiring the user to visually scan the text on the display.

We can use the acquisition times in Figure 7, along with the predicted execution times in Figure 5, to predict the total task times. The RMS error of these predictions is 21 percent, which is just as accurate as predicting the execution times alone.

Fig. 6. Predicted vs. observed execution times in the experiment.



5. Sample Applications of the Keystroke-Level Model

The experiment has provided evidence for the Keystroke-Level Model in a wide range of user-computer interactions. Given the method used, the time required for experts to perform a unit task can be predicted to within about 20 percent by a linear function of a small set of operators. This result is powerful in permitting prediction without having to do any measurements of the actual situation and in expressing the prediction as a simple algebraic expression. Its limitation lies in requiring that the method be completely specified at the level of keystrokes and in being limited to error-free expert behavior.

In this section we illustrate how the Keystroke-Level Model can be used, both to exploit its power and to work within its restrictions. The basic application—to predict a time for a specific situation by writing down a method and computing the value—has been sufficiently illustrated in the course of the experiment, where such point predictions were made for 32 different tasks involving 10 highly diverse systems. We now show three further uses: (1) calculated benchmarks for systems; (2) parametric analysis, where predictions are expressed as functions of task variables; and (3) sensitivity analysis, where changes in the predictions are examined as a function of changes in task or model parameters.

5.1 Calculated Benchmarks

Given the ability to predict tasks, it is possible to calculate the equivalent of a benchmark for a system and hence to compare systems. This has obvious cost advantages over obtaining actual measurements. More importantly, it permits benchmarking at design time, before the system exists in a form that permits measurement.

The analysis for the experimental data lets us illustrate this easily.

Consider the three text editors, POET, SOS, and DISPED. Let the benchmark be the four tasks T1 to T4. We can use the Keystroke-Level Model to compute the total time to do the benchmark for each system. The answer comes directly from Figure 5 by summing the calculated $T_{execute}$ for T1–T4 for each editor. This gives 59.8 sec, 50.2 sec, and 26.9 sec as the predicted execution times, respectively, for POET, SOS, and DISPED. Taking the POET time (the slowest) as 100, we get ratios of 100:84:45. Thus, as we might have expected, the two line-oriented editors are relatively close to each other and the display editor is substantially faster. Since we have also done the experiment, we can compare these calculated benchmarks with the observed benchmarks (by summing the observed $T_{execute}$ from Figure 5). We get 60.1 sec, 56.0 sec, and 27.6 sec, respectively. This gives experimentally determined ratios 100:93:46, which is essentially the same result. This agreement between the calculated and observed benchmark provides confidence only in using the calculated benchmark in place of a measured one. It does not provide evidence for the validity of the particular benchmark (tasks T1–T4) or whether benchmarks are generally a valid way to compare editors.

A similar analysis can be performed for the three graphics systems, using tasks T5–T9 as the benchmark. This yields predicted ratios of 100:93:46 for MARKUP, DRAW, and SIL, respectively, with observed ratios of 100:97:58. MARKUP and DRAW are close enough to raise the question of whether the predicted difference between them is too small to be reliable. The calculated difference between MARKUP and DRAW on the benchmark is $59.0 - 54.7 = 4.3$ sec or 7 percent. The model has an RMS prediction error of 21 percent for a single unit task. Since this benchmark is essentially an independent sum of five unit tasks, the RMS error should theoretically be $21 \text{ percent} / \sqrt{5} = 9 \text{ percent}$. Thus, the predictions for the two systems are within the RMS error of the model, and so the predicted difference between them can hardly

Fig. 7. Observed acquisition times in the experiment.

Task Type	Task numbers	Acquisition Time $M \pm SE^a (N)$ (sec) (sec)
All tasks	T1–T14	$2.0 \pm 2.0 (885)$
Repeated task, recalled from memory	T10, T12, T13, T14	$0.5 \pm 0.3 (130)$
Task acquired by looking at manuscript	T1–T4 (POET, SOS), T5–T9, T11	$1.8 \pm 1.9 (621)$
Task acquired by looking at manuscript, then scanning for task on display	T1–T4 (DISPED)	$4.0 \pm 1.9 (134)$

^a SE is the standard error of estimation of the population mean for samples of size N .

be reliable. The fact that the model correctly predicted that DRAW was slightly faster than MARKUP was lucky—there is no reason to expect the Keystroke-Level Model to make such close calls.

5.2 Parametric Analysis

We illustrate the notions of parametric analysis and sensitivity analysis with a new example. Consider the following task: A user is typing text into an editor and detects a misspelled word n words back from the word he is currently typing. How long will it take to correct the misspelled word and resume typing?

In DISPED there are two methods for making the correction, which we wish to compare. Since the methods may behave quite differently depending on how far back the misspelled word is, we need to determine how long each method takes as a function of n . The first method makes use of the Backword command (called by hitting the CTRL key and then W), which erases the last typed in word:

Method W (Backword):

Set up Backword command	MK[CTRL]
Execute Backword n times	$n((1/c)MK[W])$
Type new word	5.5K[word]
Retype destroyed text	5.5($n-1$)K

$$T_{execute} = (1 + n/c)t_M + (1 + 6.5n)t_K \quad (2)$$

$$= 1.6 + 2.16n \text{ sec.}$$

The execution time is a function not only of n , but also of another parameter, c . When a user has to repeat a single-keystroke command several times, such as the Backword command in the above method, he will tend to break the sequence into small bursts or *chunks*, separated by pauses, which are represented as M operations, according to Rule 2 in Figure 2. Thus, we postulate a chunk size, c , which is the average number of Backword commands in a burst. This is used in the second step in the above method, where we count $1/c$ M operations for each call of the Backword command. An exact value for c is unknown, but we use a "reasonable" value, $c = 4$, in our calculations (we will return to this decision in Section 5.3). In the calculations we also assume an average nonsecretary typist ($t_K = .28$ sec) and an average word length of 5.5 characters (including punctuation and spaces).

The second method is to get out of type-in mode, use the Replace command to correct the word, and then get back into type-in mode, so that input can be resumed:

Method R (Replace):

Terminate type-in mode	MK[ESC]
Point to target word and select it	H[mouse] P[word] K[YELLOW]
Call Replace command	H[keyboard] MK[R]
Type new word	4.5K[word]
Terminate Replace command	MK[ESC]
Point to last input word and select it	H[mouse] P[word] K[YELLOW]
Reenter type-in mode	H[keyboard] MK[I]

$$T_{execute} = 4t_M + 10.5t_K + 4t_H + 2t_P$$

$$= 12.1 \text{ sec.}$$

The predicted time for each method as a function of n is plotted as the solid lines in Figure 8(a). As the figure shows, it is faster to use the Backword method up until a certain crossover point, n_{WR} , after which it becomes faster to use the Replace method. Under the above assumptions, the crossover from the Backword method to the Replace method is found to be at 4.9 words.

Suppose a designer wants to add a feature to DISPED to improve performance on this task. We wish to determine, *before* implementation, whether the proposed feature is likely to be much of an improvement.

The designer proposes two new commands. The first is a Backskip command (CTRL S), which moves the insertion point back one word without erasing any text. The second is a Resume command (CTRL R), which moves the insertion point back to the end of the current type-in (where Backskip was first called). These commands allow:

Method S (Backskip):

Set up Backskip command	MK[CTRL]
Execute Backskip $n-1$ times	$(n-1)((1/c)MK[S])$
Call Backword command	MK[W]
Type new word	4.5K[word]
Call Resume command	M2K[CTRL R]

$$T_{execute} = (3 + (n-1)/c)t_M + (n+7.5)t_K \quad (3)$$

$$= 5.8 + .62n \text{ sec.}$$

The predicted time for the Backskip method is plotted as the dashed line in Figure 8(a). With the addition of this method there are two additional crossover points, n_{WS} and n_{RS} , between it and the other two methods. As can be seen, the Backskip method is faster than both of the other methods between n_{WS} and n_{RS} , i.e., from 2.7 to 10.2 words. Thus, a brief analysis provides evidence that the proposed new feature probably will be useful, in the sense that it will be the fastest method over a region of the task space.

5.3 Sensitivity Analysis

How sensitive to variations in the parameters of the methods are the aforementioned calculations? The question of interest is whether, over such variations, there is still a region in the task space in which the Backskip method is the fastest. An important parameter is the user's typing speed, t_K . How much does the crossover between the Backword method and the Backskip method change as a function of typing speed? Setting eq. (2) equal to (3) and solving for n as a function of t_K gives $n = 1.2 + .43/t_K$. The crossover increases with faster typists (decreasing t_K), going up to $n = 6.6$ words for the fastest typist ($t_K = .08$ sec). That is to say, faster typists should prefer the old Backword method (which involves more typing) for larger n before switching to the new Backskip method (which involves less typing, but more mental overhead).

We can plot the crossover boundary between the two methods in the space of the two parameters: n (characterizing different tasks) and t_K (characterizing different users). The two boundaries of the new Backskip method are plotted in Figure 8(b). These boundaries define the

Fig. 8(a). Execution time for three methods as a function of n .

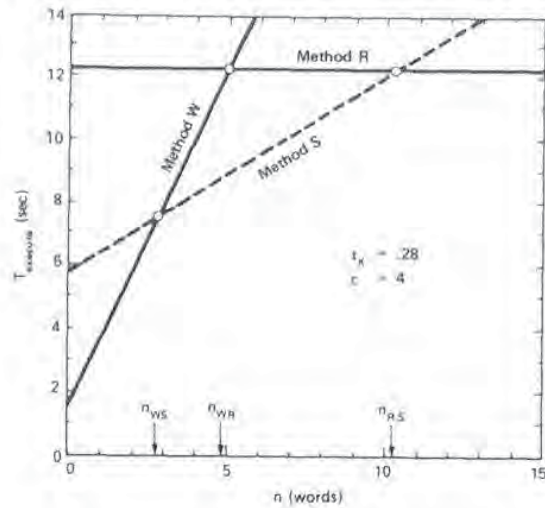


Fig. 8(b). Phase diagram for the fastest method.

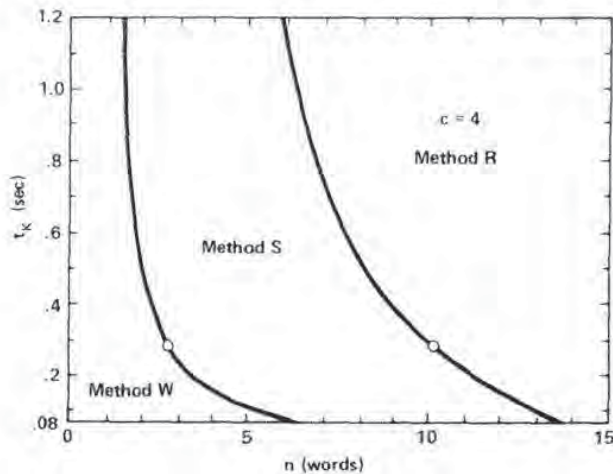
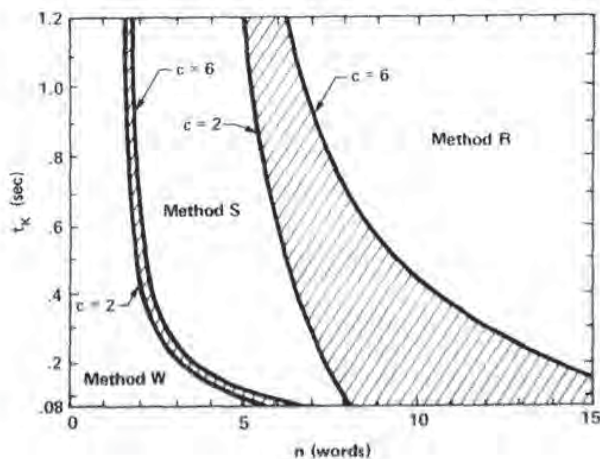


Fig. 8(c). Phase diagram adjusted for different chunk sizes.



regions in the parameter space where each method is fastest. The circles mark the crossover points corresponding to the ones in Figure 8(a) (i.e., at $t_K = .28$ sec). This diagram clearly shows the shift of crossovers for fast typists. It also shows that, for any speed of typist, there are some tasks for which the Backskip method is the fastest.

We are not sure of the exact chunk size, c , and so we must check whether our conclusions about the usefulness of the Backskip method are sensitive to the choice of a value for c . To do this, we rederive the crossover between the Backward and Backskip methods by setting eq. (2) equal to (3) and solving for n as a function of both c and t_K ; this gives $n = 1.2 + .49/t_K - .24/ct_K$. Although we do not know an exact value for c , we can be reasonably confident that it will be between 2 and 6. With $t_K = .28$ sec, for example, the crossover varies between 2.5 and 2.8 words as c varies between 2 and 6; so the value of c does not seem to have a great effect at this point.

The best way to see the overall affect of the value of c is to replot Figure 8(b) using the reasonable extreme values of c . The two crossover boundaries for the Backskip method are plotted in Figure 8(c) as "fat" lines defined by setting c to 2 and 6 in the crossover equations. This diagram clearly shows that the value of c affects one boundary more than the other. The boundary between the Backward and Backskip methods is not affected much by c , because the chunk size is involved in both methods in exactly the same way. But the boundary between the Backskip and Replace methods is greatly affected by the value of c , since c is not involved in the Replace method at all. Small chunk sizes, especially, penalize the Backskip method. Overall, however, varying c does not squeeze out the region for the Backskip method; and our basic conclusion—that the new method is a useful addition—still holds.

There are other aspects of the above methods for which we could do a sensitivity analysis. (For example, if the last two M operations of the Backskip method were eliminated according to Rule 1, how much would the value of the Backskip method increase?) However, the sensitivity analyses above illustrate how the Keystroke-Level Model can be used to evaluate design choices—even when many aspects of the calculation are uncertain—for the principal conclusions are often insensitive to many of the uncertainties.

6. Simplifications of the Keystroke-Level Model

The question naturally arises as to whether further simplifications of the Keystroke-Level Model might do reasonably well at predicting execution time. One could (a) count only the number of keystrokes, (b) count just the physical operators and prorate the time for mental activity, or (c) use a single constant time for all operators. We show below that such simplifications substantially degrade accuracy. However, they provide useful approximations where the lowered accuracy can be tolerated.

6.1 Keystrokes Only

With this simplification, execution time is proportional to the number of keystrokes:

$$T_{execute} = \kappa n_K + T_R.$$

We separate out the system response times, T_R , so as not to confound the comparison. The constant of proportionality, κ , should be distinguished from t_K , the typing speed, which is determined from standard typing tests. Estimating the value of κ from a least-squares fit of the values of n_K and the observed $T_{execute}$ in Figure 5 gives $\kappa = .49$ sec/keystroke. The correlation between the times predicted by this model and the observed times is .87, and the RMS error is 49 percent. The statistics for comparing all models are presented in Figure 9. As can be seen, using keystrokes only is substantially less accurate than the full Keystroke-Level Model. This simplification is inappropriate for tasks that are not dominated by keystroking. For example, it only predicts about a third of the observed time for the MARKUP tasks, which are dominated by pointing and drawing operations.

The above estimate of κ is held down by one outlying point in the data, T4-POET ($n_K = 92$). Estimating κ with this one point removed gives $\kappa = .60$ sec, a value close to another estimate obtained in an earlier benchmark study [1; 5, ch. 3]. T4-POET is the only task that requires any input-typing of text. One obvious refinement of the keystrokes-only model would be to distinguish two kinds of keystrokes: mass input-typing (at t_K sec/keystroke) versus command-language keying (at κ sec/keystroke). For this purpose, a κ of .60 sec is the more reasonable value.

The model of Embley et al. [9] is formally similar to our keystrokes-only version. However, their model is conceptually different from ours. The Keystroke-Level Model is based on the notion of a unit task structure; Embley et al. use commands instead. Our model is restricted to skilled expert behavior, whereas they attempt to model all kinds of users (essentially, by varying their versions of the parameters $T_{acquire}$ and κ). Unfortunately, they did not compare their model against any empirical performance data, so we cannot compare our results to theirs. The keystrokes-only model can, perhaps, be taken as an indicator of the accuracy of their model for expert behavior.

6.2 Prorated Mental Time

According to this simplification, execution time is the time required for the physical operations multiplied by a factor to account for the mental time:

$$T_{execute} = \mu(T_K + T_H + T_P + T_D) + T_R.$$

The idea is that the physical operations will require a certain average overhead of mental activity. Thus, instead of trying to predict exactly how many mental operations there are, we can do fairly well by just using a multiplicative mental overhead constant, μ .

Using a least-squares analysis to determine μ from the sum of the calculated times for the physical opera-

Fig. 9 Comparison of the keystroke model with simpler variations.

Model Variation	Parameters	Correlation (r) ^a	RMS Error ^b
Keystrokes Only	$\kappa = .49$ sec/keystroke ^c	.87	40%
Prorated Mental Time	$\mu = 1.67$	.81	45%
Constant Operator Time	$\tau = .43$ sec/operator ^c	.92	34%
Keystroke Model	(See Figure 1)	.95	22%

^a The correlations are between the execution times predicted by each of the models and the observed execution times from Figure 5.

^b The RMS error is given as a percentage of the observed execution time, 11.0 sec.

^c More useful parameter values are $\kappa = .60$ sec and $\tau = .49$ sec (see Sections 6.1 and 6.3).

tions and the observed values of $T_{execute}$ in Figure 5 gives $\mu = 1.67$; i.e., there is a 67 percent overhead for mental activity. The correlation between predicted and observed times is .81, and the RMS error is 45 percent.

This simplification is also less accurate than the Keystroke-Level Model, as can be seen in Figure 9. This suggests that the extra detail in the Keystroke-Level Model, involving the placements of the mental preparedness operator, **M**, is effective. It is this operator that qualifies the Keystroke-Level Model as a genuine psychological model and not simply as an analysis of the physical operations.

There is an interesting relation between these two simpler models and the rules for placing occurrences of **M** in the Keystroke-Level Model (Figure 2). The initial placement of **M**'s, by Rule 0, with certain **K**'s and **P**'s is essentially an assumption that mental time is proportional to a subset of the physical operators. If Rule 0 had specified all physical operators, Rule 0 by itself would have been equivalent to prorating mental time. If the other physical operators (**P**, **H**, and **D**) had been ignored, this would have been equivalent to counting keystrokes only. Therefore, the deletion of the **M**'s according to Rules 1 to 4 constitutes the ways in which the Keystroke-Level Model departs from these simpler models. The evidence for the superiority of the Keystroke-Level Model presented in Figure 9 is also evidence that Rules 1 to 4 had a significant effect. In fact, each of the rules individually makes a significant contribution, in the sense that its removal leads to a decrease in the accuracy of the Keystroke-Level Model.

6.3 Constant Operator Time

According to this simplification, execution time is proportional to the number of Keystroke-Level operations:

$$T_{execute} = \tau(n_M + n_K + n_P + n_H + n_D) + T_R.$$

The idea here is the statistical observation [18] that the accuracy of linear models is not sensitive to the differential weighting of the factors—equal weighting does nearly as well as any other weighting. Thus, we disregard the different operator times and use a single time, τ , for

all operators. Note that the constant-operator-time model is formally similar to the keystrokes-only model; the latter can be viewed as using n_K as a crude estimate of the total number of operators.

Estimating τ by a least-squares fit of the data in Figure 5 gives $\tau = .43$ sec/operator. The correlation between predicted and observed times is .92, and the RMS error is 34 percent. (For the reason discussed in Section 6.1, it is useful to estimate τ with the T4-POET task removed, getting $\tau = .49$ sec/operator.)

The constant-time model is quite a bit more accurate than the keystrokes-only model, which tells us that taking into account operators other than K is useful. In fact, most of the action in the constant-time model (over the set of data in Figure 5, at least) comes from counting only the K, P, and M operators. In any particular task, of course, any of the operators can be dominant. On the other hand, the constant-time model is still less accurate than the Keystroke-Level Model, showing that taking into account accurate estimates of each operator's time yields another increment of accuracy.

In summary, all of the simplifications presented in this section are less accurate than the Keystroke-Level Model. However, these simplified models are probably good enough for many practical applications, especially for "back-of-the-envelope" calculations, where it is too much trouble to worry about the subtleties of counting the M's that the full Keystroke-Level Model requires.

7. Conclusion

We have presented the Keystroke-Level Model for predicting the time it will take a user to perform a task using a system. We view this model as a *system design tool*. We have shaped it with two main concerns in mind. First, the tool must be quick and easy to use, if it is to be useful *during the design* of interactive systems. The existing strengths of psychology and human factors methods are primarily in the design and analysis of experiments; but experiments are too slow and cumbersome to be incorporated into practice. Ease of use implies that the tool be analytical—that it permit calculation in the style familiar to all engineers. Second, the tool must be useful to practicing computer system designers, who are not psychologists. This implies that the entire tool must be packaged to avoid requiring specialized psychological knowledge. We think that the Keystroke-Level Model satisfies these concerns, along with the primary consideration of being accurate enough to make design decisions. We believe that the Keystroke-Level Model belongs in the system designer's tool-kit.

It is possible to formulate more complicated and refined models than the Keystroke-Level Model by increasing its accuracy or by relaxing some of its serious restrictions (e.g., models that predict methods or that

predict errors). One of the great virtues of the Keystroke-Level Model, from our own perspective as scientists trying to understand how humans interact with computer systems, is that it puts a lower bound on the effectiveness of new proposals. Any new proposal must do better than the Keystroke-Level Model (improve on its accuracy or lessen its restrictions) to merit serious consideration.

The Keystroke-Level Model has several restrictions: The user must be an expert; the task must be a routine unit task; the method must be specified in detail; and the performance must be error-free. These restrictions are important and must be carefully considered when using the model. Yet, we believe that the Keystroke-Level Model represents an appropriate idealization of this aspect of performance and that it is a flexible tool allowing the system designer to deal systematically with this aspect of behavior.

The Keystroke-Level Model predicts only one aspect of the total user-computer interaction, namely, the time to perform a task. As we discussed at the beginning of this paper, there are many other important aspects of performance, there are nonexpert users, and there are nonroutine tasks. All of these must be considered by the system designer. Designing for expert, error-free performance time on routine tasks will not satisfy these other aspects. We would like to see appropriate models developed for these other aspects. However, even with a collection of such models, the designer still must make the inevitable trade-offs. Scientific models do not eliminate the design problem, but only help the designer control the different aspects.

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Professional Activities Calendar of Events

ACM's calendar policy is to list open computer science meetings that are held on a not-for-profit basis. Not included in the calendar are educational seminars, institutes, and courses. Submittals should be substantiated with name of the sponsoring organization, fee schedule, and chairman's name and full address.

One telephone number contact for those interested in attending a meeting will be given when a number is specified for this purpose.

All requests for ACM sponsorship or cooperation should be addressed to Chairman, Conferences and Symposia Committee, Seymour J. Wolfson, 643 MacKenzie Hall, Wayne State University, Detroit, MI 48202, with a copy to Louis Fiora, Conference Coordinator, ACM Headquarters, 1133 Avenue of the Americas, New York, NY 10036; 212 265-6300. For European events, a copy of the request should also be sent to the European Representative. Technical Meeting Request Forms for this purpose can be obtained from ACM Headquarters or from the European Regional Representative. Lead time should include 2 months (3 months if for Europe) for processing of the request, plus the necessary months (minimum 3) for any publicity to appear in *Communications*.

