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A.	Mark Joselli, et al.; "gRmobile: A Framework for Touch and Accelerometer Gesture Recognition for Mobile Games", published in 2009 VIII Brazilian Symposium on Games and Digital Entertainment, date of conference October 8-10, 2009.

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11. Mark Joselli, et al.; "gRmobile: A Framework for Touch and Accelerometer Gesture Recognition for Mobile Games", published in 2009 VIII Brazilian Symposium on Games and Digital Entertainment, date of conference October 8-10, 2009. Copies of the conference proceedings were made available no later than the last day of the conference. The article is currently available for public download from the IEEE digital library, IEEE Xplore.

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Gordon MacPherson
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EXHIBIT A

gRmobile: A Framework for Touch and Accelerometer Gesture Recognition for Mobile Games

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***Abstract*—Mobile phone games are usually design to be able to play using the traditional number pads of the handsets. This is stressfully difficult for the user interaction and consequently for the game design. Because of that, one of the most desired features of a mobile games is the usage of few buttons as possible. Nowadays, with the evolution of the mobile phones, more types of user interaction are appearing, like touch and accelerometer input. With these features, game developers have new forms of exploring the user input, being necessary to adapt or create new kinds of game play. With mobile phones equipped with 3D accelerometers, developers can use the simple motion of the device to control the game or use complex accelerated gestures. And with mobile phones equipped with the touch feature, they can use a simple touch or a complex touch gesture recognitions. For the gesture to be recognized one can use different methods like simple brute force gestures, that only works well on simple gestures, or more complex pattern recognition techniques like hidden Markov fields, fuzzy logic and neural networks. This work presents a novel framework for touch/accelerometer gesture recognition that uses hidden Markov model for recognition of the gestures. This framework can also be used for the development of mobile application with the use of gestures.**

***Index Terms*—Mobile Games, Gesture Recognition, Motion Sensors, Touch Phones,Tangible User Interfaces.**

I. Introduction

Digital games are defined as real-time multimedia applications that have time constraints to run their tasks. If the game is not able to execute its processing under some time threshold, it will fail [1]. Mobile games are also real-time multimedia application that runs on mobile phones that have time constraints and many others constraints [2], when compared to PC or console games, like: hardware constraints (processing power and screen size); user input, (buttons, voice, touch screen and accelerometers); and different operating systems, like Android, iPhone OS, Symbian and Windows Mobile. This makes streamilly difficult for the design and development of mobile games.

On the other hand, mobile games can have unique characteristics, making unique type of games: location based games [3], [4], voice based games [5], accelerometer based games [6], camera based games [7] and touch based games [8]. In order to develop good mobile games, they must be design to take advantages of such unique characteristics into gameplay [9].

Mobile game phones are a growing market [10] and in 2010 the sales of smartphones is expected to suppress the laptops sales [11]. More than 10 million of people worldwide play games on mobile phones and handheld devices [12] and the worldwide mobile gaming revenue is expected to reach $9.6 billion by 2011 [13]. These are important motivations for game developers and designer to create blockbusters games.

One special characteristic of most mobile phones is that the user interaction is made mostly through number input [6], [14]. Because of that, the design of games must deal with this fact and design the game to use as few buttons as possible, like just one button games [15] and no-buttons at all games [14].

The evolution of mobile phones increase the processing power of such devices and also new forms of input, like touch screen devices and devices equipped with accelerometers. With the development of touch phones, like Motorola a1200, Htc Diamond, Sony Ericson w960i, Samsung Ultra

Smart F520 and Nokia N810, new forms of user interaction has appeared through the use of the finger or pen. This innovation has led to change the way users interact with the operation system and with games.

With the popularization of the use of accelerometer by the Nintendo Wiimote [16], the major mobile phone manufactures had also equipped their hardware with accelerometer, like Nokia N95, Sony ericson F305, Samsung Omnia and Motorola W7, among others. But this new form of user interaction has not led to major change on the interaction. This is mostly because programs/games only uses the accelerometer data as orientation.

The iPhone was one of the first devices that is equipped with touch screen and accelerometer that has mostly of the user input made though touch or motion, soon others companies followed this tendency, like: RIM Blackberry Storm, Nokia 5800, LG Arena, and many others. They basically use touch for user interaction, and the use of the accelerometer data is restricted for orientation, just like the others phones equipped with accelerometer. This paper tries to fulfill a gap on user interaction by providing a framework for gesture recognition though touch input or motion input, that can be used for games or programs.

The gesture recognition is a type of pattern recognition and can be made by different ways like: brute force [17], fuzzy logic [18], Gabor wavelet transform [19], hidden Markov model [20], Support Vector Machine [21] and neural networks [22], [23]. This work has developed a framework that can be used for gesture recognition using hidden Makov model. In order to generate and recognize the gestures database the proposed framework is divided in two parts: one for database constriction and another for the gesture recognition.

Summarizing, this work provides the following contributions:

- A novel architecture for touch/motion gesture recognition on mobile phones;
- Presentation of performance and tests of the framework showing that it can be used in real-time;
- Recognition test showing a high accuracy rate;

The paper is organized as follows: Section 2 presents some related works on the mobile development and gesture recognition on devices equipped with touch screen and devices equipped with accelerometers. Section 3 presents and explain the gesture recognition framework. Section 4 present and discuss some results of the use of the framework. Section 5 presents the conclusions and future works.

II. Related Work

Since the gRmobile has two kinds of gestures recognition (thought touch input or accelerometer motion input), this section is divided in two subsections: one for touch screen devices were user interaction and gesture recognition for this kind of device works; and another for accelerometer devices presenting user interaction works and gesture recognition approaches.

This work does not cover the related work on mobile game development. For this purpose the authors suggest the works [24], [2] which covers state of the art for this topic.

A. Touch Devices

Nowadays, more and more devices are coming with touch screen, and most of this is because of the decreased in the respective price [25]. Touch screen phone devices has the characteristics of having very few buttons and most of its users input interfaces are made through touch by finger or pen. For example the Blackberry Storm has about only 8 buttons and almost all of its user interaction is made by touch.

Most touch screen devices can have two kinds of input: dragged and pressed. The first is used when the user touches softly and can be used as a mouse being dragged. The second is when the user press hard on the device, and can be used as a mouse buttons pressed. Also modern devices has multi-touch screen devices like iPhone, Android T-G1 and Blackberry Storm, among others.

Some of these devices have used some of this types of input as gestures to enable friendly user interaction: like dragging for changing the web page, zooming options on photo view and many others features. But in third-party mobile software and games this use is very restrict.

Narayanaswamy et al [26] shows an implementation of handwrite recognition on PDAs using Hidden Markov Model. Wei et al. [27] presents a

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