### Visual Memory

by

Christopher James Kellogg

Submitted to the Department of Electrical Engineering and Computer Science in partial fulfillment of the requirements for the degrees of

> Bachelor of Science and Master of Science in Computer Science

> > at the

#### MASSACHUSETTS INSTITUTE OF TECHNOLOGY

May 1993

© Christopher James Kellogg, MCMXCIII. All rights reserved.

The author hereby grants to MIT permission to reproduce and to distribute copies of this thesis document in whole or in part, and to grant others the right to do so.



### **Visual Memory**

by

### Christopher James Kellogg

Submitted to the Department of Electrical Engineering and Computer Science on April 21, 1993, in partial fulfillment of the requirements for the degrees of Bachelor of Science and Master of Science in Computer Science

### Abstract

DOCKE.

RM

Visual memory supports computer vision applications by efficiently storing and retrieving spatiotemporal information. It is a unique combination of databases, spatial representation and indexing, and temporal representation and indexing. This thesis designs a visual memory architecture that meets the requirements of a number of computer vision applications. It also presents an implementation of part of this design in support of a scene monitoring prototype.

Thesis Supervisor: Alex P. Pentland Title: Associate Professor of Media Arts and Sciences

Thesis Supervisor: Bruce E. Flinchbaugh Title: Manager of Image Understanding Branch at Texas Instruments

# Acknowledgements

My primary thanks goes to my two thesis supervisors, Bruce Flinchbaugh at Texas Instruments and Sandy Pentland at MIT. Bruce pointed me to the visual memory project that he was starting and guided my research at Texas Instruments. Sandy provided useful feedback throughout the research stage. They were both very helpful in critiquing the thesis document.

I'd also like to thank the other people at Texas Instruments who helped me with this project. Steve Ford and Tom Bannon were especially helpful in developing the visual memory design. In addition, I don't think I would have survived the bugs in PC++ without Steve's expertise. Tom Bannon and Tom O'Donnell provided a nice tracking system with which to test the visual memory prototype.

Finally, I'd like to thank my family, Fred, Jeannette, and Mark Kellogg, my fiancée Christine Bailey, and my brothers at Phi Kappa Sigma for their support throughout my MIT career.

# Contents

1	Introduction					
	1.1 Needs for Visual Memory					
	1.2	2 Goals				
2	Bac	Background				
	2.1 Database Research			11		
		2.1.1	DARPA Open OODB	11		
		2.1.2	POSTGRES	12		
	2.2	2.2 Spatial Research				
		2.2.1	CODGER	13		
		2.2.2	Core Knowledge System	13		
		2.2.3	ISR	14		
		2.2.4	Image Understanding Environments	14		
		2.2.5	PROBE	14		
		2.2.6	Spatial Indices	15		
	2.3 Temporal Research					
		2.3.1	TQuel	15		
		2.3.2	Temporal Sequences	16		
		2.3.3	Temporal Sets	16		
		2.3.4	Relative Time	17		
		2.3.5	Temporal Indices	17		

**DOCKET A L A R M** Find authenticated court documents without watermarks at <u>docketalarm.com</u>.

3	Des	sign				
	3.1	Requi	rements and Considerations	19		
		3.1.1	Database Considerations	19		
		3.1.2	Spatial and Temporal Considerations	20		
		3.1.3	Performance Considerations	20		
	3.2	Design Overview		22		
	3.3	Spatia	l Representations	24		
		3.3.1	Core Spatial Classes	24		
		3.3.2	Relative Spatial Specification	29		
		3.3.3	Uncertain Spatial Specification	31		
	3.4	Tempo	oral Representations	36		
		3.4.1	Core Temporal Classes	36		
		3.4.2	Relative Temporal Specification	40		
		3.4.3	Uncertain Temporal Specification	41		
	3.5	5 Spatiotemporal Representations		45		
	3.6	3.6 Object Storage				
		3.6.1	Identity	50		
		3.6.2	Storage Mechanism	51		
		3.6.3	Time	52		
	3.7 Queries		25	53		
		3.7.1	Query Mechanism	53		
		3.7.2	Spatial Queries	54		
		3.7.3	Temporal Queries	57		
		3.7.4	Spatiotemporal Queries	59		
	3.8	Indices				
		3.8.1	Mechanism	64		
		3.8.2	Spatial Indices	65		
		3.8.3	Temporal Indices	66		
		3.8.4	Spatiotemporal Indices	66		

# DOCKET



# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

# **Real-Time Litigation Alerts**



Keep your litigation team up-to-date with **real-time** alerts and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

# **Advanced Docket Research**



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

# **Analytics At Your Fingertips**



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

#### LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

### **FINANCIAL INSTITUTIONS**

Litigation and bankruptcy checks for companies and debtors.

### **E-DISCOVERY AND LEGAL VENDORS**

Sync your system to PACER to automate legal marketing.