■ This symbol indicates that the Conferences and Symposia Committee has given its approval for ACM sponsorship or cooperation.

In this issue the calendar is given to November 1981. New Listings are shown first; they will appear next month as Previous Listings.

NEW LISTINGS

- 19-22 July 1980
National Conference on Computer Related Crime, Washington, D.C. Sponsor: U.S. Dept. of Justice. Contact: Koba Associates, Inc., 2000 Florida Ave., NW, Washington, DC 20009; 202 328-5735.
- 3-5 September 1980
Conference and Workshop on Model Acceptance, Washington, D.C. Sponsors: SCS, GMD. Contact: Society for Computer Simulation, Box 2228, La Jolla, CA 92038; 714 459-3888.
- 6-7 October 1980
Fifth Conference on Local Computer Networks, Minneapolis, Minn. Sponsor: IEEE-CS. Contact: Abe Franck, USS: University of Minnesota, 227 Experimental Engr., 208 Union St. SE, Minneapolis, MN 55455.
- 9-10 October 1980
1980 Annual Meeting and Conference of the Museum Computer Network, New York State Museum, Albany. Sponsor: Museum Computer Network, Inc. Contact: David Vance, Center for Contemporary Arts and Letters, Library E-2340, State University of New York, Stony Brook, NY 11794; 516 246-6077.
- 15-18 October 1980
Symposium on Optimization Methods—Applied Aspects, Varna, Bulgaria. Sponsors: IFAC, IFORS. Contact: National Centre for Cybernetics & Computer Techniques, Committee for Science, 8 Slavyanska St., Sofia, Bulgaria.
- 20-22 October 1980
Texas Association for Educational Data Systems 1980 Annual Convention, Austin, Tex. Sponsor: TAEDS. Contact: Phil Gensler, Dept. of CIS, West Texas State University, Canyon, TX 79016.

4-6 November 1980
Federal Office Automation Conference, Washington, D.C. Sponsor: Office Automation Council. Contact: Federal Office Automation Conference, Box E, Wayland, MA 01778; 617 358-5119.

9-13 November 1980
Computer Related Crime: Training Workshop for Prevention, Detection, Investigation, and Prosecution, Charleston, S.C. Sponsor: U.S. Dept. of Justice. Contact: Koba Associates, Inc., 2000 Florida Ave., NW, Washington, DC 20009; 202 328-5780.

10-12 November 1980
ORSA/TIMS National Meeting, Houston, Tex. Sponsors: ORSA, TIMS. Contact: James McFarland, School of Business, University of Houston, Houston, TX 77004.

7-10 December 1980
1980 CAUSE National Conference, Phoenix, Ariz. Sponsor: CAUSE. Contact: CAUSE, 737 Twenty-Ninth Street, Boulder, CO 80303; 303 449-4430.

3-8 January 1981
Annual Meeting of AAAS, Toronto, Canada. Sponsor: American Association for the Advancement of Science. Contact: AAAS, 1515 Massachusetts Ave., NW, Washington, DC 20005.

7-9 January 1981
Second Western Conference and Exhibition, Anaheim, Calif. Sponsor: Armed Forces Communications and Electronics Association. Contact: AFCEA, Skyline Center, Suite 300, 5205 Leesburg Pike, Falls Church, VA 22041.

12-14 January 1981
PTC 81, Honolulu, Hawaii. Sponsor: Pacific Telecommunications Council. Contact: Richard J. Barber, 2424 Maile Way, #704, Honolulu, Hawaii.

26-28 January 1981
Eighth Annual ACM SIGACT-SIGPLAN Symposium on Principles of Programming Languages, Williamsburg, Va. Sponsors: ACM SIGACT, SIGPLAN. Contact: Robert E. Noonan, Dept. of Mathematics and Computer Science, College of William & Mary, Williamsburg, VA 23185.

12-13 March 1981
Computer Science and Statistics: 13th Symposium on the Interface, Pittsburgh, Pa. Sponsor: Carnegie-Mellon University Symp. chm: William F. Eddy, Dept. of Statistics, Carnegie-Mellon University, Pittsburgh, PA 15213.

6-10 April 1981
International Congress on Logic, Informatics, Law, Florence, Italy. Sponsor: Istituto per la documentazione giuridica di Consiglio Nazionale delle Ricerche. Contact: Istituto per la documentazione giuridica, Via Panciatichi, 56/16-50127 Florence, Italy.

30 April-1 May 1981
Twelfth Annual Pittsburgh Conference on Modeling and Simulation, Pittsburgh, Pa. Sponsor: University of Pittsburgh in cooperation with Pittsburgh sections of IEEE, Systems, Man and Cybernetics Society, ISA, SCS, International Association for Mathematics and Computers in Simulation. Conf. co-chm: William G. Vogt and Marlin H. Mickle, 348 Benedum Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15261.

5-8 May 1981
AEDS Annual Convention, Minneapolis, Minn. Sponsor: Association for Educational Data Systems. Contact: Shirley Easterwood, AEDS, 1201 Sixteenth St., NW, Washington, DC 20036.

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the ACM

10-12 June 1981
Seventh Conference of the Canadian Man-Computer Communications Society, Waterloo, Ontario (in conjunction with CIPS National Conference). Sponsor: Canadian Man-Computer Communications Society. Prog. chm: Marcell Wein, Computer Graphics Section, Division of EE, National Research Council, Ottawa, Ontario, Canada K1A 0R8.

3-7 August 1981
ACM SIGGRAPH 81, Dallas, Tex. Sponsor: ACM Special Interest Group on Computer Graphics. Conf. chm: Anthony Lucido, Industrial Engineering Dept., CS Services Division, Texas A&M University, College Station, TX 77843; 713 845-5531.

24-28 August 1981
CO 81, Conference on Combinatorial Optimization, Stirling, Scotland. Sponsor: Stirling University. Contact: L. Wilson (CO 81), Dept. of Computing, Stirling University, Stirling, Scotland.

9-11 September 1981
Eurographics 81, Annual Conference of the Eurographics Society, Technische Hochschule, Darmstadt, FRG. Sponsor: German Computer Society. Prog. chm: J. Encarnacao, Eurographics 81, Technische Hochschule Darmstadt, FG Graphisch-Interaktive Systeme, Steubenplatz 12, D-6100 Darmstadt, Federal Republic of Germany.

14-16 September 1981
ACM SIGMETRICS Conference on Measurement and Modeling of Computer Systems, Las Vegas, Nev. Sponsor: ACM Special Interest Group on Measurement and Evaluation. Conference Chm: Herbert Schwetman, Dept. of Computer Science, Purdue University, West Lafayette, IN 47907; 317 494-8566.

PREVIOUS LISTINGS

- 21-23 July 1980
Sixth South African Symposium on Numerical Mathematics, Durban, Rep. of South Africa. Sponsor: University of Natal. Contact: Chairman, Computer Science Dept., University of Natal, King George V Ave., Durban 4001, Republic of South Africa.
- 6-8 August 1980
Conference on Human Aided Optimization, Wharton School, Philadelphia, Pa. Sponsors: Office of Naval Research, Wharton School. Conf. chm: Gerald Hurst, Decision Sciences, W-83 Dietrich Hall/CC, University of Pennsylvania, Philadelphia, PA 19104; 215 243-7730.
- 17-21 August 1980
1980 Urban and Regional Information Systems Association Conference, Toronto, Ont., Canada. Sponsor: URISA. Contact: URISA, 180 North Michigan Ave., Suite 800, Chicago, IL 60601.
- 18-22 August 1980
4th Symposium on Computational Statistics, Edinburgh University, Scotland. Sponsor: International Association for Statistical Computing. Contact: COMPSTAT 1980, c/o Director, Program Library Unit, Edinburgh University, 18 Buccleuch Place, Edinburgh EH8 9LN, Scotland.
- 19-21 August 1980
National Artificial Intelligence Conference, Palo Alto, Calif. Sponsor: American Association for Artificial Intelligence in cooperation with ACM SIGART. Conf. chm: J. Marty Tenenbaum, SRI International, 333 Ravenswood Ave., Menlo Park, CA 94025; 415 326-6200 x4167.
- 20-22 August 1980
8th SIMULA Users' Conference, California State University, Northridge, Calif. Sponsor: Association for Simulation (continued on p. 414)

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APPENDIX B

[OLSE 07]

Evaluating User Interface Systems Research

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ABSTRACT

The development of user interface systems has languished with the stability of desktop computing. Future systems, however, that are off-the-desktop, nomadic or physical in nature will involve new devices and new software systems for creating interactive applications. Simple usability testing is not adequate for evaluating complex systems. The problems with evaluating systems work are explored and a set of criteria for evaluating new UI systems work is presented.

ACM Classification Keywords

H.5.2 User Interfaces

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Human Factors

Author Keywords:

User Interface Systems Evaluation

INTRODUCTION

In the early days of graphical user interfaces, the creation of new architectures for interactive systems was a lively and healthy area of research. This has declined in recent years. There are three reasons for this decline in new systems ideas. The first is that, unlike those early days, there are essentially three stable platforms (Windows, Mac, Linux) upon which virtually all software is built and those platforms have dictated the user interface architecture. This is in contrast to the state of UI research 15 years ago when there were many competing toolkits and platforms. The second is that the stability of these platforms has lead to a new generation of researchers who lack skills in toolkit or windowing system architecture and design. The third reason is the lack of appropriate criteria for evaluating systems architectures. This paper addresses the last question of "How should we evaluate new user interface systems so that true progress is being made?"

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WHY UI SYSTEMS RESEARCH?

Before addressing the evaluation question we must first consider the value of user interface systems research. The systems we have are stable. Applications are being written. Work is progressing. The users are happy (sort of). Why then does the world need yet another windowing system?

Forces for change

A very important reason for new UI systems architectures is that many of the hardware and operating system assumptions that drove the designs of early systems no longer hold. Saving a byte of memory, the time criticality of dispatching an input event to the right window or lack of CPU power for geometric and image transformations are no longer an issue. Yet those assumptions are built into the functionality of existing systems. The constraints of screen size are rapidly falling and we are finding that interaction in a 10M pixel space is very different from interaction in a 250K pixel space.

Our assumptions about users and their expertise have radically changed. Most of our windowing systems are designed to deal with a populace who had never used a graphical user interface. That assumption is no longer valid. The rising generation is completely comfortable with computing technology in a variety of forms and is increasingly comfortable with change.

Our existing system models are barriers to the inclusion of many of the interactive techniques that have been developed. Research as shown that manipulating the mouse gain can improve selection in various spaces [1] yet this does not fit smoothly into any UI system model. Cameras and touch tables produce inputs that are the size of a hand or finger rather than a point, yet we force such techniques into the standard mouse point model because that is all that our systems support. Multiple input points and multiple users are all discarded when compressing everything into the mouse/keyboard input model. Lots of good research into input techniques will never be deployed until better systems models are created to unify these techniques for application developers.

The advent of new interactive platforms also drives a need for new systems architectures. The WWW forms a huge base of interactive use, yet its interaction model is primitive and the toolkits built around it are difficult. People are increasingly moving their digital lives to PDAs, cell phones

and other portable platforms. Many people live and work across many platforms and interact with many people, yet our UI systems architectures support none of this.

In the early days of the Mac and Windows, an industry leader said “Almost none of our customers own a mouse or a graphics card. The installed market is too large and too entrenched to change.” Barely 5 years later that company had fallen from market dominance to near irrelevance because the market had moved to screen/keyboard/mouse. We now stand at a similar position. Systems based on one screen, one keyboard and one mouse are the new equivalent of command-line interfaces. We need new UI systems solutions. Our current systems architectures are beginning to impede progress rather than empower it.

Value added by UI systems architecture

Before addressing the evaluation of research claims we should look at the value UI systems architectures bring to the table.

Reduce development viscosity

A good UI toolkit will reduce the time it takes to create a new solution. The faster new solutions can be created, the easier it is to try more solutions on users. The more solutions that users experience, the more effective the UI design process will be.

Least resistance to good solutions

UI programmers, like most programmers, are optimizers. They tend to follow the path of least resistance. Apple spent a lot of time and effort writing a style manual and evangelizing the value of a common look and feel. None of this effort had the impact of providing a standard widget set built into the system that was available for free. The toolkit made adoption of a common look and feel much cheaper and easier than custom solutions.

A related concept is that toolkits can encapsulate and simplify expertise. When exploration of a space of possibilities finally settles on a few good solutions, these can be packaged into a toolkit to simplify the development of future systems.

Lower skill barriers

Bill Buxton’s MenuRay [2] demonstrated that large portions of the UI design problem could be handled by drawing rather than code. Systems like HyperCard and Visual Basic commercialized these ideas and allowed people with a much different set of skills to participate in UI development. The right toolkit design meant that artists and designers rather than programmers were dictating the visual appearance of user interfaces. Good toolkit design can expand the set of people who can effectively create new applications.

Power in common infrastructure

Though the current mouse/keyboard event model is standing in the way of many new interactive devices and

techniques, it has also empowered many new techniques. Pen-based interfaces have benefited from pretending to be a mouse. Though the pen has many unique advantages, by pretending to be a mouse it is usable for most existing applications. In our current event model, any device that can produce 2D input events is usable by any existing application. This has real power in supporting new combinations to create new solutions. What we need is an upgrade to this common denominator to empower more advanced techniques.

The HTTP/HTML standard is a clear example of the power of common infrastructure. By adhering to this simple standard any user can acquire a browser that will give them access to a vast number of services. Conversely any new service that adheres to the standard can gain access to multitudes of potential customers.

UI toolkits and system architectures define the ways in which interactive components are combined. The power of such techniques is also their curse. The importance of such standards makes the cost of changing them very high. However, if we do not search out and develop new ways to combine UI technologies we stunt our potential.

Enabling scale

Laying stable foundations makes possible larger more powerful solutions than ever before. The set of applications that can be economically built without a good toolkit is substantially smaller than with one.

EVALUATION ERRORS

Before exploring better ways to evaluate interactive software architectures, it is helpful to look at some ways that misapplied evaluation methods can damage the field. There are three to be discussed here: the usability trap, the fatal flaw fallacy and legacy code.

The Usability trap

When evaluating interactive systems the first concept that comes to mind is usability. There are several common measures of usability such as time to complete a standard task, time to reach a certain level of proficiency and minimize number of errors. Usability measures have driven a great deal of good research in the CHI community.

Many usability experiments are built on three key assumptions. The first is “walk up and use.” This assumes that all potential users have minimal training. This is a great goal for home appliances and for software tools used by many people. This goal also works if there is a large pool of potential users with shared expertise, such as secretaries or chemists. The assumption is that anyone with the shared expertise should be able to walk up and use the system. The “walk up and use” assumption does not work well for problem domains that require substantial specialized expertise, such as user interface programming or design.

The second is the standardized task assumption. To make valid comparisons between systems one must have a task

that is reasonably similar between the two systems and does not have many confounding complexities. The task of entering a string of text is fairly standard across any set of text entry techniques. There are not many ways to approach the task. A task of painting a picture or designing a circuit is not a good task for a usability experiment. There are too many variables in the task to make valid comparisons. Individual differences in creativity and skill create too many variations in the potential user population. A task that is suitable for a usability experiment must have low inherent variability so that any variance can be assigned to the differing techniques being tested not to variations in approach to the task or user expertise.

The third assumption is scale of the problem. The economics of usability testing are such that it must be possible to complete any test in 1-2 hours. More extensive testing may allow multiple sessions over many weeks but any practical experiment cannot afford thousands or tens of thousands of experiment hours. A usability test of a toolkit that requires 10 programmers over 6 months would incur at least \$300,000 in user subject compensation for just that one test. The cost is high and the statistical significance very low.

Usability testing is attractive because it can produce a statistically valid, clearly explained, easily compared result. However, toolkit and UI architecture work rarely meets any of the three assumptions of usability testing.

Usability testing of interactive tools and architectures

Any UI toolkit that addresses substantive problems will require expertise in using the toolkit. By definition any new toolkit will have no population that possesses that expertise. Any comparison between a new toolkit and an existing toolkit will be confounded by familiarity with the existing toolkit and the need for expertise in using the new one. The only way to eliminate this confound is to find a population that is equally ignorant of both systems. This produces comparison results that are not representative of the intended populations of either tool.

The standardized task assumption is also violated in systems architecture research. Any problem that requires a system architecture or a toolkit in its solution is by nature complex. UI applications are known to be complex with many possible paths to a solution. Meaningful comparisons between two tools for a realistically complex problem are confounded in so many ways as to make statistical comparisons more fantasy than fact.

The task scale assumption is also violated by UI systems work. Building a significant application using two different tools, even if valid comparisons were possible, would be very costly. Performing many iterations on a toolkit solution using this evaluation technique would be out of the question.

The usability trap lies in how we respond to nature of usability measurement for systems architectures and

toolkits. There are those who respond with “If it can’t be measured it is not research.” This reduces research to the study of the trivially measurable. There is a slightly different response which is “Focus on the measurable it is easier to publish.” This limits our power to effect significant change. A much more interesting response would be “If not usability then how do we evaluate systems?” This is the topic of this paper.

The fatal flaw fallacy

When evaluating small interactive techniques or specific behaviors it is good practice to carefully examine all of the possible ways in which the technique or its validation might be in error. If such a fatal flaw is discovered then the reported results may not be valid and the work should be remanded to the authors for repair.

This search for fatal flaws is devastating for systems research. It is virtually impossible for a small team of researchers to recreate all of the capabilities of existing systems or to completely examine all of the eventualities of new concepts. The farther such a team reaches into new territory the more compromises will be required and the more supporting ideas must be left unresolved. If a new systems approach is attempted, the omission of some important feature is guaranteed. The existence of a fatal flaw is a given. If the evaluation of the work is focused on “what does it not do” no research system will ever pass. Flaw analysis will frequently be a barrier to new systems research.

Legacy code

In the late 1970s many people objected to new UI architectures because of the vast amount of legacy code written with command-line or text screen interfaces. When the Macintosh hit the market followed by Windows suddenly all that legacy code became irrelevant. The WWW has precipitated a vast rewrite of the ways in which companies deal with the public. Many desktop applications have been rewritten for cell phones and PDAs. And yet people still invoke the “legacy code” standard for UI systems research.

If a toolkit can run legacy applications while providing some new advance that is a good thing. If a new architecture necessitates rewriting applications, that is just the price of progress. The legacy code requirement is a barrier to progress.

EVALUATING EFFECTIVENESS OF SYSTEMS AND TOOLS

To find ways to evaluate systems and tools we must revisit the claims that are made. Our list of advantages presented for toolkits and systems provides us a framework of possible claims. Given a set of possible claims we can then outline ways to demonstrate each of them.

STU: Situations, Tasks and Users

Every new piece of interactive technology addresses a particular set of users, performing some set of tasks, in some set of situations. It is critical that interactive innovation be clearly set in a context of situations, tasks and users. The STU context forms a framework for evaluating the quality of a system innovation.

In systems and toolkit work there are frequently two different STU contexts. The users of a toolkit are developers. The task is to design quality interfaces that fit some end user STU context. For example we may develop tools for programmers (users) who are creating applications (task) for doctors (end user) accessing medical records (end task) while making hospital rounds (end situation). These tools might be designed to allow programmers (users) to do development while following doctors around (situation).

Importance

Before all other claims a system, toolkit or interactive technique must demonstrate importance. Tools are invariably associated with expertise gained over time. People will not discard a familiar tool and its associated expertise for a 1% improvement. In most cases at least a 100% improvement is required for someone to change tools. Without establishing the importance of the problem and its proposed solution, nothing else matters.

Importance analysis proceeds directly from the intended STU context. The first question is the importance of the user population (U). Populations can be important because they are large (every sentient being over the age of 10). User populations may be important because their performance is critical to the well being of others (doctors, emergency personnel, or teachers). User populations may be important because of tremendous need (disabled, poverty). Every population is important to itself. We must give some consideration to the population's importance to society in general. Sports fans in the bleachers behind left field at Yankee stadium would not be a very important population no matter how fervid they may be.

Assuming that the user population is important we must then evaluate how important the target tasks (T) are to that user population. Importance might be established by how frequently the task occurs. It might also be established by looking at the consequences of not being able to do the task. It is a serious problem if a doctor cannot access a patient's records.

We must look at the set of situations (S). How often do the target users find themselves in these situations and do they need to perform these tasks (T) in those situations? We must also look at the importance of the STU context as a whole. Many doctors go scuba diving. Doctors are important. Scuba diving is a novel situation but accessing patient records while scuba diving does not seem particularly important.

Lastly we must consider the difference that our new technology will make. Changing work practice requires a lot of effort. Although data analysis is good, if the difference offered by our new technology must be carefully analyzed for statistical significance in order to establish an improvement, then it is probably not important.

Problem not previously solved

This is one of the more compelling claims for a tool. This claim says that there is a STU context that has no current solution. It is a powerful claim to demonstrate that T can be performed effectively with a new tool. Usability testing is irrelevant when comparing what can be done against what cannot.

Such a claim is seriously weakened if there is only a single task T. What has been created is not a design tool but an application. That application may be important to the user population U, in which case it may be more appropriately published in the literature of population U. This novelty claim is strengthened if population U is very, very large (i.e. everyone who can read). The larger and more diverse the STU context is, the stronger the claim to the importance of a solution. The World Wide Web could make the claim that previously it was impossible for non-programmers to interconnect many disparate information resources.

Generality

The new solution claim is much stronger if there are several populations U_i that each have tasks T_i that do not have effective solutions with existing technology. If the new tool can solve all of T_i then a claim for a general tool is quite strong. The generality of the new solution claim is strengthened as the populations U_i are increasingly diverse from each other.

The problem with this claim is that proving solutions for all T_i is not possible. In fact the more general the tool the less likely one can demonstrate all of the possible solutions for which the tool is useful. The best proof of a generality claim is the diversity of the STU contexts for which a solution is demonstrated. If one has used the tool to solve three diverse problems then one can argue that the tool solves most of the problems lying in the space between the demonstrated solutions. The greater the diversity and the larger the number of demonstrated solutions, the stronger the generality claim.

Reduce solution viscosity

One of the important attributes of good tools is that they foster good design by reducing the effort required to iterate on many possible solutions. The more cumbersome the tool, the greater the viscosity in the design process with fewer and less diverse alternatives being explored. There are at least three ways in which a tool can reduce solution viscosity: flexibility, expressive leverage and expressive match.

Flexibility

A UI tool is flexible if it is possible to make rapid design changes that can then be evaluated by users. This has been the claim of interpreted programming languages. By eliminating the compile step, it is faster to try many different solutions. By evaluating code created at run-time more flexible solutions are possible. Visual UI design tools exhibit flexibility when one can rapidly make changes to the appearance of the user interface.

The flexibility claim is relatively easy to support. Define some interesting and diverse set of possible design changes and show that such changes take significantly less effort in the new tool relative to the competition.

