Media Matrix: Self-organizing Distributed Physical Database

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ABSTRACT
We introduce Media Matrix, a system applying distributed, embedded computing techniques to the creation and maintenance of a queriable database of physical objects such as compact discs, video cassettes, books, and component bins. This paper provides theory, design, and implementation details as well as future work and potential applications.

Keywords
Distributed computing, self-organizing, embedded, database, searchable, collection management.

INTRODUCTION
Management of a large collection of physical objects such that any individual object can be easily searched for, recognized and located is a complex and enduring problem taking on many guises. Overcoming various forms of this problem is an integral function of inventory warehouses, libraries, delivery companies, grocery stores, movie rental stores and car dealerships, among others [1]. Indeed, bar-codes and bar-code scanning, the Dewey decimal system, package routing and lexicographic ordering are among the most familiar solutions to the collection management problem. Although these and other solutions have met with some success, much room for improvement remains.

Collection Management Trade-offs
The field of Information Science concerns itself in part with designing and evaluating systems of information categorization. Indeed, some institutions have even published entire documents addressing solely how best to select a collection management system [3]. Plenty of useful design points can be found in an informal treatment of the subject, however.

Information Needed to Use the System
A collection management system assumes the user has some knowledge of how to operate it. For any given system, a balance must be struck between how much information on how to use the system is embedded within the system itself and how much is the user required to know beforehand. For example, there is a much steeper learning curve for using the Dewey decimal system than for using a system employing alphabetical order.

Figure 1. Existing storage system for a collection of mini DV tapes.

Upkeep and Infrastructure Costs
Every collection management system incurs some cost for system upkeep and initial overhead. For example, all of the movies in a movie rental store must be sorted somehow (e.g. by author, title, genre) before put out for display and movies returned to the store must be resorted before being put back on the shelf.

Accessibility of Information
A collection management system loses all its value if the user cannot access the system efficiently. For example, bar-codes located on an item are often hard to find and almost impossible to decipher without a bar-code reader. In addition, items to be categorized are getting smaller and therefore more difficult to label conventionally.

DESIGN IMPLICATION
We set several goals for the Media Matrix project with the overall intent of providing a viable alternative to traditional collection management systems. Our main goal was to create a self-organizing system requiring minimal upkeep after the initial overhead of adding a new item to the collection. Efficiency and ease of use were also goals that heavily influenced this project. The Media Matrix project offers several features above and beyond traditional collection management systems.

- <u>Scalable</u>: there is no limit to the number items that can be added to the collection. This system would work for an entire library just as well as it would for a personal collection of mini DVs.

- Decentralized: there is no central database or computer acting as a bottleneck or weak link. Any portion of the database can cease functioning without hindering overall search performance.
- Self-organizing: the items in the collection never need to be manually sorted as long as they remain on the shelf. Furthermore, the act of physically adding/removing an item to/from the shelf automatically registers/unregisters it with the rest of the collection.
- Fast: all queries are carried out in parallel, making for a fast response time.

A SELF-ORGANIZING DATABASE

We chose to apply the Media Matrix system to the problem of managing a collection of miniature digital video cassettes (mini DVs), (fig. 1). To this end, we outfitted each mini DV cassette case with a tag consisting of a small microprocessor, the hardware needed to communicate wirelessly with other nearby tags, and small light to serve as an indicator to the user. Each of these tags contains information stored on the microprocessor about the contents of the mini DV it is tagged to. For example, a list of keywords describing the contents of the cassette or other meta-data could be stored electronically within the tag. In this way, items in the collection can query their neighbors and gain an understanding of what information is in the immediate vicinity. This allows for a system that does not require any sorting at all, but rather relies on items in the collection passing the query on to their neighbors until a match is found (fig. 2).

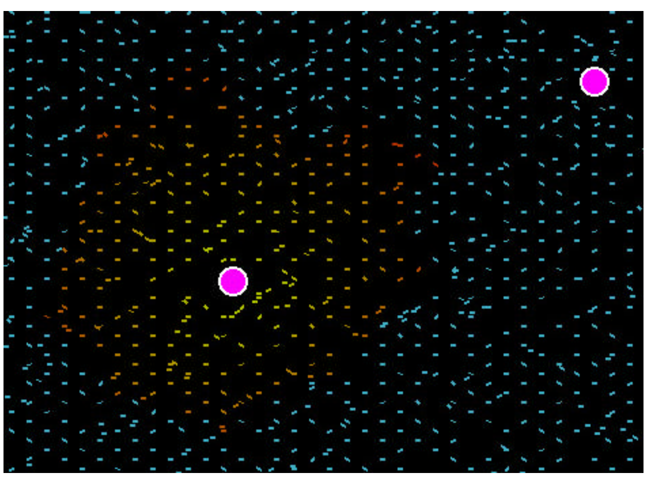

Figure 2. A simulation depicting a query diffusively propagating out from one point hoping to reach another point in a randomized lattice of nodes. Each dot represents a node. The large pink circles represent the start and end nodes. Orange nodes represent nodes that have received the query, the shade of orange indicating how many hops between nodes the query has made before reaching that particular node. Blue nodes are those that have not yet received the query. Use of simulator courtesy of Bill Butera.

IMPLEMENTATION

The microprocessor used in each tag is a Microchip PIC16F84. This PIC chip runs on a 10MHz clock, has 1K of flash ROM, and 68 bytes of data RAM [2].

A small red light emitting diode (LED) serves as an indicator. For example, when a query reaches a tag that matches the requirements of the query, that tag lights up. Furthermore, should the collection be exceptionally large, a trail of lights lead the user directly to the appropriate tagged item.

We use an infrared (IR) system to provide wireless communication [4]. The system consists of an IR LED as a transmitter and an IR sensor as a receiver. With this hardware, we implemented the Infrared Data Association (IrDA) protocol to communicate between tags.

Rather than powering each tag with its own battery, each item in the collection receives power via conductive strips from the shelf itself, which in turn is plugged into a power outlet.

USER INTERACTION

There are two instances in which a user needs to input information into the Media Matrix system. First, whenever a new item is added to the collection a tag must be made for it and initialized to hold the appropriate data. This can be accomplished relatively easily with a personal computer but it is possible to further streamline this process. Second, the user must be able to query the system in search for a particular item. This is accomplished with a hand held personal digital assistant (PDA) able to send infrared data (e.g. Palm Pilot devices). Note that communicating with any one of the items in the collection suffices for communicating with all of them as long as they can communicate amongst themselves.

CONCLUSION and FUTURE WORK

Although tagging every item in a collection with a small computer may seem somewhat extreme, we believe that falling integrated circuit prices and shrinking integrated circuit sizes will make the concept behind the Media Matrix a compelling solution in the very near future. This project serves as a proof of concept and provides an initial implementation using currently available technology. We plan to explore other distributed embedded computing projects using this same philosophy and technology.

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References

1. Fitzmaurice, G. *Situated Information Space and Spatially Aware Palmtop Computers*. in CAVM 36(7), July 1993, pp.38-49
2. Microchip Technology Inc., (1998) *PIC16F8X*, p. 1
3. Oregon State University Records Management Program, (1994). *Oregon State Archives Filing Systems*, http://www.orst.edu/Dept/archives/state/record_6.1.html
4. Poor, Robert. *iRX 2 Prototyping Board*, http://www.media.mit.edu/~r/projects/picsem/