Expressive Leverage

Expressive leverage is where a designer can accomplish more by expressing less. The dominant cost of any design processes is the making, expression and evaluation of choices. Expressive leverage is achieved when a tool reduces the total number of choices that a designer must make to express a desired solution. There are several ways this might be done.

Eliminating repetitive choices is an easy technique for achieving leverage. The simplest mechanism is reuse. The claim is that a large class of STU contexts include the expression of choice Y, yet Y is the same across all of these solutions. A tool that encapsulates Y so that the choice is made only once is more expressive. One must show that every solution in the class of solutions includes Y and that every instance of Y is similar or show that the differences are easily parameterized. The size/importance of the STU contexts in which choice Y must be made is key to this claim.

There are pitfalls to the “generalize and reuse” strategy for expressive leverage. In many cases the manipulation of the parameters is more complex than redoing a custom instance of Y. This comes when there is more variation in Y than was originally anticipated. This also comes when one generalizes too far.

A good example of over-generalization is the Table widget. At first glance it has rows, columns and cells. Columns have headers and cells contain text. It is relatively easy to write such a widget and its interface to the data for the model is quite straightforward. The temptation, however, is to add fonts, colors, special layout rules, arbitrary data types for the cells, icons for the columns and specialized cell editors with four or five different ways of embedding those editors into the cells/table layout. Suddenly the correct specification of the parameters to the Table widget is more complex and less predictable than implementing it from scratch. A generalize and reuse strategy must demonstrate that there has been a clear reduction in the number of choices that a designer must make and that the implications of those choices are clear to the designer.

A second means for reducing the required number of design choices comes from observing that many choices are not independent but are almost always implied by other choices. Having made choices A, B and C, then design choices U, V and W are determined. We get our expressive leverage by automatically computing U, V and W from A, B and C rather than requiring the designer to express them. An example would be the automatic calculation of complimentary colors once a background color is selected. A variation is that default values U, V and W are computed and then only manually changed when necessary. In the common cases the complexities of U, V and W are gone.

A third means for achieving expressive leverage comes from the progress of technology. For example the GIGO event handling system [3] was widely acclaimed in its time because of its small memory footprint and that event dispatch that could be accomplished in less than 10 machine instructions. For years various event dispatch mechanisms were proposed to optimize the interactive loop. This need for optimal event dispatch imposed various design choices on programmers to achieve the desired speed. When 500 KHz processors became 3GHz processors these design choices became irrelevant. Eliminating such choices and simplifying what a designer must do becomes possible as more memory, processor and communications power becomes available.

Claims of increased expressive leverage may often be unjustly discounted by reviewers. Most of the leverage comes from some insight about the way in which systems have been used or developed. Once the insight is exposed, the implications are obvious. It is very tempting for reviewers to site the obvious nature of the implication and thus discount the value of the insight. It is incumbent on the reviewer to demonstrate that the insight is either trivial or was already known.

Expressive Match

Tools for creating new user interfaces can be improved by increasing the expressive match of the system. Expressive match is an estimate of how close the means for expressing design choices are to the problem being solved. For example one can express a color in hexadecimal or one can pop up a color picker that displays the color space in various ways and shows the color currently selected. Both are completely accurate means for expressing color, but the color picker is a much closer match to the design problem.

Most interface design environments provide a tool for placing widgets in a form and dragging them around until the resulting layout is visually appealing and readily understood. Encoding the coordinates of each widget in C++ or a text file will accomplish the same goal, but the visual tool is a better expressive match for the task of creating a usable and pleasing layout.

There are several requirements when making a claim of greater expressive match. One must demonstrate that the

new form of expression is actually a better match. If the problems are small enough one can compare times to create a design or express a set of choices. This may or may not fall into the usability trap described above. Frequently greater expressive match is tied to a claim to lower skill barriers.

Another test for expressive match is a “design flaw challenge”. A design that is deficient in some way is encoded in the two different forms. Users are each given one of the forms of expression and asked to locate and remedy the flaw. Time, errors, difficulties and success rates can be used to compare two forms of expression. In many cases such challenges are trivially obvious. “Match this color” can be given in hex or in a color picker. For most people the task is virtually impossible in hex and even for experienced designers there is a lot of trial and error required. Similarly a flaw in the input handling of some widget can be posed. Some designers are given state diagrams and some are given the equivalent Java/Swing code. Each is challenged to find and remedy the flaw.

Greater expressive match sometimes introduces difficulty in integrating multiple forms of representation and their associated tools. A long term challenge in the UI community has been the integration of various visual representations with program code. Despite years of research and dozens of alternative proposals, algorithms and data structures are still best represented in a general-purpose programming language. State machines showed real promise as a representation for input, yet they always reached expressive limitations that required a transition to code and the transition was awkward. Visual Basic addressed this problem by integrating a full interpreted programming language into its UI layout tool. The key point is that any new form of expression must be computationally complete or must have a clear integration mechanism with a programming language. When there are many different forms of expression, the tools must show how they integrate effectively with each other. In many cases the integration effort swamps the benefits of the new tool or notation.

Empowering new design participants

The previous set of claims focused on the speed or ease with which a user interface could be designed. Tools can also make a contribution by introducing new populations to the UI design process. Frequently this is done by dealing with expressive leverage and expressive match issues, but the claims are different. The “new design participants” claim is that there is some population U who would benefit by being more directly involved with the UI design process. It has long been claimed that empowering artists will lead to better visual designs. Participatory design advocates the involvement of end-users in the design process.

The first part of the claim must be to describe some population of participants and show why they should be involved in the UI creation process. Secondly one must

establish why existing tools are not acceptable for this population. This may include lack of appropriate training, different norms of expression or design goals that are not supported by existing tools. Lastly one must demonstrate that the new tools are accessible, easier or more effective for this desired population.

The simplest criterion is that the existing tools simply could not be used by the target population at all. Demonstrating that artists cannot reliably encode colors in hex is an easy claim to make. A second claim is that the new tools are easier for this population. Here usability tests are possible. However, the representation may not scale to full-sized UI designs and the usability trap will be reintroduced. There is also an importance issue. If there is not a substantial improvement in ease or usability to this population or the population is only peripherally involved then there just may not be much value in the new tool. People will only change tools for substantial (2 times or better) improvements. The last claim is that the resulting UI designs are “better” when the new tools are used by this population. The question of defining “better” is problematic.

Power in combination

Many tools demonstrate their effectiveness by supporting combinations of more basic building blocks. There are two basic variations of this claim. The first is an inductive claim that an infinite set of solutions can be built from primitives and their combinations. The second is the N to 1 reduction. Both of these approaches are based on clearly defining mechanisms for combining pieces of design to create a more powerful whole.

Inductive Combination

This is the basis for grammars, UI component trees and a variety of other innovations. The idea is that there is some set of primitive design components and some mechanism for combining them into more complex designs. Some simple set of string tokens can be combined using non-terminals and production rules to create an infinite number of different programming languages. Simple widgets that each perform some interactive task can be combined using panes, tabs, tables and other visual constructors to create an infinitely diverse set of UI designs.

Making this sort of claim requires that one show that the set of primitives is either relatively small or can be easily extended. User interface toolkits use both of these strategies. There is usually a small set of primitive widgets (less than 30) from which many interesting designs can be built. In addition, most toolkits provide a mechanism for creating new primitives that can be readily integrated into the set. The power comes from the means for combining these pieces into more complex designs. The induction to an infinite set of possibilities comes when any of these combinations can be used wherever a primitive solution can be used.

This claim introduces the question of coverage. For example, context-free grammars define an infinite set of textual languages. However, it can be readily proved that they cannot fully represent most programming languages. It can also be readily shown that combining menus, scroll-bars, labels and text boxes into forms can produce an infinite number of UI designs. However, many UI designs (painting, drawing or animation time lines) will not fit this model. Virtually any combination scheme will leave out some design solutions. Therefore one must show that the set of designs within the system are interesting and that there are mechanisms outside the system for addressing issues that are not covered. Compilers added symbol tables to context-free grammars to make them effective. UI toolkits generally provide a means for adding new primitive components for extensibility.

Simplifying Interconnection

There are many situations where components must communicate and integrate with each other. This interconnectivity is critical to the deployment of new technology. A system of N components that must work together imposes a serious burden on the N+1 component. If every component must implement an interconnection with every other component then the N+1 component must include N interconnections with other pieces. A good interconnection model will reduce the cost of a new component from N to 1. With a good interconnection model the new component must only implement the standard interface. It will then be integrated with all N existing components.

An early example was the use of pipes in UNIX. Applications would read from standard-in and write to standard-out. Pipes could connect the standard-out of one program directly to the standard-in of another, allowing applications to be plugged together in any number of useful ways without new code.

A more compelling example is the World Wide Web. When one creates a new web browser one automatically inherits the value of all of the web sites that have been created. When one creates a new web site one inherits the value of all of the browsers that have been installed. Adding a new browser or a new site incurs only the cost of that site and not the cost of creating, connecting or deploying the remainder of the needed infrastructure. The power is in the connectivity architecture that reduces cost from N (one for every related component) to 1.

To make the interconnection claim, one must show 1) that there is an interesting diversity of choices on both sides of the connective architecture, 2) that they are all cleanly supported by the architecture, and 3) that the space of combinations is interesting and non-trivial.

Ease of Combination

The fact that architectural components can connect is generally not sufficient. It is important that the

interconnection be simple and straightforward. In most UI toolkits a new widget must only implement the *redraw()* and *resize()* methods to integrate with the rest of the system. Additional event-handling methods will provide interactivity but these two are sufficient. Many of the interconnection complexities are hidden in inherited code. The WWW has a similar ease of combination. The HTTP protocol that connects browsers to servers is very straightforward and easy to learn. My personal counter example is SOAP which took the relatively simple HTTP and XML techniques and created a very complex model for interconnecting with web services. This model is very difficult to use without additional layers of code generation to obscure its complexity.

Can it scale up?

An important question that must be asked of every new UI system is whether it can scale up to large problems. This was the fundamental drawback of state machines for describing user interface dialogs. For simple examples like dragging a rubber-band line, the state machine dialog was clear and direct. However, for any reasonable application the representation acquired hundreds of states interconnecting in hundreds of ways that were impossible to visualize, present on a screen, or debug. Constraint systems have similar problems. They nicely model small local relationships yet produce serious debugging challenges when hundreds of constraints are all being evaluated simultaneously. Any new UI system must either show that it can scale up to the size of realistic problems or that such scaling is irrelevant because there is an important class of smaller problems that the new system addresses. To evaluate this criteria one must try the system on a reasonably large problem and show that the advantages of the new model still hold.

SUMMARY

User interface technology, like any other science, moves forward based on the ability to evaluate new improvements to ensure that progress is being made. However, simple metrics can produce simplistic progress that is not necessarily meaningful. Complex systems generally do not yield to simple controlled experimentation. This is mostly due to the fact that good systems deal in complexity and complexity confounds controlled experimentation. This paper shows a variety of alternative standards by which complex systems can be compared and evaluated. These criteria are not novel but recently have been out of favor. We must avoid the trap of only creating what a usability test can measure. We must also avoid the trap of requiring new systems to meet all of the evaluations required above. This would recreate the fatal flaw fallacy. We must look to our evaluation strategy to answer the fundamental question "Has important progress been made?" If the answer is yes then we happily take our share of the new knowledge and move forward to fill in the gaps.

ACKNOWLEDGEMENTS

Though the opinions are the author's own they have been influenced by discussions with Scott Hudson, James Landay, Saul Greenberg and Ben Bederson.

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APPENDIX C

Nov. 20, 1928.

1,692,601

W. H. WHEELER

SPEEDOMETER MOUNTING FOR VEHICLES

Filed Sept. 20, 1926

2 Sheets-Sheet 1

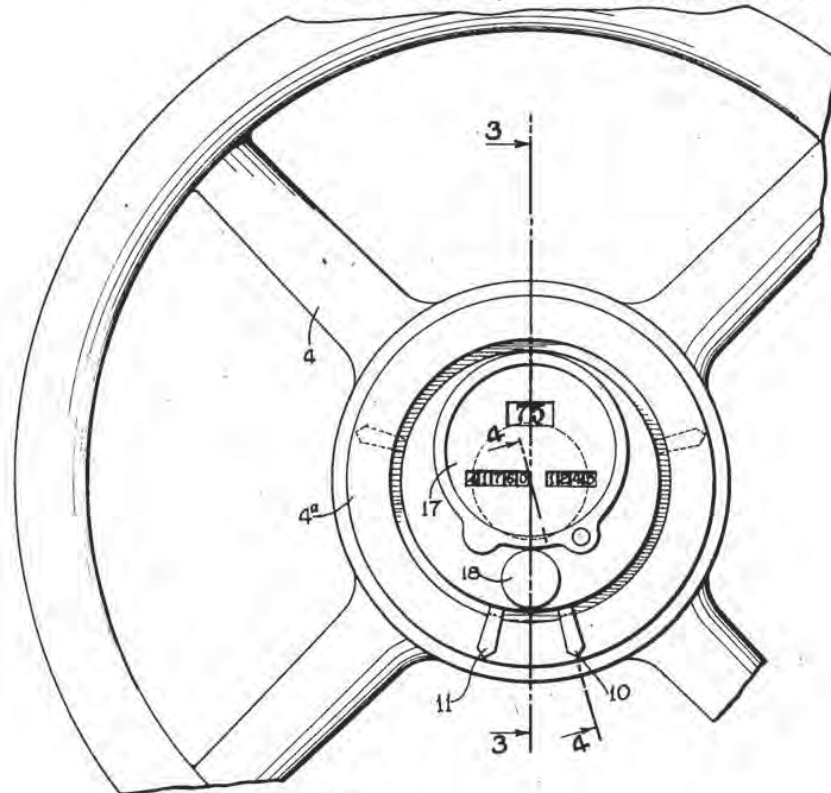


FIG. 1

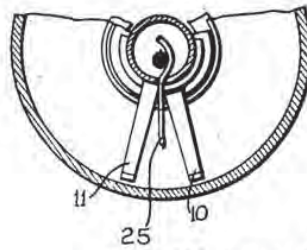


FIG. 2.

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Nov. 20, 1928.

1,692,601

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SPEEDOMETER MOUNTING FOR VEHICLES

Filed Sept. 20, 1926

2 Sheets-Sheet 2

FIG. 3.

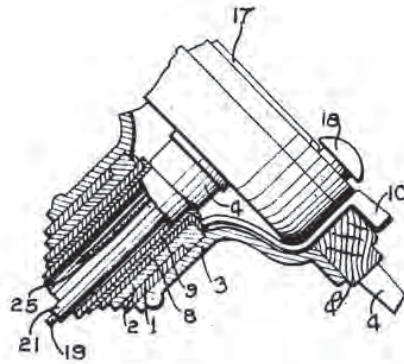
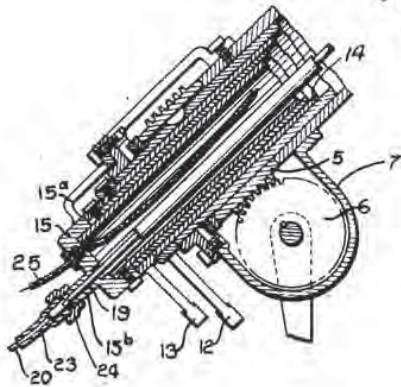
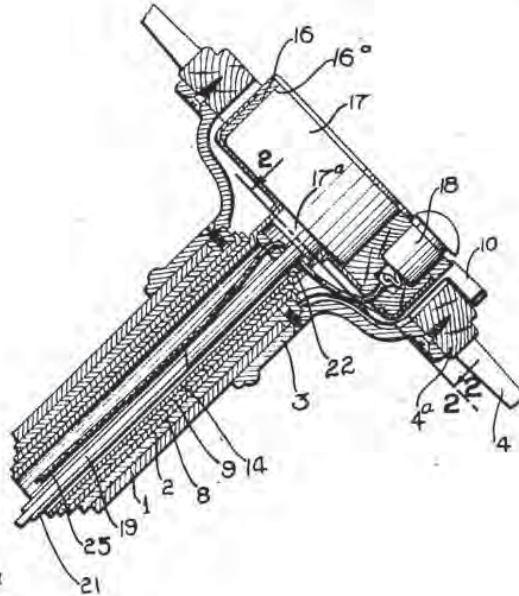


FIG. 4

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SPEEDOMETER MOUNTING FOR VEHICLES.

Application filed September 20, 1926. Serial No. 136,505.

My invention relates to speedometer mountings for vehicles, and the objects of my invention are; first, to provide a steering control means for vehicles on which is mounted a speedometer whereby the speed of the vehicle may be readily determined by merely dropping the vision slightly to the middle portion of the steering wheel which is substantially in line with the line of vision of the driver and as close to the eyes of the driver as possible, thus determining the speed of the vehicle with least danger to the driver and other occupants; second, to provide a steering post and steering wheel for automobiles which are so constructed that a speedometer may be mounted on the steering post at the middle portion of the steering wheel and substantially flush with the hub portion of the steering wheel, thus rigidly mounting the speedometer in plain view of the driver and in such a manner as not to interfere with the vision and necessary movements of the driver; third, to provide a steering post and steering wheel for automobiles which are so constructed as to receive and support a speedometer at the upper end of the steering post and at the middle portion of the steering wheel and to one side of the axis of the wheel so as to provide a convenient space for a signal button or other switch mechanism at the opposite side of the axis of the wheel and on the stationary portion at the middle portion thereof; fourth, to provide as a whole a novelly constructed and arranged mounting for a speedometer in connection with the steering post and steering wheel of an automobile; fifth, to provide a rigid drive shaft means for a speedometer mounted on the steering post, which drive shaft means extends through the steering post, thus materially decreasing the length of the flexible cable usually employed in connecting a revolving part of the automobile with the speedometer; and, sixth, to provide a speedometer mounting, in connection with the steering post and steering wheel of an automobile, which is simple and economical of construction, durable and which will not readily deteriorate or get out of order.

With these and other objects in view, as will appear hereinafter, my invention consists of certain novel features of construction, combination and arrangement of parts and portions as will be hereinafter described in detail, and particularly set forth in the appended claims, reference being had to the ac-

companying drawings and to the characters of reference thereon which form a part of this application, in which:

Figure 1 is a fragmentary view of an automobile steering wheel taken from the driver's side thereof, showing the speedometer mounted at the middle portion of the steering wheel; Fig. 2 is a fragmentary sectional view taken through 2-2 of Fig. 3, showing the construction of the upper end of the steering post below the steering wheel; Fig. 3 is a fragmentary longitudinal sectional view taken through 3-3 of Fig. 1, showing the construction and arrangement of the steering post, steering wheel and associated members and showing the speedometer mounted at the upper end of the steering post; and, Fig. 4 is a fragmentary sectional view thereof taken through 4-4 of Fig. 1.

Like characters of reference refer to similar parts and portions throughout the several views of the drawings.

In the steering post construction of certain types of conventional automobiles, the steering shaft or tube and also the ignition and fuel controls, as well as certain electric cables, extend through or are directly associated with a stationary hollow post. Such a construction and arrangement is illustrated in the drawings and will be briefly described hereafter.

The steering post 1 is rigidly mounted on the automobile frame in any suitable manner. Within the post 1, which is in the form of a tube, is rotatably mounted the steering tube 2 to the upper end of which is secured the metallic hub member 3 of the steering wheel, the lower end of the hub member 3 extending around the upper end of the steering post 1. To the upper or outer side of the hub member 3, is secured the annular portion 4^a of the steering wheel 4. To the opposite end of the steering tube 2, is secured a worm which is adapted to drive the steering worm gear 6 mounted in a casing 7. The casing 7 is secured to the lower end of the steering post 1 and rotatably supports the lower end of the steering tube. Within the tube 2 is rotatably mounted the fuel control tube 8 and within the latter is rotatably mounted the ignition control tube 9. Said tubes are provided at their upper ends with control levers 10 and 11 respectively which extend preferably beyond the upper side of the annular portion or hub portion of the steering wheel. To the lower ends of the tubes 8 and 9, are secured

the fuel and ignition operating levers 12 and 13. Within the ignition tube 9, is nonrotatably mounted the tube 14 which usually extends beyond the upper and lower ends of the tubes 8 and 9 and is fixedly secured at its lower end, in any suitable manner, to the gear casing 7 or the steering post 1. The means shown in the drawings consists of a cap for the lower end of the tube 14, which cap is provided with arms 15^a secured to the gear casing 7. At the upper end of the stationary tube 14 is usually provided a stationary support in which is mounted a signal button or other switch means, the electric cable, connecting the same to the mechanism to be controlled, extending through the tube 14.

In my construction I have provided a relatively large and deep supporting member 16 which is positioned within the annular portion 4^a of the steering wheel and an inwardly offset recess in the hub member 3, and is secured at its under or inner side to the end of the stationary inner tube 14, extending beyond the fuel and ignition tubes. The large supporting member 16 is spaced at its peripheral portion from the annular portion 4^a of the steering wheel and also from the hub member 3 so as to provide sufficient space for the fuel and ignition levers 10 and 11, connected to the upper ends of the tubes 8 and 9 respectively and extending beyond and over the front side of the annular portion of the steering wheel, to be shifted and operated freely. The outer side of the supporting member 16 may be flush with or extended slightly beyond the outer face of the annular portion of the steering wheel, as shown.

In the outer side of the supporting member 16, is provided a deep recess 16^a in which is mounted the speedometer 17, the connecting boss 17^a of which extends preferably into the upper end of the stationary tube 14. The center or axis of the recess 16^a is preferably positioned eccentrically relative to the axis of the supporting member 16 and the steering wheel 4. Thus a space is provided at the opposite side of the axis of the stationary supporting member 16, between the speedometer 17 and the lower side of the member 16, for a signal button 18 or other switch mechanism or means.

The speedometer 17 is operated by a small rigid shaft 19 which connects the speedometer at the back side thereof with a flexible cable 20 usually employed in connecting a moving part of the automobile with the speedometer. The shaft 19 is revolubly mounted in a casing or tube 21 which is secured at its lower or forward end in the head portion of the cap 15 and is positioned at its upper end by a head member 22 positioned at the upper end of the stationary tube 14. The flexible tube 23 in which the flexible shaft 20 is mounted, is connected with an extended

boss 15^b of the cap 15 by means of a nut 24. Thus the length of the usual flexible cable is considerably reduced.

The electric cable 25 for the signal button 18 extends, preferably, backwardly through the supporting member 16 into the upper end of the stationary tube 14, through the head member 22, through the tube 14 alongside the speedometer shaft tube and out through the head of the cap 15.

The arms or levers 10 and 11, for controlling the fuel and ignition, are preferably positioned at the opposite sides of the electric cable 25, as shown best in Fig. 2, so as not to interfere with the same.

Though I have shown and described a particular construction, combination and arrangement of mounting a speedometer and also a signal button in connection with the steering post and steering wheel of an automobile, I do not wish to be limited to this particular construction, combination and arrangement but desire to include in the scope of my invention the construction, combination and arrangement substantially as set forth in the appended claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In a speedometer mounting for vehicles, the combination with a steering post and a steering wheel mounted thereon, of a supporting tube extending through said post and non-rotatably fixed relative thereto, said tube having an enlarged supporting portion at the end contiguous to said wheel, said supporting portion being spaced from said wheel, a speedometer mounted on said supporting portion, a small rigid shaft revolubly mounted within said tube and operatively connected at one end to the back side of said speedometer, and a flexible cable directly connecting the end of said shaft extending beyond said tube to a revolving part of the vehicle.

2. In a speedometer mounting for vehicles, the combination with a steering post and a steering wheel mounted thereon and provided with a hollow hub, of a supporting tube extending through said post and non-rotatably fixed relative thereto, said tube having an enlarged supporting portion at the end contiguous to said hub, said supporting portion being positioned within and spaced from said hub, and a speedometer mounted in the supporting portion of said tube substantially flush with the front side of the hub of the steering wheel.

3. In a speedometer mounting for vehicles, the combination with a steering post and a steering wheel mounted thereon and provided with a hollow hub, of a supporting tube extending through said post and non-rotatably fixed relative thereto, said tube having an enlarged supporting portion at the end contiguous to said wheel, said supporting portion

being spaced from said wheel, and a speedometer mounted within the supporting portion of said tube and substantially flush with the hub, a speedometer drive means extending through said tube and operatively connected with said speedometer, and vehicle control levers positioned in the hollow portion of the hub outside of said supporting portion with their ends extending beyond the hub.

4. In a speedometer mounting for vehicles, the combination with a hollow steering post and a steering wheel rotatably mounted at the outer end thereof, said wheel having a hollow hub, of fuel and ignition control tubes, the one being rotatable within the other and the other rotatable within the steering post, a stationary supporting tube extending

through said tubes and said post and non-rotatably fixed relative to said post, a supporting means mounted at the outer end of said supporting tube positioned within the hollow hub and spaced from the walls thereof, a speedometer supported within said supporting means, a speedometer drive means extending through said supporting tube and connected with said speedometer, and fuel and ignition control levers connected to said fuel and ignition control tubes and extending through and beyond the space between said hub and said supporting means.

In testimony whereof, I have hereunto set my hand at San Diego, California, this 30 day of August, 1926.

WILLIAM H. WHEELER.

APPENDIX D

No. 714,878.

Patented Dec. 2, 1902.

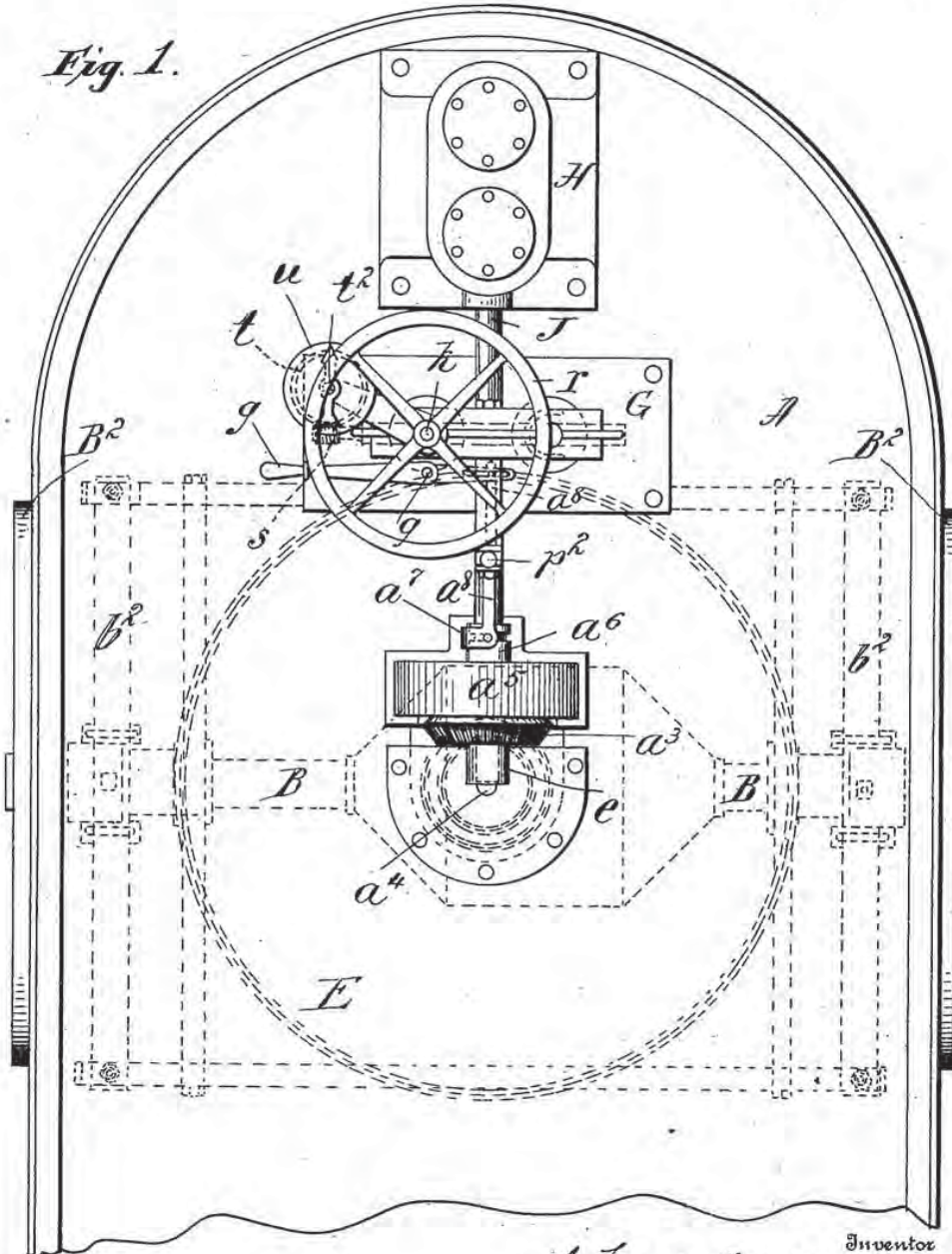
J. F. DURYEY,
STEERING MECHANISM FOR VEHICLES.

(Application filed May 10, 1900.)

(No Model.)

3 Sheets—Sheet 1.

Fig. 1.



Witnesses
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No. 714,878.

Patented Dec. 2, 1902.

J. F. DURYEY.

STEERING MECHANISM FOR VEHICLES

(Application filed May 10, 1900.)

(No Model.)

3 Sheets—Sheet 2.

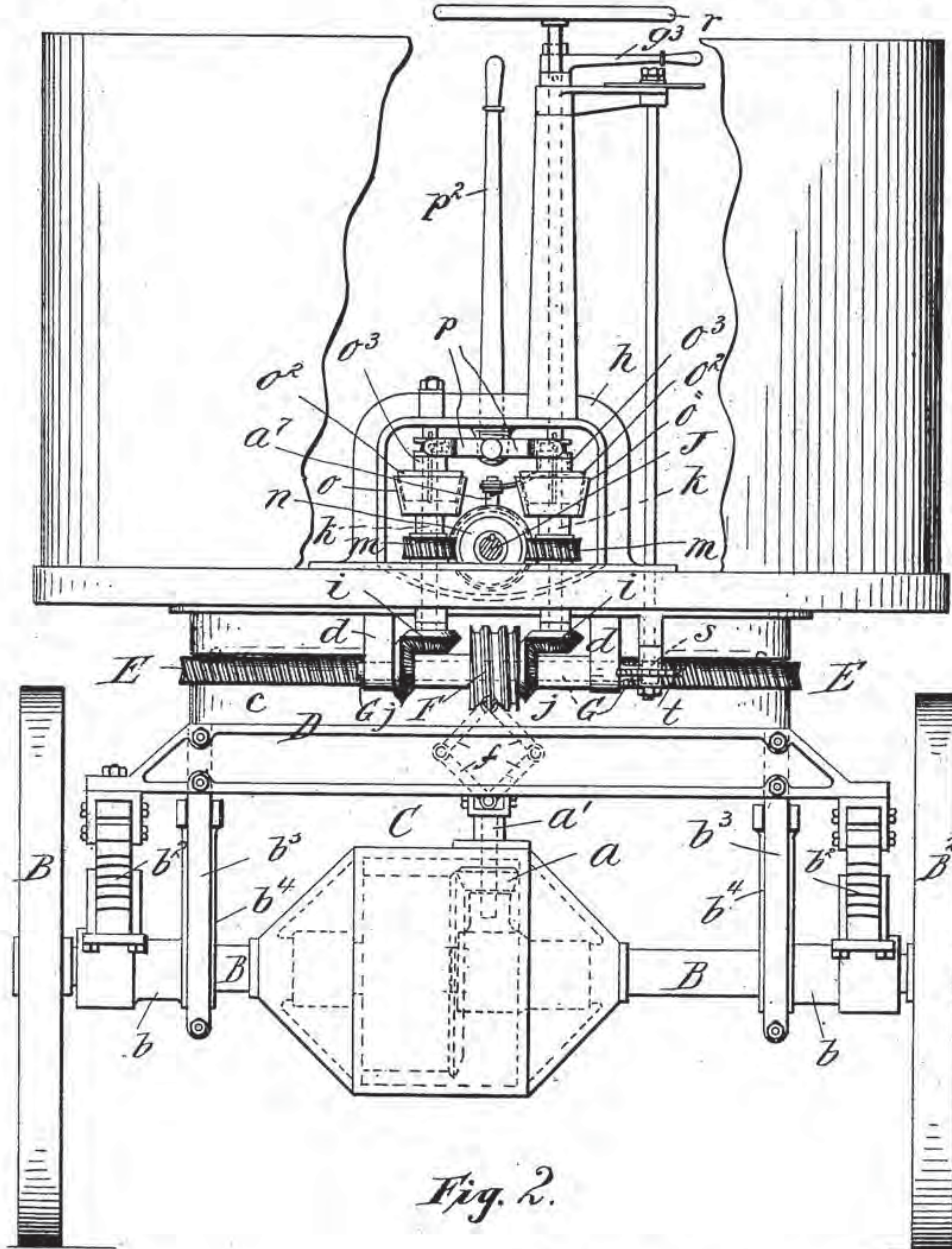


Fig. 2.

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THE MORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

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STEERING MECHANISM FOR VEHICLES.

SPECIFICATION forming part of Letters Patent No. 714,878, dated December 2, 1902.

Application filed May 10, 1900. Serial No. 16,241. (No model.)

To all whom it may concern:

Be it known that I, JAMES FRANK DURYEA, a citizen of the United States of America, and a resident of Springfield, in the county of Hampden and State of Massachusetts, have invented certain new and useful Improvements in Steering Mechanism for Vehicles, of which the following is a full, clear, and exact description.

This invention relates to improvements in motor-vehicles or automobiles, and more particularly to the class of such vehicles wherein the front wheels are both the driven and the steering wheels; and the invention more especially pertains to the mechanisms and controlling appliances whereby the motor may be made available for the propulsion of the vehicle through the front steering-wheels, whereby the motor may be employed to swing the steering-wheels to steer, whereby the motor may be simultaneously caused to both drive and steer, and whereby the motor may only drive the steering-wheels, the steering being operated manually.

The improved mechanism is especially useful on large and heavy motor wagons or trucks in which, especially at the time of starting the same, considerable power is necessary to change the relative position of the wheels under the body.

Another object of the invention is to insure that in the operation of the steering mechanism when the connections for changing the positions of the wheels toward one side are in engagement the connections for reversely changing the positions of the wheels must be necessarily out of engagement.

Another object of the invention is to provide an indicator observable at the place occupied by the rider or person in control of the motor-wagon for enabling him to know whether the steering-wheels range straight with the length of the vehicle or are turned to either side, this being especially advantageous at the time of starting the vehicle, which may have been left with the front wheels considerably deflected toward either side of the wagon.

The invention consists in combinations and arrangements of mechanisms and appliances and in constructions and combinations of

parts, all substantially as hereinafter fully described, and set forth in the claims.

Reference is to be had to the accompanying drawings, in which the views show the forward portion of the motor-vehicle having an engine or motor mounted thereon and showing the forward driving and steering wheels and the means for controlling the driving and steering, and in said drawings—

Figure 1 is a plan view. Fig. 2 is a front view with parts broken away and the engine-shaft being seen in cross-section as taken next to the rear of the engine. Fig. 3 is a side elevation. Figs. 4 and 5 are views in detail at right angles to each other of articulated driving connections hereinafter particularly referred to.

In the drawings, A represents the forward portion of the body of the motor-wagon or automobile vehicle, beneath which is the divided axle B for the forward wheels B² B², which are in this mechanism both the driving and the steering wheels, and, as common in the divided axles for the driving-wheels of motor-vehicles, the two adjacent parts of the axle are equipped with the compensating gearing indicated within the casing C, and comprised in which compensating gearing is the bevel gear-wheel A, to which continuous rotary motion may be imparted through driving connections from the engine thereto to secure the propulsion of the vehicle.

Above the divided axle is a truck-frame D, there being interposed between the truck-frame and the journals *b b* for the axles the spring *b²*, and the truck-frame has the depending pedestals *b³*, in which guide-blocks or parts *b⁴* of the axle-journals have relatively thereto a vertical play. The platform-like upper part *c* of the truck-frame supports thereon the large worm-wheel E, meshing with which is the worm F, the same being carried as a fixed part on a shaft G, which is horizontally and transversely mounted in the hangers or brackets *d d*, which are secured to and depend below the bottom of the wagon-body A.

H indicates the engine or motor, supported at extreme forward part of the wagon, the main or driving shaft J of the engine extending longitudinally along about the central line

of the wagon near the wagon-bottom, and its rear end is mounted in the journal-lug *e*, rising suitably above the bottom of the wagon-body. On the rear end portion of the shaft 5 is a bevel gear-wheel a^3 , which rotates in a vertical plane and in mesh with which is a bevel gear-wheel a^2 , which is mounted on the upper end of a vertical shaft a^1 , which shaft is shackled to the shaft-section a' of the bevel gear-wheel a , which is in driving connection 10 with the axle-sections B B.

For the reason that the gear-wheel and shaft section a^2 a^4 have vertical movements relatively to the wheels and axle corresponding to the movements of the spring-supported wagon-body and the gear-wheel a and its shaft-section a' are practically or relatively immovable the shaft-sections a' and a^4 are united by the double toggles f , which are articulated in 15 such manner that the endwise contraction of the two shaft-sections is readily permitted, but so that the turning of the upper shaft-section insures necessarily the turning of the lower shaft-section and the gear thereon.

The gear a^3 is understood as being loose on the engine-shaft J, and this gear-wheel a^3 has as one therewith the loose clutch-wheel a^5 , also loose on the engine-shaft, and with the grooved hub a^6 , which is splined to slide on the shaft J and which operates the shoes of the clutch, which may be of the most common and well-known type, the yoke a^7 is engaged, said yoke having the extension or connecting-rod a^8 , with which is connected or 20 engaged an arm or lever g^2 , which is carried at the lower end of a vertical shaft or post g , which at its upper end is provided with the operating-lever handle g^3 . The said shaft g or rotatable post is mounted in its vertical position in suitable bearings or brackets of the supporting structure, (indicated in a general way by the letter *h*.)

Of course it is apparent that by properly swinging the handle-lever g^3 in a horizontal 45 plane the engine will be in or out of driving connection with the front-wheel axle.

Mounted on the elongated hubs of the aforementioned worm F are bevel gear-wheels j j for rotations in vertical planes as one with 50 the shaft G, and both gear-wheels i i are in mesh with the said gears j j , the same being fixed at the lower ends of vertical shafts k k , which extend from the positions of said gears i below the wagon-body upwardly through the latter and have suitable bearings both near their lower ends and also in the arch-like part of the supporting frame or casting *h*.

Loose on the shafts k k are worm-wheels m m , intermediate between and in engagement with both of which is a worm n , (seen in Fig. 2,) said worm being fast on the engine-shaft J. Formed with or affixed to move in unison with the normally free-running worm-wheels m m are annular clutch members o o , for coaction with which are arranged 65 the correspondingly-provided clutch members o^2 o^2 , which are carried by the rotatable

sleeves o^3 , which slide vertically on the shafts k , but have spline engagements therewith, whereby they are rotated in unison with said 70 shafts.

p represents a two-armed lever, (best seen in Fig. 2,) the same being intermediately pivoted beneath the upper part of the arch-like supporting-casting *h* and between the said 75 shafts k k , and the extremities of the arms p are formed into yokes which engage the clutch-sleeves of the parts o^3 , and the extended intermediate journal-stud or rock-shaft, of which the said lever-arms p are extensions, has affixed thereto the upwardly-extending operating-lever handle p^2 . It will be understood that for the reason that the worm-wheels m m are, as shown in Fig. 2, arranged on opposite sides of the worm n the said 85 worm-wheels will be rotated by the worm in reversed directions, and so will be the shafts k k , one after the other, if placed in clutch with the respectively-provided worm-wheel, and rotational movement of either shaft imparted 90 thereto from the power-driven worm n when such shaft is in clutch with its worm-wheel will correspondingly turn the shaft G, which is below the wagon-body and on which is the worm F, so that the rotational movement of 95 said worm F will cause the partial turning of the large worm-wheel E and the front running-gear on which said large worm-wheel is an equipment. Thus it will be seen that the steering of the vehicle either to the right or 100 to the left may be accomplished, using the engine-power of the vehicle as the force for causing the deflection of the front-wheel axle and body under the control of the rider, who has merely to manipulate the clutch-operating lever p^2 . 105

In addition to the capability for the power-steering, as just explained, one of the shafts k (it is immaterial which) may be upwardly extended, as seen in the drawings, and provided with a hand-wheel r , by means of which 110 to operate the shaft on which it is mounted manually. Therefore by leaving the lever p^2 in its upright position, so that both of the shafts k k are out of connection with the engine-shaft, the entire steering may be performed by turning the hand-wheel in either 115 direction, as required.

For the reason that in many types of motor-vehicles in which the present steering mechanism is applicable the steering-wheels will not be visible to the person in control of the vehicle I make provision whereby the position of the wheels is indicated, the same consisting of a small worm s on the end of the shaft G, with which is in mesh a worm-wheel 120 t , the same being supported at the lower end of a vertical shaft t^2 , the upper end of which is journaled through a bracket h^3 , supported by the casting *h* at an upper extension thereof, and also supported movably on this bracket is a dial-plate u , while the upper end of the shaft has fast thereto an index or pointer t^3 . 125 The dial-plate may have graduations and in-

dicating characters as means for increased convenience of the person in charge of the running of the motor-vehicle.

The worm-wheel E, provided as an equip-
 5 ment to the steering-axle, and with which worm-wheel the axle must necessarily turn in unison, and the worm on the vehicle-body having the capability of being turned by the application of intelligently-directed power
 10 from above the body constitute valuable features in the present invention for improvements in motor-wagons, more especially because the worm-wheel and worm constitute a lock against any force tending to turn or
 15 swing the axle, which may be directed by pressure or stress on or through the wheels and axle, while at the same time the movements for the proper steering may be most readily imparted through the appliances
 20 (either power or manually operated) for turning the worm.

Having thus described my invention, what I claim, and desire to secure by Letters Patent, is—

25 1. A vehicle having on its body a motor-driven shaft, a clutch-engaged gear-wheel to be driven by said motor-shaft, and a depending shaft-section, the axle for the forward
 30 wheels arranged under said depending shaft-section and a gear-wheel in driving connection with the axle having a rising shaft-section, means of engagement between said shaft-sections whereby they rotate in unison, but
 35 may have contracted and distended relations, journal-sleeves surrounding said axles, having upward extensions $b^2 b^4$, and supporting the springs, a part, D, supported by said
 40 springs having the pedestals depending over and embracing said journal-sleeve extensions, and on which part D the forward part of the vehicle-body rests, and between which said
 45 part and body there is relatively a swiveling movement and means provided and actuated on the body, and operating on the said part D, for turning same, substantially as described.

2. A vehicle having on its body a motor-driven shaft, a clutch-engaged gear-wheel, to be driven by said motor-shaft, and having a
 50 depending shaft-section, the part D, having the worm-wheel, E, below the body and relatively to which it turns about the axis of said shaft-section, and provided with the pedestals b^3 , the axle having the journal-sleeves
 55 provided with the rising extensions b^4 engaging and adapted to play within, said pedestals, and having supported thereon the springs on which said part D is yieldingly mounted, a gear-wheel in rotatably-driving connection
 60 with the axle, having the upstanding shaft-section, double links jointed to the two said shaft-sections, a worm supported by the body, engaging said worm-wheel, and mechanism intervening between the motor-shaft and said
 65 worm connected with the worm and having clutching and unclutching connections with

the motor-shaft, substantially as and for the purposes set forth.

3. In a motor-vehicle the combination with the forward axle, equipped with a worm-
 70 wheel, of the vehicle-body carrying a motor and provided with a worm in engagement with the worm-wheel, which worm has, to rotate in unison therewith, two gear-wheels, two shafts located at opposite sides of the motor-
 75 shaft, on which are gear-wheels meshing said two gears provided to the worm, a worm mounted on the motor-shaft, worm-wheels $m m$ loosely mounted on the said two shafts and
 80 engaging at opposite sides of the said motor-shaft worm, clutch members mounted on and constrained to turn with said two shafts, and adapted to be thrown into engagement with said worm-wheels $m m$, for the purpose set
 85 forth.

4. In a motor-vehicle, the combination with the forward axle, equipped with a worm-
 wheel, of the vehicle-body carrying a motor and provided with a worm, in engagement
 90 with the worm-wheel, which worm has, to rotate in unison therewith, two gear-wheels, two shafts located at opposite sides of the motor-shaft, on which are gear-wheels meshing
 95 said two gears provided to the worm, a worm mounted on the motor-shaft, worm-wheels $m m$ loosely mounted on the said two shafts and engaging at opposite sides of the said motor-shaft worm, clutch members mounted on and constrained to turn with said two shafts, and mechanism for controlling said
 100 clutches having united members engaging both thereof, whereby when one is in engagement with its adjacent worm-wheel m , the other clutch necessarily is placed out of engagement with the other worm-gear, substantially
 105 as described.

5. In a motor-vehicle the combination with the forward axle, equipped with a worm-
 wheel, of the vehicle-body carrying a motor and provided with a worm in engagement
 110 with the worm-wheel, which worm has, to rotate in unison therewith, two gear-wheels, two shafts located at opposite sides of the motor-shaft, on which are gear-wheels meshing said two gears provided to the worm, a worm
 115 mounted on the motor-shaft, worm-wheels $m m$ loosely mounted on the said two shafts and engaging at opposite sides of the said motor-shaft worm, and having clutch members $o o$, clutch members $o^2 o^3$ sliding on and
 120 turning with said two shafts, and having grooved extension-sleeves o^3 , a handle-lever p^2 mounted for a rocking motion and leaving the double lever members $p p$ which engage said clutch-sleeves o^3 , substantially as de-
 125 scribed.

6. The combination with the vehicle-body having the shaft provided with the worm F and the worm s , the front-wheel axle equipped with the worm-wheel E, with which the worm
 130 F is in engagement, means for causing the rotation of the said worm F in either direc-

tion, a shaft having a worm-wheel *t* in engagement with worm *s*, and having an indicator, substantially as and for the purpose set forth.

5 7. In a motor-vehicle in combination, the front-wheel axle supporting the worm-wheel in unison with which the axle is constrained to turn or swing horizontally, the vehicle-
10 body having the motor and its shaft mounted thereon, and provided with the gear-wheel *a*³, a clutch for connecting and disconnecting said gear-wheel with and from the axle, and means for operating the clutch, the shaft *G*
15 *F* and the bevel-gears *j j*, the shafts *k k* mounted on the body at opposite sides of the motor-shaft, a worm *n* on the motor-shaft, worm-wheels *m m* loose on the shafts *k k* having
20 clutch members, clutch members turning with, but slidable along, said shafts *k*, coacting with the worm-wheel clutch members, means for manually operating the sliding
25 clutch members simultaneously in opposite directions, and means for manually rotating one of said shafts *k* in either direction, substantially as and for the purposes set forth.

8. In a motor-vehicle in combination, the front-wheel axle having the spring-supported truck-frame *D* provided with a worm-
30 wheel *E*, and a vertical shaft-section *a'* with

a gear in driving connection with the axle, the vehicle-body having the shaft-section *a*⁴ link-connected with shaft-section *a'*, the engine-shaft having the worm *n*, and the loose
35 clutch-wheel *a*⁵ geared to the shaft-section *a*⁴, the clutch-sleeve turning with and movable along the engine-shaft, the lever *g*³ and connections between same and the clutch-sleeve, the shaft *G* supported below the motor-body,
40 having the worm *E* engaging said worm-wheel, and having the bevel gear-wheels *j j*, the vertical shafts *k k* at opposite sides of the engine-shaft having the gear-wheels, *i i*, meshing the ones *j* and having loose thereon
45 the worm-wheels *m m* both meshing said engine-shaft worm, and provided with clutch members the clutch-sleeves turning with and slidable along the shafts *k k* cooperating with the worm-wheel clutch members, the two-
50 armed lever *p* and common operating handle-lever *p*² and a means for manually turning one of said shafts *k*, substantially as described.

Signed by me at Springfield, Massachusetts, in presence of two subscribing witnesses.

J. FRANK DURYEA.

Witnesses:

WM. S. BELLOWS,
NETTIE M. BELLOWS.

APPENDIX E

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technology

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technology

[play](#)

noun tech·nol·o·gy /tek-'nā-lə-jē/

Popularity: Top 1% of lookups

Simple Definition of *technology*

- the use of science in industry, engineering, etc., to invent useful things or to solve problems
- a machine, piece of equipment, method, etc., that is created by technology

Source: Merriam-Webster's Learner's Dictionary

[Examples: technology in a sentence](#)

- -
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Full Definition of *technology*

plural

technologies

1. *1a*: the practical [application](#) of knowledge especially in a particular area : [engineering](#) 2 <medical technology> *b*: a capability given by the practical application of knowledge <a car's fuel-saving technology>
2. *2*: a manner of accomplishing a task especially using [technical](#) processes, methods, or knowledge <new technologies for information storage>
3. *3*: the specialized aspects of a particular field of endeavor <educational technology>

technologist

[play](#) \-jɪst\ *noun*

See [technology](#) defined for English-language learners

See [technology](#) defined for kids

Examples of *technology* in a sentence

1. One by one, the pieces take flight: a parachute, the stowed Martian balloon—a Montgolfiere hot-air type, named for the French brothers who pioneered the *technology* in 1782—and a sensor package with guidance system, radio transmitter, and video camera. —Joe Pappalardo, *Air & Space*, June/July 2006
2. There's no question the industry has been subjected to a great deal of competitive pressure over the past decade or so, with promises of more to come as the Internet and wireless *technology* transform the way Americans receive news and information. —*Wall Street Journal*, 14 Mar. 2006
3. The rapid shift in *technology* over the last 10 years has created an entirely new world in which viruses can replicate. While in 1989, viruses were primarily spread by “sneakernet,” as users walked diskettes from machine to machine, modern viruses ... are capable of spreading around the world in the blink of a digital eye. —Sarah Gordon, *Information Security*, November 1999
4. ... all *technology* and energy revving up for the greatest clash of arms in history. —William Styron, *This Quiet Dust And Other Writings*, (1953) 1982
5. Recent advances in medical *technology* have saved countless lives.
6. The company is on the cutting edge of *technology*.
7. The government is developing innovative *technologies* to improve the safety of its soldiers.
8. How can we apply this new *technology* to our everyday lives?
9. The car has the latest in fuel-saving *technology*.

Are you ready for 5G?

Prototype and design next-gen wireless communications systems.



Origin and Etymology of *technology*

Greek *technologia* systematic treatment of an art, from *technē* art, skill + *-o-* + *-logia* -logy

First Known Use: 1859

Rhymes with *technology*

[andrology](#), [anthology](#), [apology](#), [astrology](#), [biology](#), [bryology](#), [cetology](#), [Christology](#), [chronology](#), [conchology](#), [cosmology](#), [cryptology](#), [cytology](#), [dendrology](#), [doxology](#), [ecology](#), [enology](#), [ethnology](#), [ethology](#), [fetology](#), [garbology](#), [gemology](#), [geology](#), [graphology](#), [hanology](#), [histology](#), [homology](#), [horology](#), [hydrology](#), [hymnology](#), [Indology](#), [limnology](#), [lithology](#), [mixology](#), [morphology](#), [mycology](#), [myology](#), [mythology](#), [necrology](#), [nephrology](#), [neurology](#), [nosology](#), [oncology](#), [ontology](#), [oology](#), [pathology](#), [pedology](#), [penology](#), [petrology](#), [phlebology](#), [phonology](#), [phrenology](#), [phycology](#), [proctology](#), [psychology](#), [scatology](#), [seismology](#), [serology](#), [sexology](#), [sinology](#), [symbology](#), [tautology](#), [tetralogy](#), [theology](#), [topology](#), [trichology](#), [typology](#), [ufology](#), [urology](#), [virology](#), [zoology](#)

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Related Phrases

- [technology park](#)

TECHNOLOGY Defined for Kids

technology

[play](#)

noun tech·nol·o·gy \tek- 'nā-lə-jē\

Definition of *technology* for Students

plural

technologies

1. 1 : the use of science in solving problems (as in industry or engineering)
2. 2 : a method of or machine for doing something that is created by technology

Medical Dictionary

technology

[play](#)

noun tech·nol·o·gy \jē\

Medical Definition of *technology*

plural

technologies

1. 1: the science of the application of knowledge to practical purposes : applied science
2. 2: a scientific method of achieving a practical purpose.

technological

\,tek-nə-'lāj-i-kəl\ [play](#) *also*

technologic

\-ik\ [play](#) *adjective*

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Singular 'They'

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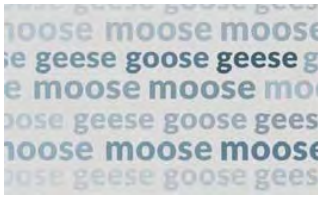
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[Pants On Fire - A Quiz](#)

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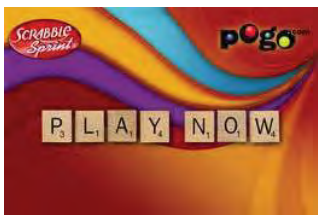
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APPENDIX F

Jan. 30, 1962

F. W. MEREDITH ET AL
AIRCRAFT INSTRUMENTS

3,018,661

Filed March 4, 1957

3 Sheets-Sheet 1

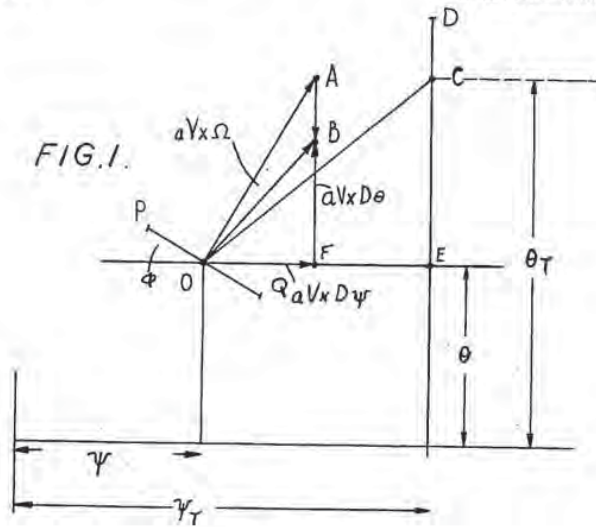
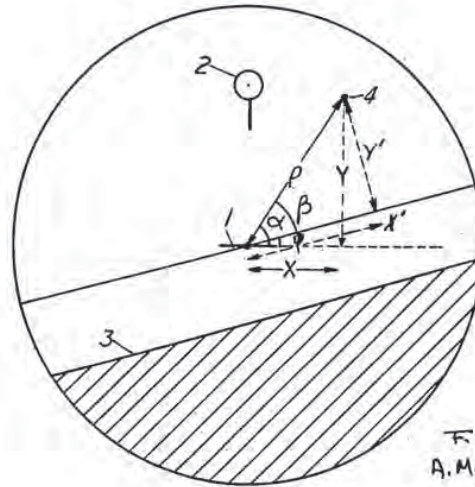


FIG. 2.



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Jan. 30, 1962

F. W. MEREDITH ET AL
AIRCRAFT INSTRUMENTS

3,018,661

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3 Sheets-Sheet 2

FIG. 3.

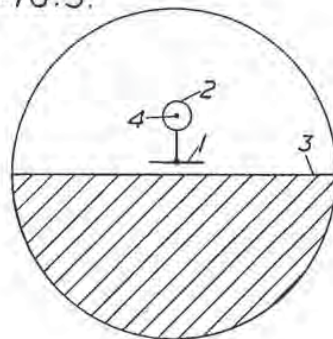


FIG. 4.

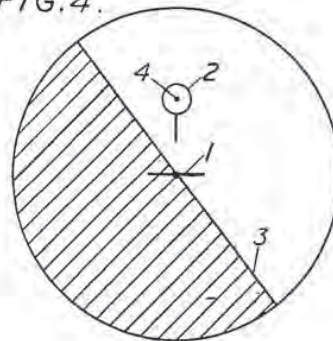
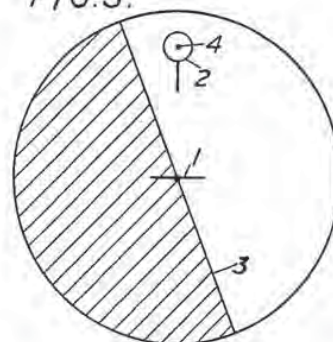


FIG. 5.



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3,018,661

AIRCRAFT INSTRUMENTS

Filed March 4, 1957

3 Sheets-Sheet 3

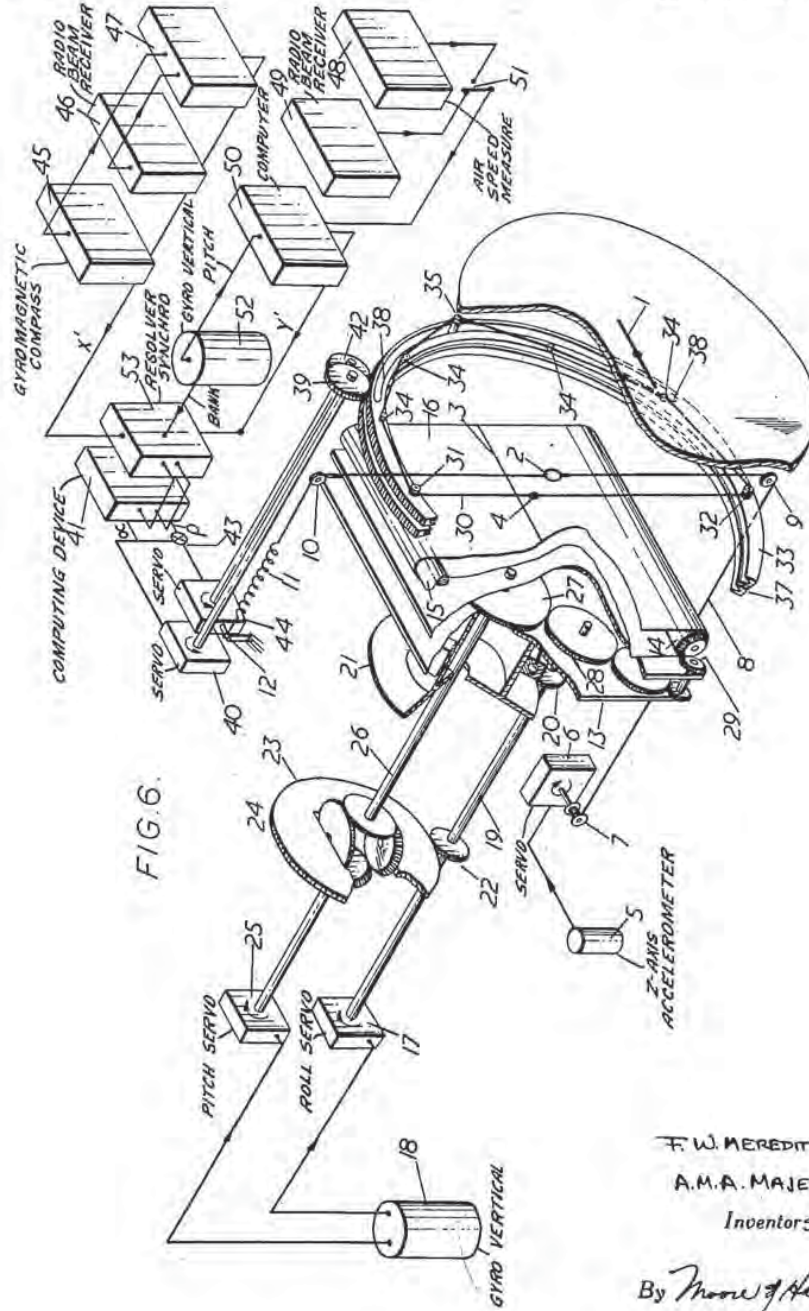


FIG. 6.

F. W. MEREDITH &
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 Inventors

By *Thomas J. Keel*
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1

3,018,661

AIRCRAFT INSTRUMENTS

Frederick William Meredith, "Ardvarna," Cleeve Hill, Cheltenham, England, and Alastair Michael Adair Majendie, High Ridge, Winter Hill, Cookham Dean, England

Filed Mar. 4, 1957, Ser. No. 643,835
11 Claims. (Cl. 73-178)

The present invention relates to aircraft instruments for assisting the control of an aircraft by a human pilot in such a manner that the direction of its line of flight (that of its flight vector) is such as to achieve and maintain a desired flight path.

It is an object of the present invention to provide an aircraft instrument constructed to facilitate the control of an aircraft simultaneously in pitch and roll by a human pilot and which preferably is combined with means to display the pitch and roll attitude of the aircraft to give a readily appreciated indication of the actual attitude of the aircraft and the action which is required to attain the desired flight path.

The attitude of an aircraft can be defined by the directions of three mutually perpendicular axes in the aircraft through its centre of gravity. The X and Z axes lie in the symmetry plane, the X axis being a fixed line, pointing forward, approximately parallel to the centre line of the body, and the Z axis at right angles to this and pointing downward when in straight and level flight. The Y axis is normal to the plane of symmetry and directed towards the starboard wing. It is convenient to fix the direction of the X axis to point in the direction of flight (the wind axis) in normal undisturbed flight. During any changes from straight and level flight the X axis may deviate from the wind axis, the angular deviation in the symmetry plane being the change of angle of incidence and the angular deviation normal to this being the sideslip angle. In correct operation of an aircraft, both these angles are sufficiently small that the difference which they could make on the display to be described can be ignored. Thus it is assumed that the flight vector (whose direction is that of the wind axis and whose magnitude is equal to the airspeed) coincides with the X axis of the aircraft in all conditions.

It is convenient to resolve every force or acceleration into components, one along the X axis and the other in the YZ plane, hereinafter referred to as the normal plane. The algebraic sum of the components of the forces along the X axis, including forces produced aerodynamically, by the propulsive mechanism, and by the action of gravity, determines the rate of change of the magnitude of the flight vector. The vector sum of the components of the forces in the normal plane determines the magnitude and direction of the rate of turn of the flight vector. In the absence of side slip and also, as will be assumed, in the absence of transverse wind components, the component of the aerodynamic forces in the normal plane must coincide with the Z axis.

For a complete understanding of the invention it is desirable to refer to three special frames of reference, defined by appropriate sets of axes:

By the term absolute aircraft axes we mean a set of axes which instantaneously coincide with the aircraft axes but are non-rotating and of which the origin is falling free. Thus a mass free from restraint will be unaccelerated in relation to absolute axes as defined.

By the term roll stabilised axes we mean a non-rotating set of axes in which the origin coincides with the origin of the aircraft axes, the X axis instantaneously coincides with the aircraft X axis but the Y axis is horizontal and the Z axis is never above the horizontal.

By the term roll stabilised absolute axes we mean a

2

set of axes which instantaneously coincide with the roll stabilised axes, are non-rotating and of which the origin is falling free.

By the term absolute acceleration we mean the external force to which the aeroplane is subject (excluding gravity) divided by the mass of the aircraft, i.e. the acceleration of the aircraft referred to absolute axes.

By the term normal plane acceleration we shall mean that component of acceleration normal to the flight vector, i.e. in the normal plane.

In these definitions and throughout this specification and the appended claims, the effects of wind on the aircraft are ignored.

In accordance with the invention we provide an instrument having an index, means to displace the said index relative to a datum in accordance with the normal plane absolute acceleration along the Z axis, a further index and means to displace the further index in relation to the datum in accordance with a demanded value (both as to magnitude and direction) of the normal plane absolute acceleration, whereby manoeuvre of the aircraft, by banking to rotate the direction of the demanded normal plane absolute acceleration relative to the aircraft and by pitching to vary the magnitude of the normal plane absolute acceleration so as to superpose the index and the further index results in the attainment of the demanded normal plane absolute acceleration.

One convenient method for displaying the normal absolute acceleration is by displacement of the index along a line whose orientation is fixed relative to the case of the instrument. The datum for the normal absolute acceleration may be defined by a fixed index indicative of the Y or transverse axis of the aircraft.

A conventional representation of the horizon may be provided, displaced relative to the fixed index in accordance with the pitch and roll attitude of the aircraft.

A convenient method of displaying the demanded normal plane absolute acceleration is by displacement of the further index along and at right angles to the horizon, in accordance with the components of demanded normal plane absolute acceleration in these directions.

An instrument according to the present invention thus may display to a pilot information relating to the present attitude and normal plane absolute acceleration of his aircraft, and simultaneously the normal plane absolute acceleration which the aircraft should assume to follow some desired flight path.

It will be seen that by use of the invention the required manoeuvre demands are displayed in relation to one of the two sets of absolute axes. This is particularly advantageous, since the acceleration force under the control of the pilot produces accelerations in relation to these axes.

The invention, and various embodiments thereof, will now be described with reference to the accompanying drawings, of which

FIGURE 1 shows diagrammatically the attitude of an aircraft, the direction of its flight vector, the normal absolute acceleration to which it is subjected, and the component of gravity in the normal plane.

FIGURES 2 to 5 show the display provided by an instrument embodying features of the present invention in various flight conditions.

FIGURE 6 shows schematically one particular form of instrument constructed in accordance with the present invention.

Referring to FIGURE 1 the point O represents, by means of a suitable projection, the intersection of the aircraft X-axis with the surface of a reference sphere centred on the aircraft. The aircraft attitude is denoted

by the angles: ψ heading; θ pitch; ϕ bank; as conventionally defined.

The transverse of Y axis of the aircraft is indicated by the line POQ. The desired on-target attitude is shown by point C, where the desired values of heading and pitch are indicated as ψ_T and θ_T .

The normal plane absolute acceleration of magnitude Ng is represented by a vector of length aNg ("a" being a scale factor, "N" being a positive number and "g" the acceleration due to gravity) indicated at OA.

The component of acceleration, referred to fixed axes, due to gravity in the normal plane is of magnitude $g \cos \theta$ and is at an angle $(90^\circ - \phi)$ to the transverse axis of the aircraft. It may thus be represented by a vector AB of length $ag \cos \theta$ in the direction of θ decreasing. Thus the vector OB represents the acceleration referred to fixed axes in the plane normal to the flight vector, which is, in accordance with ordinary dynamical principles, the vector product $V \times \Omega$ where Ω is the instantaneous rate of rotation of the flight vector and V is the flight vector. OB thus has length $aV \times \Omega$. Vector OB can be resolved into a horizontal component $aD \times D\psi$ and a component at right angles thereto $aV \times D\theta$. Here and elsewhere the symbol "D" is used to represent the operator of differentiation with respect to time. OE, in the direction of ψ increasing, represents the discrepancy between demanded and actual heading and EC, in the direction of θ increasing, represents the discrepancy between demanded and actual pitch. The discrepancies $(\psi_T - \psi)$ and $(\theta_T - \theta)$ may be denoted $-\psi_E$ and $-\theta_E$ respectively.

If now the aircraft is manoeuvred so that B and C coincide and ψ_T and θ_T are fixed, we shall have the relations

$$\begin{aligned} aV \times D\psi_E + \psi_E &= 0 \\ aD \times D\theta_E + \theta_E &= 0 \end{aligned}$$

i.e. the flight vector subsides on to the desired direction with time constant aV (if V is constant).

It is evident that the point C, which has been defined as determined by a demanded direction, may also be regarded as defined by a demanded acceleration referred to fixed axes in the normal plane.

It will be seen that precisely the same result may be attained by introducing a further vector CD, extending in the direction of θ increasing, of magnitude $ag \cos \theta$, i.e. equal and opposite to vector AB, and controlling the aircraft in such a manner that point A lies on point D.

It will be appreciated that the vector OC represents, referred to axes through O in the direction of ψ increasing and θ increasing respectively, the required normal plane acceleration referred to roll stabilised axes, whereas the vector OD represents the same quantity referred to roll stabilised absolute axes. Also the vector OB represents the actual normal plane acceleration referred to roll stabilised axes and OA represents the same quantity referred to absolute roll stabilised axes, i.e. the normal plane absolute acceleration.

Referred to axes lying along and at right angles to the line POQ, these vectors represent the same quantities referred to the corresponding aircraft axes.

In an instrument in accordance with the present invention the vectors OA and OD are displayed, i.e. the normal plane absolute acceleration (by point A) and the demanded normal plane absolute acceleration (by point D). It will be appreciated that the vector OA represents the quantity, the normal plane absolute acceleration, directly under the pilot's control for the manoeuvre of the aircraft, its direction being controlled by banking and its magnitude by pitching.

Most conveniently the display is provided by movement of points A and D in relation to an index, fixed in the instrument, corresponding to the line POQ.

In the embodiment of the invention shown in the re-

maining figures the instrument indications are provided within the compass of a conventional circular viewing aperture upon an indicator, as shown. In the ensuing description connecting lines indicate channels for the flow of information, which information will be preferably conveyed by amplitude-modulated A.C. signals. A fixed index 1 is provided, in the form of a symbolic representation of the rear view of the wings of an aircraft, its Y axis across the display and Z axis down the display and thus corresponding to line POQ in FIGURE 1. A normal plane absolute acceleration index 2 is provided in the form of a ring with a downwardly-extending line. In accordance with the assumption that the normal plane absolute acceleration is along the aircraft Z axis, index 2 is displaced along the Z axis (positive or negative) of the aircraft representation forming index 1, so that the centre of the circle is displaced from the centre of index 1 by an amount proportional to the normal plane absolute acceleration, under the control of a conventional accelerometer mounted on the aircraft so as to be responsive to acceleration of the aircraft along the Z axis. The accelerometer 5 controls a servo 6 fixed in the indicator. Servo 6 positions a drum 7 upon which is wrapped a wire 8 carrying index 2, the wire passing round pulleys 9, 10, and being attached to one end of a tension spring 11 whose other end is fixed, at 12. The wire 8 and the pulleys 9 and 10 constitute means guiding the index for displacement along a line whose orientation is fixed in the instrument.

Behind indices 1 and 2 is mounted a "roller blind" type of artificial horizon indicator, giving "moving horizon" presentation. This comprises a carriage 13 mounted for rotation about an axis passing through the centre of index 1, the "indicator axis," carrying a pair of rollers 14, 15 over which a flexible band 16 passes. Carriage 13 is positioned by an electric servo system 17 controlled from a remotely situated first gyro vertical 18 in accordance with the roll attitude of the aircraft, the servo system rotating a shaft 19 carrying a pinion 20 engaging with a gear 21 attached to carriage 13. Shaft 19 also carries a pinion 22 engaging with a gear 23 forming one input of a conventional mechanical differential 24. The other input of the differential 24 is positioned in accordance with the pitch attitude of the aircraft by an electric servo 25 also controlled from gyro vertical 18. The output of the differential 24 is transmitted by a shaft 26 lying on the indicator axis. Shaft 26 carries a gear 27 capable of driving, through a train 28 and bevel gears 29, roller 14.

The servo systems 17 and 25 and the various gear ratios are such that the rotation of the carriage 13 relative to the index 1 is equal to the bank angle of the aircraft and rotation of shaft 19 with servo 25 stationary results in no relative movement between gear 27 and carriage 13. It thus follows that roller 14, and hence band 16, are moved in accordance with the pitch attitude of the aircraft, and this movement is such that the total extent of band 16 visible corresponds to about 120° of pitch movement. The band 16 is distinctively coloured to give an indication of the horizon, as at 3, and representations of the zenith and nadir are also provided on the band, so that the index 1 co-operates with the band to give a display corresponding to that of a conventional gyroscope artificial horizon instrument.

A director index 4 is provided, in the form of a dot rather smaller than the internal diameter of the ring of index 2. Director index 4 is positioned so that its distance from the representation of the horizon 3 corresponds to the desired pitch attitude of the aircraft plus $ag \cos \theta$, and its distance from the centre line of the band 16 corresponds to the difference between the desired and actual heading of the aircraft. If lines parallel and perpendicular to the horizon are imagined drawn through the centre of index 1, then it follows from the above that the displacement of index 4 from the imaginary line parallel to the horizon, indicated by Y' in FIGURE 2, is propor-

tional to $ag \cos \theta - \theta_B$, and its distance from the line perpendicular to the horizon, indicated at X' in FIGURE 2, corresponds to $-\psi_B$.

The intelligence by means of which index 4 is positioned may be obtained from instruments completely separate from the gyro vertical 18 controlling the position of the band 16.

Index 4 is mounted upon a wire 30 passed round rollers 31, 32 mounted upon a ring gear 33 centred on the indicator axis. Wire 30 lies diametrically across gear 33, and passes round further guide rollers 34 mounted on gear 33, being attached at one point to a peg 35 attached to a further ring gear 37 extending through an arcuate slot 38 in gear 33. Gear 37 is also mounted for rotation about the indicator axis. Gear 33 is engaged by a pinion 39 positioned by a servo 40. Servo 40 is controlled by a first output from a computing device 41, which is proportional to the angle α indicated in FIGURE 2. Gear 37 is engaged by a pinion 42, positioned by a servo 44 controlled by the output from a differential 43. The inputs to differential 43 consist of the two outputs from device 41. The second of these is proportional to the distance ρ indicated in FIGURE 2. Thus it will be seen that the angular position of wire 30 will be given by the angle α , and the radial position of index 4 will be given by the distance ρ .

One manner in which the intelligence for positioning index 4 (i.e. the quantities α and ρ) may be obtained will now be described.

A directional device is provided to generate a signal representing the difference between the actual heading of the craft and the desired heading if some desired flight path is to be followed. In a particular form, as indicated in FIGURE 6, this includes a gyromagnetic compass 45 and a radio device 46, such as a conventional directional radio beam receiver, or a conventional radar installation or instrument landing system, providing a signal representing the bearing of a target being tracked, which respectively provide signals representing the actual heading of the craft and the desired heading if some desired flight path is to be followed. These signals are applied to a computer 47 which generates a signal representing the difference between the signals applied to it. The output from this device is thus proportional to $-\psi_B$, or the quantity X' of FIGURE 2.

An air speed responsive device, indicated at 48, and a further radio device, indicated at 49, such as a conventional glide path receiver or a conventional radar installation providing a signal representing the elevation of a target being tracked, provide signals one or other of which can be applied to the input of a further computer device 50, as indicated by a change-over switch 51. Computer 50 determines from these signals and from pitch signals derived from a gyro vertical 52 the difference between the actual pitch attitude of the aircraft and that required if some desired flight path is to be followed—that is to say the quantity $-\theta_B$. This is added to a signal proportional to $ag \cos \theta$ (derived from intelligence also obtained from gyro vertical 52), to give a total output proportional to the quantity Y' of FIGURE 2.

The X' and Y' signals from devices 47 and 50 are applied to the separate stator inputs of a conventional resolver synchro indicated at 53. The rotor of the resolver is positioned in accordance with the bank angle ϕ under the control of gyro vertical 52, and outputs are obtained from the separate rotor windings respectively proportional to

$$X' \cos \phi - Y' \sin \phi$$

and

$$X' \sin \phi + Y' \cos \phi$$

These quantities are related to ρ and α by the relations

$$\rho \cos \alpha = X' \cos \phi - Y' \sin \phi$$

$$\rho \sin \alpha = X' \sin \phi + Y' \cos \phi$$

They are applied as inputs to computer 41, previously referred to. Computer 41 comprises a further resolver

synchro, to the separate stator windings of which the " $\rho \cos \alpha$ " and " $\rho \sin \alpha$ " signals are applied. The rotor of the synchro is positioned by a motor energised from one of the rotor windings of the synchro, which thus positions the rotor so that this winding is at right angles to the resultant field produced by the stator windings, i.e. the rotor is so positioned that its angular displacement from some datum position is equal to α , and a suitable signal generating device positioned by the motor is utilised to give the desired α signal output from computer 41. The signal induced in the second rotor winding will be proportional to ρ and is utilised to provide the ρ signal output from computer 41.

As described above the manoeuvre demand is derived from position information, and the use of the instrument will eventually, if there is no change in the desired flight path, bring the aircraft to a condition of non-turning flight. However, the manoeuvre demand could be, for example, for continuously turning flight at a constant rate of turn.

As noted above, as far as the scale of the display is concerned, it is convenient to make the radius of the visible portion of the band 16, correspond to 60° (i.e. approximately 1 radian) pitch (or heading) deviation, when one at least of the representations of zenith, horizon and nadir on the band will always be in view.

A maximum manoeuvre demand will then be given by

$$aN_g = 1$$

If we limit the maximum acceleration to be demanded in any manoeuvre to, say, $6g$, this means that

$$ag = \frac{1}{6}$$

and the time constant of subsidence will be $\frac{1}{6} V/g$. The displacement of the centre of the ring of index 2 from the centre of index 1 will in conditions of straight and level flight correspond to a normal acceleration of g , and the length of the vertical stroke of the index 2 is preferably such that, under these conditions, its end lies at the centre of index 1. Preferably also in such conditions the centre of index 2 lies at the centre of the display.

FIGURES 3, 4 and 5 show the display in various flight conditions, when the manoeuvre demand is being met, that is to say when index 2 is brought into alignment with index 4.

FIGURE 3 shows the display when climbing at about 2° with the aircraft level in bank and on the demanded attitude.

FIGURE 4 shows the display when following a demand for a steady horizontal turn at 52° bank to the left.

FIGURE 5 shows the display when following a demand for a horizontal $4\frac{1}{2}g$ turn to the left.

The sense of the pitch and bank corrections required are always clear from the display, even if negative lift manoeuvre is required.

The particular instrument described with reference to FIGURES 2 to 6 utilises a "moving horizon" presentation for aircraft attitude, the aircraft representation (index 1) being fixed in the instrument. Alternatively a "moving aircraft" presentation of aircraft attitude could be used, (the representation of the horizon then being fixed in the instrument), various mechanical means by which this could be achieved being obvious to those skilled in the art. However, a "moving aircraft" presentation would be substantially more complicated mechanically.

While there have been described above what are presently believed to be the preferred forms of the invention, variations thereof will be obvious to those skilled in the art and all such changes and variations which fall within the spirit of the invention are intended to be covered by the generic terms in the appended claims, which are variably worded to that end.

We claim:

1. An aircraft instrument comprising means to define a viewing aperture, a first index supported for movement within the aperture, means within the aperture to define a datum position for the first index, driving means con-

ected to the first index, means to control the driving means in accordance with the component of the normal plane absolute acceleration of the aircraft in direction of its Z axis so that the displacement of the first index from the said datum position is proportional to the said component of the normal plane absolute acceleration of the aircraft, a further index supported for movement within the aperture and means to displace the further index in relation to the said datum position in accordance with a demanded value, both as to magnitude and direction of the normal plane absolute acceleration, said demanded value being that required if some desired flight path is to be achieved and a maneuver of the aircraft in bank and pitch to superpose the first index and further index thus resulting in the attainment of the demanded normal plane acceleration and the desired flight path, neglecting any components of the normal plane absolute acceleration in the direction of the transverse axis of the aircraft.

2. An instrument according to claim 1 comprising means for guiding the displacement of the index along a line whose orientation is fixed in the instrument.

3. An instrument according to claim 2 wherein the means to define the datum position comprises a fixed index indicative of the transverse axis of the aircraft.

4. An instrument according to claim 3 wherein the means to displace the further index are operative to displace it linearly from and to rotate it angularly about the fixed index in accordance with the magnitude and direction of the demanded value of the normal plane absolute acceleration referred to absolute aircraft axes.

5. An instrument according to claim 4 wherein the means to displace the further index comprise both devices responsive to deviation of the aircraft from some selected flight path and a device responsive to the pitch and roll attitude of the aircraft.

6. An instrument according to claim 5 comprising also means to provide a representation of the horizon and means to position the same in relation to the fixed index in accordance with the pitch and roll attitude of the aircraft.

7. An instrument according to claim 6 wherein the means to position the representation of the horizon are independent of the means to position the further index.

8. An aircraft instrument comprising means to define a viewing aperture, a first index supported for movement and positioned to be viewed through the aperture, datum position defining means for said first index, driving means connected to the first index, means connected to control said driving means in accordance with the component of normal plane absolute acceleration of the aircraft in the direction of its Z axis so that the displacement of the first index from the said datum position is proportional to the said component of the normal plane absolute acceleration, a second index supported for movement and positioned to be viewed through the aperture and means connected to displace said second index relative to said datum position defining means in accordance with a demanded vector value of the normal plane absolute acceleration, said demanded value being that required by a desired flight path and a maneuver of the aircraft in bank and pitch to superpose said indices giving an indication that the desired flight path of the plane has been attained.

9. An aircraft instrument for assisting a human pilot to control an aircraft simultaneously in pitch and roll, comprising in combination a first index means supported for movement relative to the aircraft, means to define a datum position for said first index, driving means connected to move said first index, means to control said driving means in accordance with the component of the normal plane absolute acceleration of the aircraft along its Z axis, a second index means supported for movement relative to the aircraft, and means to displace said second index means relative to said datum position in accordance with a demanded value, both as to magnitude and direction of the effective value of the normal plane absolute acceleration, said demanded value being that required to achieve a desired flight path and the superposition of said first and second index means.

10. The combination set forth in claim 9, said first index means being in the form of a ring with a downwardly extending line, said driving means comprising a servo motor and movable wire means carrying said first index for movement in translation, said means to control said driving means comprising an accelerometer means mounted on the aircraft so as to be responsive to acceleration of the aircraft along its Z axis, said second index means being a director index in the form of a dot of smaller diameter than the internal diameter of said ring, said means to displace said second index means comprising a second wire means, a ring gear mounting said second wire means diametrically thereacross, a second ring gear carrying means acting to move said second wire to displace said second index, dual servo means for rotating said ring gears independently, a gyro vertical mounted on the aircraft to supply pitch signals, computer means connected to said gyro and to said dual servo means for supplying a first output for rotating said first ring gear to move said second index by rotation of its supporting wire means and for supplying a second output for rotating said second ring gear to move said second index radially in translation.

11. The combination set forth in claim 10, an artificial horizon indicator means mounted behind said first index means, said second index means and said means to define a datum position, said horizon indicator means comprising carriage means mounted for rotation about an axis passing through the center of said means to define a datum position, a pair of rollers having a flexible band bearing a horizon indication line thereon rotatably mounted on said carriage means, a gyro vertical means, differential means controlled by said gyro for rotating said rollers and moving said horizon indication in translation with respect to said means to define a datum position and drive means controlled by said gyro for rotating said carriage means for rotating said horizon indication with respect to said means to define a datum position.

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APPENDIX G



US005960411A

United States Patent [19]
Hartman et al.

[11] **Patent Number:** **5,960,411**
[45] **Date of Patent:** **Sep. 28, 1999**

- [54] **METHOD AND SYSTEM FOR PLACING A PURCHASE ORDER VIA A COMMUNICATIONS NETWORK**
- [75] Inventors: **Peri Hartman; Jeffrey P. Bezos; Shel Kaphan; Joel Spiegel**, all of Seattle, Wash.
- [73] Assignee: **Amazon.com, Inc.**, Seattle, Wash.
- [21] Appl. No.: **08/928,951**
- [22] Filed: **Sep. 12, 1997**
- [51] **Int. Cl.⁶** **G06F 17/60**
- [52] **U.S. Cl.** **705/26; 705/27; 345/962**
- [58] **Field of Search** **705/26, 27; 380/24, 380/25; 235/2, 375, 378, 381; 395/188.01; 345/962**

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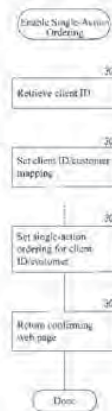
Primary Examiner—James P. Trammell
Assistant Examiner—Demetra R. Smith
Attorney, Agent, or Firm—Perkins Coie LLP

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[57] **ABSTRACT**

A method and system for placing an order to purchase an item via the Internet. The order is placed by a purchaser at a client system and received by a server system. The server system receives purchaser information including identification of the purchaser, payment information, and shipment information from the client system. The server system then assigns a client identifier to the client system and associates the assigned client identifier with the received purchaser information. The server system sends to the client system the assigned client identifier and an HTML document identifying the item and including an order button. The client system receives and stores the assigned client identifier and receives and displays the HTML document. In response to the selection of the order button, the client system sends to the server system a request to purchase the identified item. The server system receives the request and combines the purchaser information associated with the client identifier of the client system to generate an order to purchase the item in accordance with the billing and shipment information whereby the purchaser effects the ordering of the product by selection of the order button.

26 Claims, 11 Drawing Sheets



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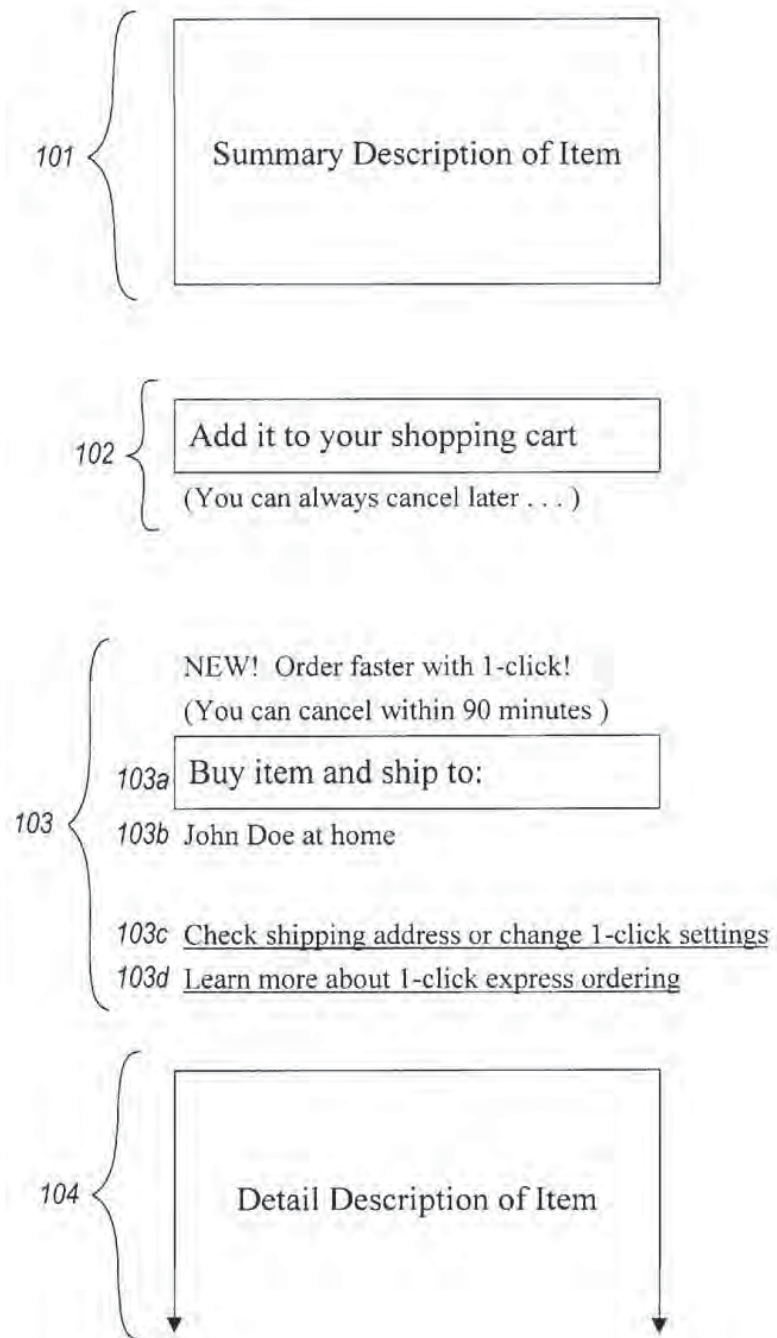


Fig. 1A

105 { Thank you for your 1-click order!

A quantity of 1 of [the item] will be shipped to you as soon as possible. We will do our best to minimize your shipping costs by combining your 1-click orders into as few shipments as possible.

Please continue browsing.

Review or change your 1-click orders

101 { Summary Description of Item

⋮

Fig. 1B

Summary of 1-Click Express Orders

Press this button if you Changed Quantities of any item below. If you don't press it, your changes won't "stick." You can set the quantity to 0 (zero) to cancel an item.

The 1-click orders below (available in 3 or fewer days) will be shipped together.

106 {

Order # 098337		
<input type="checkbox"/>	Item 1	\$10.00
<input type="checkbox"/>	Item 2	\$15.00
	Total	\$25.00

The 1-click orders below (available in one week or more) will be shipped together.

107 {

Order # 098336		
<input type="checkbox"/>	Item 3	\$20.00
<input type="checkbox"/>	Item 4	\$ 6.00
	Total	\$26.00

108 {

Ship to:	John Doe at home
Shipment Method:	Standard Domestic Shipping
Payment Method:	**** _**** _***1_2345
<input type="button" value="Continue Shopping"/>	

[1-Click Express shipping policies](#)

Fig. 1C

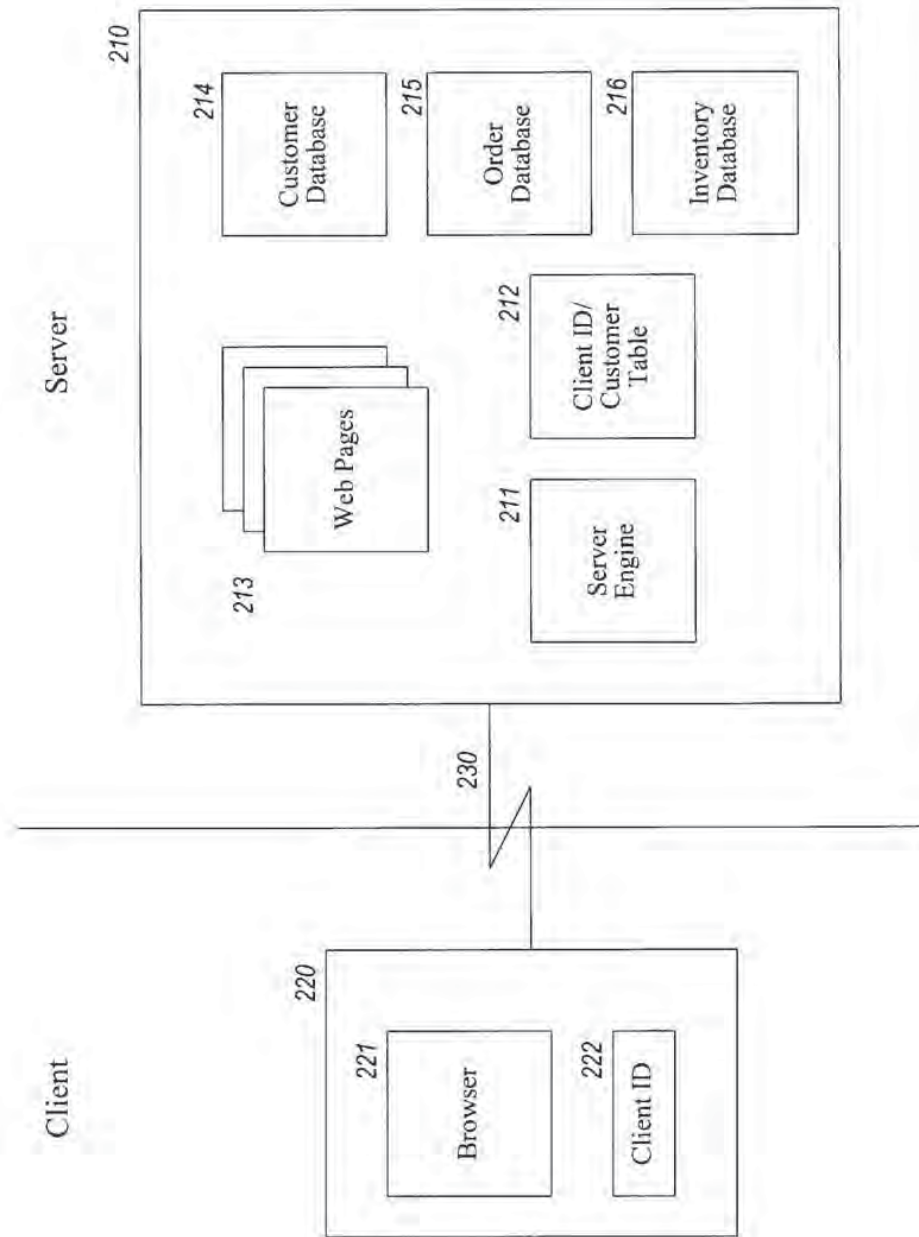


Fig. 2

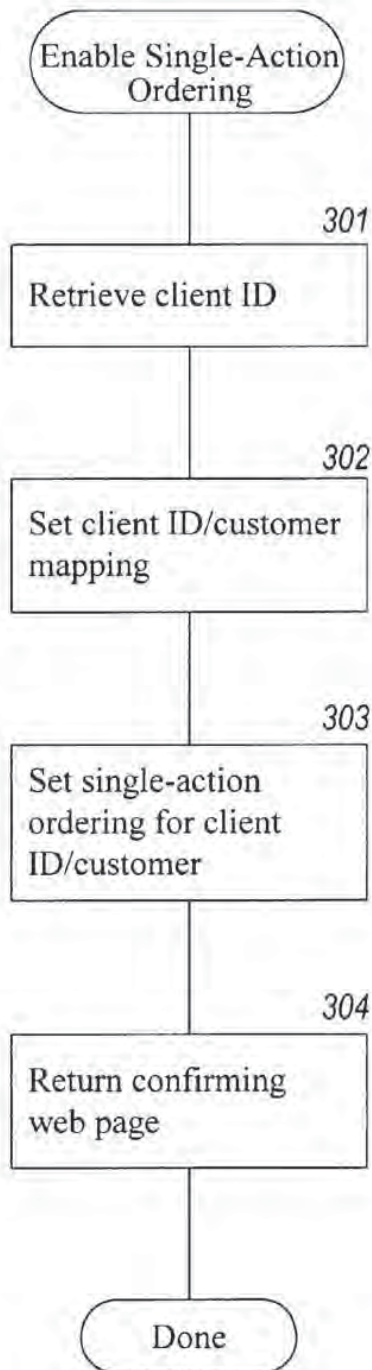


Fig. 3

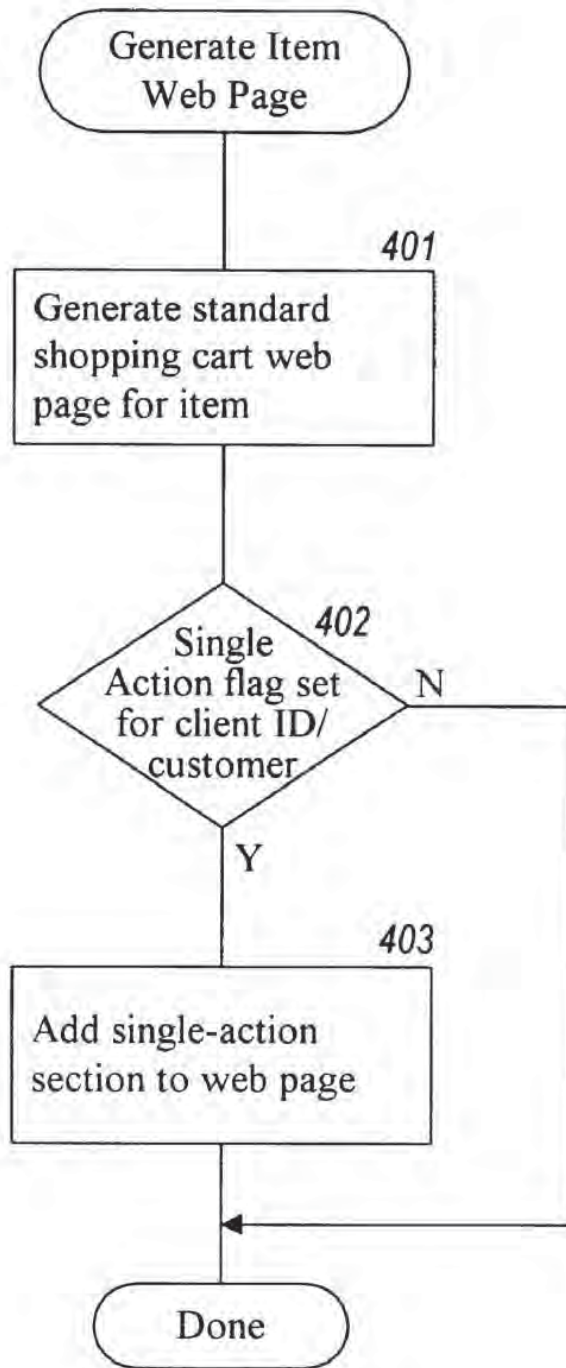


Fig. 4

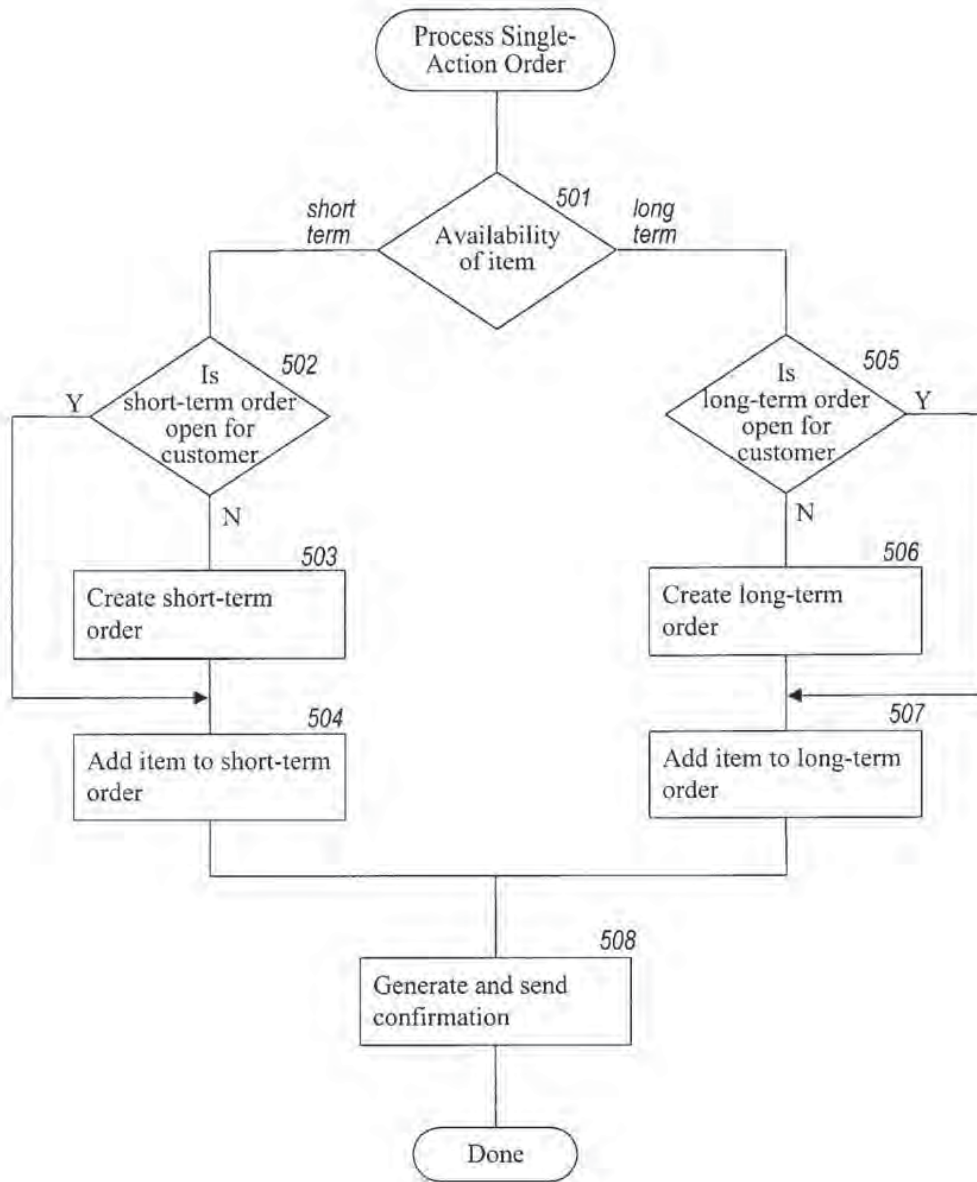


Fig. 5

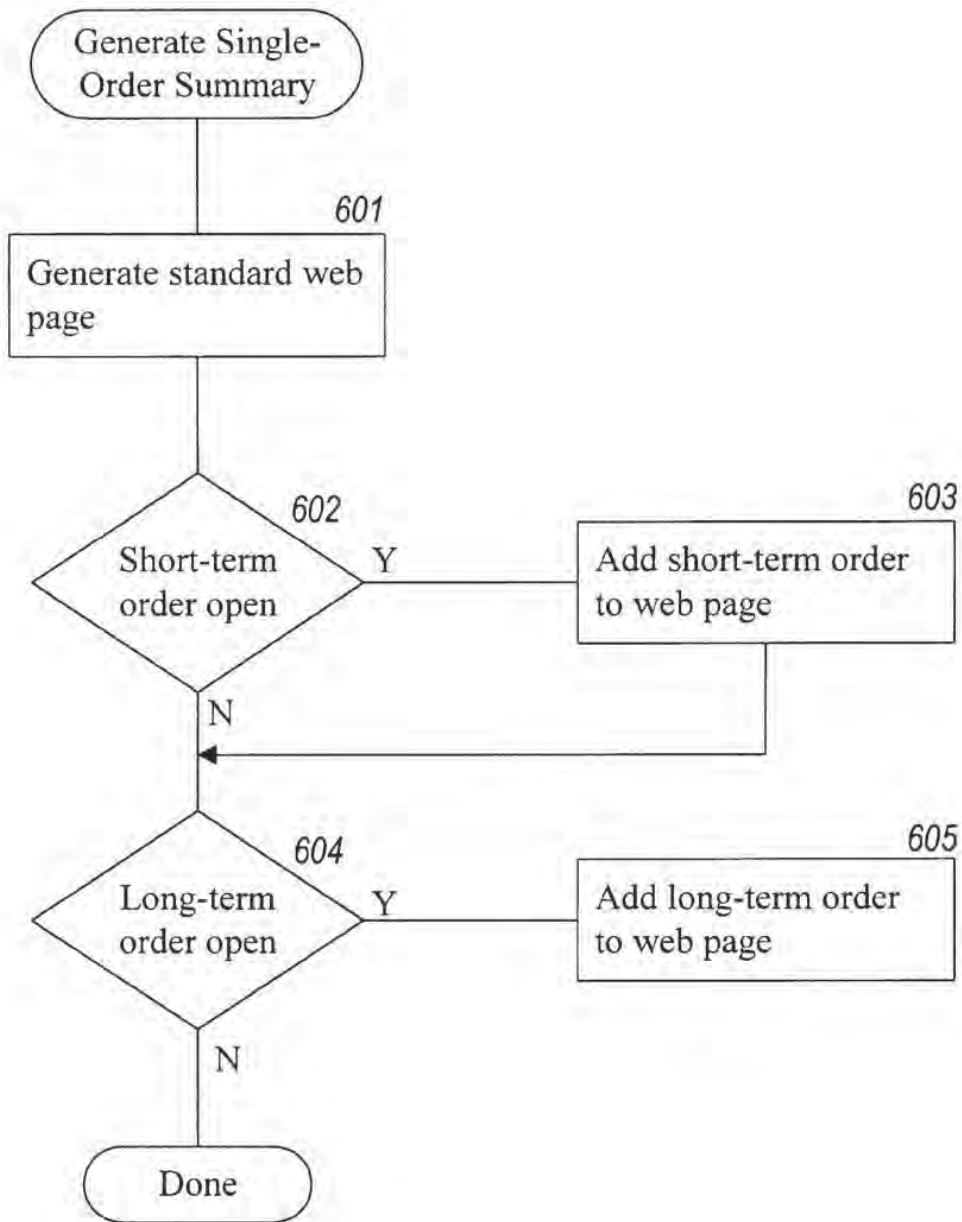


Fig. 6

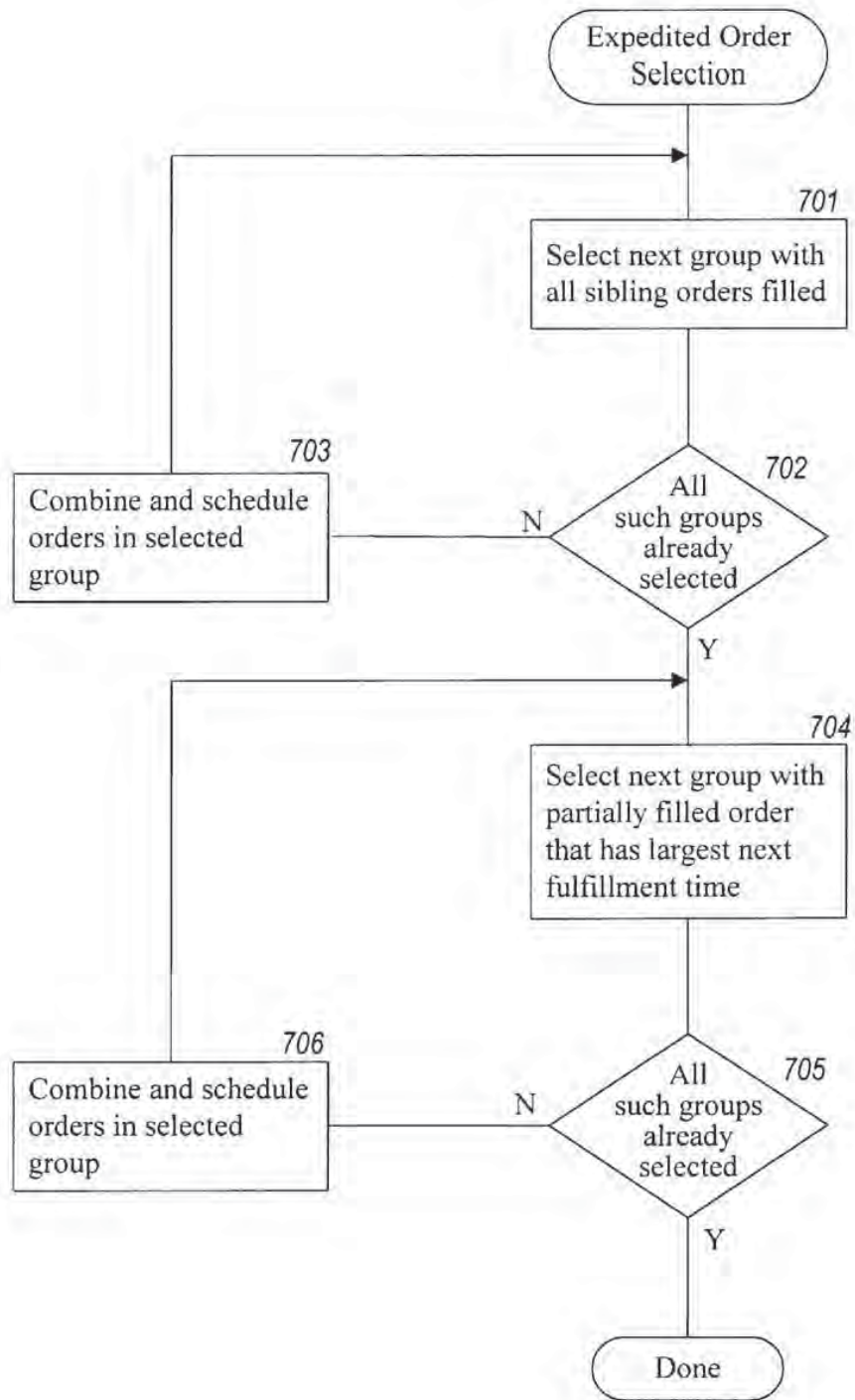


Fig. 7

START

- A: Customer Name & Address
- B: Customer Financial Info
- C: Customer Employment Info
- D: Customer Education Info
- .
- .
- .

Fig. 8A

A: First Name :

M.I. :

Last Name :

Street :

City :

State : Zip :

Next

Previous

- B: Customer Financial Info
- C: Customer Employment Info
- D: Customer Education Info
- .
- .
- .

Fig. 8B

A: Customer Name & Address

B: Net Worth:

Annual Income:

Spouse's Annual Income:

Other Income:

C: Customer Employment Info

D: Customer Education Info

·
·
·

Fig. 8C

METHOD AND SYSTEM FOR PLACING A PURCHASE ORDER VIA A COMMUNICATIONS NETWORK

TECHNICAL FIELD

The present invention relates to a computer method and system for placing an order and, more particularly, to a method and system for ordering items over the Internet.

BACKGROUND OF THE INVENTION

The Internet comprises a vast number of computers and computer networks that are interconnected through communication links. The interconnected computers exchange information using various services, such as electronic mail, Gopher, and the World Wide Web ("WWW"). The WWW service allows a server computer system (i.e., Web server or Web site) to send graphical Web pages of information to a remote client computer system. The remote client computer system can then display the Web pages. Each resource (e.g., computer or Web page) of the WWW is uniquely identifiable by a Uniform Resource Locator ("URL"). To view a specific Web page, a client computer system specifies the URL for that Web page in a request (e.g., a HyperText Transfer Protocol ("HTTP") request). The request is forwarded to the Web server that supports that Web page. When that Web server receives the request, it sends that Web page to the client computer system. When the client computer system receives that Web page, it typically displays the Web page using a browser. A browser is a special-purpose application program that effects the requesting of Web pages and the displaying of Web pages.

Currently, Web pages are typically defined using HyperText Markup Language ("HTML"). HTML provides a standard set of tags that define how a Web page is to be displayed. When a user indicates to the browser to display a Web page, the browser sends a request to the server computer system to transfer to the client computer system an HTML document that defines the Web page. When the requested HTML document is received by the client computer system, the browser displays the Web page as defined by the HTML document. The HTML document contains various tags that control the displaying of text, graphics, controls, and other features. The HTML document may contain URLs of other Web pages available on that server computer system or other server computer systems.

The World Wide Web is especially conducive to conducting electronic commerce. Many Web servers have been developed through which vendors can advertise and sell product. The products can include items (e.g., music) that are delivered electronically to the purchaser over the Internet and items (e.g., books) that are delivered through conventional distribution channels (e.g., a common carrier). A server computer system may provide an electronic version of a catalog that lists the items that are available. A user, who is a potential purchaser, may browse through the catalog using a browser and select various items that are to be purchased. When the user has completed selecting the items to be purchased, the server computer system then prompts the user for information to complete the ordering of the items. This purchaser-specific order information may include the purchaser's name, the purchaser's credit card number, and a shipping address for the order. The server computer system then typically confirms the order by sending a confirming Web page to the client computer system and schedules shipment of the items.

Since the purchaser-specific order information contains sensitive information (e.g., a credit card number), both

vendors and purchasers want to ensure the security of such information. Security is a concern because information transmitted over the Internet may pass through various intermediate computer systems on its way to its final destination. The information could be intercepted by an unscrupulous person at an intermediate system. To help ensure the security of the sensitive information, various encryption techniques are used when transmitting such information between a client computer system and a server computer system. Even though such encrypted information can be intercepted, because the information is encrypted, it is generally useless to the interceptor. Nevertheless, there is always a possibility that such sensitive information may be successfully decrypted by the interceptor. Therefore, it would be desirable to minimize the sensitive information transmitted when placing an order.

The selection of the various items from the electronic catalogs is generally based on the "shopping cart" model. When the purchaser selects an item from the electronic catalog, the server computer system metaphorically adds that item to a shopping cart. When the purchaser is done selecting items, then all the items in the shopping cart are "checked out" (i.e., ordered) when the purchaser provides billing and shipment information. In some models, when a purchaser selects any one item, then that item is "checked out" by automatically prompting the user for the billing and shipment information. Although the shopping cart model is very flexible and intuitive, it has a downside in that it requires many interactions by the purchaser. For example, the purchaser selects the various items from the electronic catalog, and then indicates that the selection is complete. The purchaser is then presented with an order Web page that prompts the purchaser for the purchaser-specific order information to complete the order. That Web page may be prefilled with information that was provided by the purchaser when placing another order. The information is then validated by the server computer system, and the order is completed. Such an ordering model can be problematic for a couple of reasons. If a purchaser is ordering only one item, then the overhead of confirming the various steps of the ordering process and waiting for, viewing, and updating the purchaser-specific order information can be much more than the overhead of selecting the item itself. This overhead makes the purchase of a single item cumbersome. Also, with such an ordering model, each time an order is placed sensitive information is transmitted over the Internet. Each time the sensitive information is transmitted over the Internet, it is susceptible to being intercepted and decrypted.

SUMMARY OF THE INVENTION

An embodiment of the present invention provides a method and system for ordering an item from a client system. The client system is provided with an identifier that identifies a customer. The client system displays information that identifies the item and displays an indication of an action (e.g., a single action such as clicking a mouse button) that a purchaser is to perform to order the identified item. In response to the indicated action being performed, the client system sends to a server system the provided identifier and a request to order the identified item. The server system uses the identifier to identify additional information needed to generate an order for the item and then generates the order.

The server system receives and stores the additional information for customers using various computer systems so that the server system can generate such orders. The server system stores the received additional information in association with an identifier of the customer and provides

the identifier to the client system. When requested by the client system, the server system provides information describing the item to the requesting client system. When the server system receives a request from a client system, the server system combines the additional information stored in association with the identifier included in the request to effect the ordering of the item.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A–1C illustrate single-action ordering in one embodiment of the present invention.

FIG. 2 is a block diagram illustrating an embodiment of the present invention.

FIG. 3 is a flow diagram of a routine that enables single-action ordering for a customer.

FIG. 4 is a flow diagram of a routine to generate a Web page in which single-action ordering is enabled.

FIG. 5 is a flow diagram of a routine which processes a single-action order.

FIG. 6 is a flow diagram of a routine for generating a single-action order summary Web page.

FIG. 7 is a flow diagram of a routine that implements an expedited order selection algorithm.

FIGS. 8A–8C illustrate a hierarchical data entry mechanism in one embodiment.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a method and system for single-action ordering of items in a client/server environment. The single-action ordering system of the present invention reduces the number of purchaser interactions needed to place an order and reduces the amount of sensitive information that is transmitted between a client system and a server system. In one embodiment, the server system assigns a unique client identifier to each client system. The server system also stores purchaser-specific order information for various potential purchasers. The purchaser-specific order information may have been collected from a previous order placed by the purchaser. The server system maps each client identifier to a purchaser that may use that client system to place an order. The server system may map the client identifiers to the purchaser who last placed an order using that client system. When a purchaser wants to place an order, the purchaser uses a client system to send the request for information describing the item to be ordered along with its client identifier. The server system determines whether the client identifier for that client system is mapped to a purchaser. If so mapped, the server system determines whether single-action ordering is enabled for that purchaser at that client system. If enabled, the server system sends the requested information (e.g., via a Web page) to the client computer system along with an indication of the single action to perform to place the order for the item. When single-action ordering is enabled, the purchaser need only perform a single action (e.g., click a mouse button) to order the item. When the purchaser performs that single action, the client system notifies the server system. The server system then completes the order by adding the purchaser-specific order information for the purchaser that is mapped to that client identifier to the item order information (e.g., product identifier and quantity). Thus, once the description of an item is displayed, the purchaser need only take a single action to place the order to purchase that item. Also, since the client identifier identifies purchaser-specific order infor-

mation already stored at the server system, there is no need for such sensitive information to be transmitted via the Internet or other communications medium.

FIGS. 1A–1C illustrate single-action ordering in one embodiment of the present invention. FIG. 1A illustrates the display of a Web page describing an item that may be ordered. This example Web page was sent from the server system to the client system when the purchaser requested to review detailed information about the item. This example Web page contains a summary description section 101, a shopping cart section 102, a single-action ordering section 103, and a detailed description section 104. One skilled in the art would appreciate that these various sections can be omitted or rearranged or adapted in various ways. In general, the purchaser need only be aware of the item or items to be ordered by the single action and of the single action needed to place the order. The summary description and the detailed description sections provide information that identifies and describes the item(s) that may be ordered. The shopping cart section provides the conventional capability to add the described item to a shopping cart. The server system adds the summary description, the detailed description, and the shopping cart sections to each Web page for an item that may be ordered. The server system, however, only adds the single-action ordering section when single-action ordering is enabled for that purchaser at that client system. (One skilled in the art would appreciate that a single Web page on the server system may contain all these sections but the single-action ordering section can be selectively included or excluded before sending the Web page to the client system.)

This example single-action ordering section allows the purchaser to specify with a single click of a mouse button to order the described item. Once the purchaser clicks the mouse button, the item is ordered, unless the purchaser then takes some action to modify the order. The single-action ordering section contains a single-action ordering button 103a, purchaser identification subsection 103b, and single-action ordering information subsections 103c and 103d. The purchaser information subsection displays enough information so that the purchaser can verify that the server system correctly recognizes the purchaser. To reduce the chances of sensitive information being intercepted, the server system sends only enough information so that the purchaser is confident that the server system correctly identified the purchaser but yet not enough information to be useful to an unscrupulous interceptor. The additional information subsections allow the purchaser to obtain various settings or obtain more information related to the single-action ordering. If the purchaser wants to verify the shipping address, the purchaser can select the “check shipping address” label. In response to this selection, the server system may require the purchaser to perform a “login” so that the identity of the purchaser can be verified before the shipping information is viewed or modified. The server system then sends a Web page to the client system for display and possible modification of the shipping address. In this way, the transmitting of the sensitive shipping address can be avoided unless requested by the verified purchaser.

When the purchaser selects the single-action ordering button, the client system sends a message to the server system requesting that the displayed item be ordered. After the server system processes the message, the server system provides to the client system a new Web page that confirms receipt of the single-action order. FIG. 1B illustrates the display of a Web page confirming a single-action order. The confirming Web page contains essentially the same information as the Web page describing the item (i.e., FIG. 1A)

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except that an order confirmation section **105** is displayed at the top of the Web page. The order confirmation section confirms that the order has been placed and provides an opportunity for the purchaser to review and change the single-action order. Alternatively, the confirming Web page can be identical to the Web page describing the item (i.e., FIG. 1A), except that the single-action ordering button is replaced with a message confirming the order.

If a single-action ordering is not currently enabled for the client system but could be enabled, then the server system can generate a Web page like FIG. 1A, except that the single-action ordering button **103a** is replaced by a single-action ordering enable button. Such a replacement button could contain text instructing the purchaser to click on the button to enable single-action ordering. When the purchaser clicks on that button, the server system would send the Web page of FIG. 1A to be displayed. Single-action ordering can be enabled whenever the server system has stored sufficient purchaser-specific order information for that client system to complete a single-action order. If the server system does not have sufficient information, then when the purchaser selects the single-action ordering button, the server system can provide a Web page to collect the additional information that is needed. The server system may require the purchaser to "login" so that the identity of the purchaser can be verified before the single-action ordering is enabled.

To help minimize shipping costs and purchaser confusion, the server system may combine various single-action orders into a multiple-item order. For example, if a purchaser orders one item using the single-action ordering and five minutes later orders another item using the single-action ordering, then those orders may be cost effectively combined into a single order for shipping. The server system combines the single-action orders when their expected ship dates are similar. For example, if one item is immediately available and the other item will be available in one day, then the two single-action orders may be cost-effectively combined. However, if the other item will not be available for two weeks, then the two single-item orders would not be combined. FIG. 1C illustrates the display of a Web page representing four single-action orders that have been combined into two separate multiple-item orders based on the availability of the items. The order information **106** indicates that item **1** and item **2**, which will be available in three or fewer days, have been combined into one order. The order information **107** indicates that items **3** and **4**, which will not be available within one week, are combined into a separate order. In one embodiment, the server system may combine single-action orders that are placed within a certain time period (e.g., 90 minutes). Also, the server system may combine or divide orders when the orders are scheduled for shipment based on the then current availability of the items ordered. This delayed modification of the orders is referred to as "expedited order selection" and is described below in detail.

FIG. 2 is a block diagram illustrating an embodiment of the present invention. This embodiment supports the single-action ordering over the Internet using the World Wide Web. The server system **210** includes a server engine **211**, a client identifier/customer table **212**, various Web pages **213**, a customer database **214**, an order database **215**, and an inventory database **216**. The server engine receives HTTP requests to access Web pages identified by URLs and provides the Web pages to the various client systems. Such an HTTP request may indicate that the purchaser has performed the single action to effect single-action ordering. The customer database contains customer information for vari-

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ous purchasers or potential purchasers. The customer information includes purchaser-specific order information such as the name of the customer, billing information, and shipping information. The order database **215** contains an entry for each order that has not yet been shipped to a purchaser. The inventory database **216** contains a description of the various items that may be ordered. The client identifier/customer table **212** contains a mapping from each client identifier, which is a globally unique identifier that uniquely identifies a client system, to the customer last associated with that client system. The client system **220** contains a browser and its assigned client identifier. The client identifier is stored in a file, referred to as a "cookie." In one embodiment, the server system assigns and sends the client identifier to the client system once when the client system first interacts with the server system. From then on, the client system includes its client identifier with all messages sent to the server system so that the server system can identify the source of the message. The server and client systems interact by exchanging information via communications link **230**, which may include transmission over the Internet.

One skilled in the art would appreciate that the single-action ordering techniques can be used in various environments other than the Internet. For example, single-action ordering can also be in an electronic mail environment in which an item is described in an electronic mail message along with an indication of the single action that is to be performed to effect the ordering of the item. Also, various communication channels may be used such as local area network, wide area network, or point-to-point dial up connection. Also, a server system may comprise any combination of hardware or software that can generate orders in response to the single action being performed. A client system may comprise any combination of hardware or software that can interact with the server system. These systems may include television-based systems or various other consumer products through which orders may be placed.

FIG. 3 is a flow diagram of a routine that enables single-action ordering for a customer. To enable single-action ordering, a server system needs to have information about the customer that is equivalent to the purchaser-specific order information. The server system can obtain this information in various ways. First, the server system could ask the customer if they would like to have single-action ordering enabled. If so, then the server system could prompt the customer using a Web page for the purchaser-specific order information. Second, the server system could also save the purchaser-specific order information collected when an order is placed conventionally. The server system could, either automatically or with the customer's assent, enable single-action ordering. In step **301**, the server system retrieves the client identifier that was sent by the client system. In step **302**, the server system updates the client identifier/customer table to indicate that the generated client identifier has been associated with that customer. In step **303**, the server system sets a flag indicating that single-action ordering is enabled for that client identifier and that customer combination. That flag may be stored in the client identifier/customer table. In step **304**, the server system supplies a confirming Web page to the client system. The next time a purchaser attempts to order an item, the client system will supply its client identifier to the server system. If single-action ordering is enabled for that purchaser, the server system will assume that the purchaser is the customer associated with that client identifier in the client identifier/customer table. Thus, a purchaser may not want to allow the

server system to enable single-action ordering if there is a possibility that someone else may use that same client system.

FIG. 4 is a flow diagram of a routine to generate a Web page in which single-action ordering is enabled. When single-action ordering is enabled, the server system generates a Web page describing an item as is conventionally done and then adds a single-action ordering section. In one embodiment, the server system adds partial purchaser-specific order information to the section. This information may include the customer's name, a shipping address monitor selected by the purchaser (e.g., "at home"), and the last five digits of a credit card number or a nickname selected by the purchaser. Such partial information should be the minimum information sufficient to indicate to the purchaser whether or not the server system is using the correct purchaser-specific order information. In step 401, the server system generates a standard shopping cart-type Web page for the item. In step 402, if the single-action ordering flag has been set for the client identifier and customer combination, then the server system continues at step 403, else the server system completes. In step 403, the server system adds the single-action section to the Web page and completes.

FIG. 5 is a flow diagram of a routine which processes a single-action order. When a purchaser performs the single action needed to place an order, the client system notifies the server system. The server system then combines the purchaser-specific order information for the customer associated with the client system with the item order information to complete the order. The single-action order may also be combined with other single-action orders and possibly with other conventionally placed orders to reduce shipping costs. In one embodiment, single-action orders can be combined if they are placed within a certain time period of each other (e.g., 90 minutes). This routine illustrates the combining of the single-action orders into a short-term order (e.g., available to be shipped in less than a week) and a long-term order (e.g., available to be shipped in more than a week). One skilled in the art would appreciate that the single-action orders can be combined in various ways based on other factors, such as size of shipment and intermediate-term availability. In step 501, if the item is expected to be shipped in the short term, then the server system continues at step 502, else the server system continues at step 505. In step 502, if a short-term order has already been opened for the purchaser, then the server system continues at step 504, else the server system continues at step 503. In step 503, the server system creates a short-term order for the purchaser. In step 504, the server system adds the item to the short-term order and continues at step 508. In step 505, if a long-term order has already been opened for the purchaser, then the server system continues at step 507, else the server system continues at step 506. In step 506, the server system creates a long-term order for the purchaser. In step 507, the server system adds the item to the long-term order. In step 508, the server system generates and sends the confirmation and completes.

FIG. 6 is a flow diagram of a routine for generating a single-action order summary Web page. This Web page (e.g., FIG. 1C) gives the user the opportunity to view and modify the short-term and long-term single-action orders. In step 601, the server system adds the standard single-action order information to the Web page. In step 602, if a short-term order is open, then the server system adds the short-term order to the Web page in step 603. In step 604, if a long-term order is open, then the server system adds the long-term order information to the Web page in step 605 and completes.

FIG. 7 is a flow diagram of a routine that implements an expedited order selection algorithm. The goal of the expedited order selection algorithm is to minimize the number of orders sent to each destination so that shipping costs are reduced. A destination may be a specific shipping address plus a specific purchaser's billing details. Orders that are sent to the same destination are known as "sibling orders." The algorithm has two stages. In the first stage, the algorithm schedules for shipment the orders for destinations for which all the sibling orders are filled. An order is filled when all its items are currently in inventory (i.e., available) and can be shipped. For each group of sibling orders, the algorithm combines those sibling orders into a single combined order so that only one order is currently scheduled for shipment to each destination. In the second stage, the algorithm combines and schedules groups of sibling orders for which some of the sibling orders are not filled or partially filled. The algorithm may split each partially filled sibling order into a filled sibling order and a completely unfilled sibling order. The algorithm then combines all the filled sibling orders into a single combined order and schedules the combined order for shipment. If any group has only one sibling order and that order is partially filled, then the algorithm in one embodiment does not split that order to avoid making an extra shipment to that destination.

During the second stage, the algorithm may select and schedule groups of sibling orders in a sequence that is based on the next fulfillment time for an item in the group. The next fulfillment time for a group of sibling orders is the minimum expected fulfillment time of the items in that group of sibling orders. For example, if a group of sibling orders has seven items that are not yet fulfilled and their expected fulfillment times range from 3 days to 14 days, then the next fulfillment time for that group is 3 days. The algorithm first schedules those groups of sibling orders with the largest next fulfillment time. For example, if 6 groups have next fulfillment times of 3, 5, 7, 10, 11, and 14 days, respectively, then the algorithm first selects and schedules the sibling orders in the group with the next fulfillment time of 14 days, followed by the group with the next fulfillment time of 11 days, and so on. By delaying the scheduling of groups with short next fulfillment times, the algorithm increases the chances of additional items becoming available (because of the shortness of the next fulfillment time) and thus combined with the scheduled order.

Steps 701-703 represent the first stage of the expedited order selection algorithm, and steps 704-706 represent the second stage of the expedited selection order algorithm. In steps 701-703, the algorithm loops selecting groups in which all sibling orders are filled and combining the orders. In step 701, the algorithm selects the next group with all sibling orders that are filled. In step 703, if all such groups have already been selected, then the algorithm continues with the second stage in step 704, else the algorithm continues at step 703. In step 703, the algorithm combines and schedules the orders in the selected group and loops to step 701. In step 704, the algorithm selects the next group of sibling orders that has the largest next fulfillment time. In step 705, if all such groups have already been selected, then the algorithm is done, else the algorithm continues at step 706. In step 706, the algorithm combines and schedules the orders in the selected group and loops to step 704. When the expedited order selection algorithm is being performed, new orders and new inventory may be received. Whenever such new orders and new inventory is received, then the algorithm restarts to schedule and combine the new orders as appropriate.

Although the algorithm has been described as having two stages, it could be implemented in an incremental fashion where the assessment of the first and second stages are redone after each order is scheduled. One skilled in the art would recognize that there are other possible combinations of these stages which still express the same essential algorithm.

FIGS. 8A–8C illustrate a hierarchical data entry mechanism in one embodiment. When collecting information from a user, a Web page typically consists of a long series of data entry fields that may not all fit onto the display at the same time. Thus, a user needs to scroll through the Web page to enter the information. When the data entry fields do not fit onto the display at the same time, it is difficult for the user to get an overall understanding of the type and organization of the data to be entered. The hierarchical data entry mechanism allows a user to understand the overall organization of the data to be entered even though the all data entry fields would not fit onto the display at the same time. FIG. 8A illustrates an outline format of a sample form to be filled in. The sample form contains various sections identified by letters A, B, C, and D. When the user selects the start button, then section A expands to include the data entry fields for the customer name and address. FIG. 8B illustrates the expansion of section A. Since only section A has been expanded, the user can view the data entry fields of section A and summary information of the other sections at the same time. The user then enters data in the various data entry fields that are displayed. Upon completion, the user selects either the next or previous buttons. The next button causes section A to be collapsed and section B to be expanded so that financial information may be entered. FIG. 8C illustrates the expansion of section B. If the previous button is selected, then section A would collapse and be displayed as shown in FIG. 8A. This collapsing and expanding is repeated for each section. At any time during the data entry, if an error is detected, then a Web page is generated with the error message in close proximity (e.g., on the line below) to the data entry field that contains the error. This Web page is then displayed by the client system to inform the user of the error. In addition, each of the data “entry” fields may not be editable until the user clicks on the data entry field or selects an edit button associated with the data entry field. In this way, the user is prevented from inadvertently changing the contents of an edit field. When the user clicks on a data entry field, a new Web page is presented to the user that allows for the editing of the data associated with the field. When editing is complete, the edited data is displayed in the data “entry” field. Because the fields of the form are thus not directly editable, neither “named-submit” buttons nor Java are needed. Also, the form is more compact because the various data entry options (e.g., radio button) are displayed only on the new Web page when the field is to be edited.

Although the present invention has been described in terms of various embodiments, it is not intended that the invention be limited to these embodiments. Modification within the spirit of the invention will be apparent to those skilled in the art. For example, the server system can map a client identifier for multiple customers who have recently used the client system. The server system can then allow the user to identify themselves by selecting one of the mappings based preferably on a display of partial purchaser-specific order information. Also, various different single actions can be used to effect the placement of an order. For example, a voice command may be spoken by the purchaser, a key may be depressed by the purchaser, a button on a television remote control device may be depressed by the purchaser, or

selection using any pointing device may be effected by the purchaser. Although a single action may be preceded by multiple physical movements of the purchaser (e.g., moving a mouse so that a mouse pointer is over a button), the single action generally refers to a single event received by a client system that indicates to place the order. Finally, the purchaser can be alternately identified by a unique customer identifier that is provided by the customer when the customer initiates access to the server system and sent to the server system with each message. This customer identifier could be also stored persistently on the client system so that the purchaser does not need to re-enter their customer identifier each time access is initiated. The scope of the present invention is defined by the claims that follow.

We claim:

1. A method of placing an order for an item comprising:
 - under control of a client system,
 - displaying information identifying the item; and
 - in response to only a single action being performed,
 - sending a request to order the item along with an identifier of a purchaser of the item to a server system;
- under control of a single-action ordering component of the server system,
- receiving the request;
- retrieving additional information previously stored for the purchaser identified by the identifier in the received request; and
- generating an order to purchase the requested item for the purchaser identified by the identifier in the received request using the retrieved additional information; and fulfilling the generated order to complete purchase of the item
- whereby the item is ordered without using a shopping cart ordering model.
2. The method of claim 1 wherein the displaying of information includes displaying information indicating the single action.
3. The method of claim 1 wherein the single action is clicking a button.
4. The method of claim 1 wherein the single action is speaking of a sound.
5. The method of claim 1 wherein a user of the client system does not need to explicitly identify themselves when placing an order.
6. A client system for ordering an item comprising:
 - an identifier that identifies a customer;
 - a display component for displaying information identifying the item;
 - a single-action ordering component that in response to performance of only a single action, sends a request to a server system to order the identified item, the request including the identifier so that the server system can locate additional information needed to complete the order and so that the server system can fulfill the generated order to complete purchase of the item; and
 - a shopping cart ordering component that in response to performance of an add-to-shopping-cart action, sends a request to the server system to add the item to a shopping cart.
7. The client system of claim 6 wherein the display component is a browser.
8. The client system of claim 6 wherein the predefined action is the clicking of a mouse button.
9. A server system for generating an order comprising:
 - a shopping cart ordering component; and

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a single-action ordering component including:
 a data storage medium storing information for a plurality of users;
 a receiving component for receiving requests to order an item, a request including an indication of one of the plurality of users, the request being sent in response to only a single action being performed; and
 an order placement component that retrieves from the data storage medium information for the indicated user and that uses the retrieved information to place an order for the indicated user for the item; and
 an order fulfillment component that completes a purchase of the item in accordance with the order placed by the single-action ordering component.

10. The server system of claim 9 wherein the request is sent by a client system in response to a single action being performed.

11. A method for ordering an item using a client system, the method comprising:
 displaying information identifying the item and displaying an indication of a single action that is to be performed to order the identified item; and
 in response to only the indicated single action being performed, sending to a server system a request to order the identified item
 whereby the item is ordered independently of a shopping cart model and the order is fulfilled to complete a purchase of the item.

12. The method of claim 11 wherein the server system uses an identifier sent along with the request to identify additional information needed to generate an order for the item.

13. The method of claim 12 wherein the identifier identifies the client system and the server system provides the identifier to the client system.

14. The method of claim 11 wherein the client system and server system communicate via the Internet.

15. The method of claim 11 wherein the displaying includes displaying an HTML document provided by the server system.

16. The method of claim 11 including sending from the server system to the client system a confirmation that the order was generated.

17. The method of claim 11 wherein the single action is clicking a mouse button when a cursor is positioned over a predefined area of the displayed information.

18. The method of claim 11 wherein the single action is a sound generated by a user.

19. The method of claim 11 wherein the single action is selection using a television remote control.

20. The method of claim 11 wherein the single action is depressing of a key on a key pad.

21. The method of claim 11 wherein the single action is selecting using a pointing device.

22. The method of claim 11 wherein the single action is selection of a displayed indication.

23. The method of claim 11 wherein the displaying includes displaying partial information supplied by the server system as to the identity of a user of the client system.

24. The method of claim 11 wherein the displaying includes displaying partial shipping information supplied by the server system.

25. The method of claim 11 wherein the displaying includes displaying partial payment information supplied by the server system.

26. The method of claim 11 wherein the displaying includes displaying a moniker identifying a shipping address for the customer.

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(54) **METHOD AND SYSTEM FOR PLACING A PURCHASE ORDER VIA A COMMUNICATIONS NETWORK**

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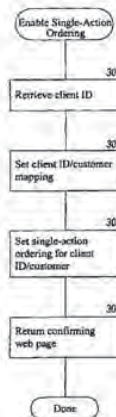
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(57) **ABSTRACT**

A method and system for placing an order to purchase an item via the Internet. The order is placed by a purchaser at a client system and received by a server system. The server system receives purchaser information including identification of the purchaser, payment information, and shipment information from the client system. The server system then assigns a client identifier to the client system and associates the assigned client identifier with the received purchaser information. The server system sends to the client system the assigned client identifier and an HTML document identifying the item and including an order button. The client system receives and stores the assigned client identifier and receives and displays the HTML document. In response to the selection of the order button, the client system sends to the server system a request to purchase the identified item. The server system receives the request and combines the purchaser information associated with the client identifier of the client system to generate an order to purchase the item in accordance with the billing and shipment information whereby the purchaser effects the ordering of the product by selection of the order button.



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**EX PARTE
REEXAMINATION CERTIFICATE
ISSUED UNDER 35 U.S.C. 307**

THE PATENT IS HEREBY AMENDED AS
INDICATED BELOW.

Matter enclosed in heavy brackets [] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims 6-10 is confirmed.

Claims 1 and 11 are determined to be patentable as amended.

Claims 2-5 and 12-26, dependent on an amended claim, are determined to be patentable.

1. A method of placing an order for an item comprising:
under control of a client system,
displaying information identifying the item *purchasable through a shopping cart model*; and
in response to only a single action being performed, sending a request to order the item along with an identifier of a purchaser of the item to a server system;

2

under control of a single-action ordering component of the server system,
receiving the request;

retrieving additional information previously stored for the purchaser identified by the identifier in the received request; and

generating an order to purchase the requested item for the purchaser identified by the identifier in the received request using the retrieved additional information; and
fulfilling the generated order to complete purchase of the item

whereby the item is ordered without using [a] *the shopping cart [ordering] model*.

11. A method for ordering an item using a client system, the method comprising:

displaying information identifying the item *purchasable through a shopping cart model* and displaying an indication of a single action that is to be performed to order the identified item; and

in response to only the indicated single action being performed, sending to a server system a request to order the identified item

whereby the item is ordered independently of [a] *the shopping cart model* and the order is fulfilled to complete a purchase of the item.

* * * * *