MICROPROCESSOR SUPPORT FOR URBAN STREET NAVIGATION

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ABSTRACT

The suitability of using a cheap microprocessor based system for the display and navigation of urban street networks is examined. The primary goals of such a system are to provide selective display, scrolling, high-lighting, and zooming in real time on a stand-alone system costing under $5,000. A prototype system using an IBM PC is used as a basis for a discussion of the practicality of building such a system. The deficiencies of this prototype system are presented, and ongoing work to solve these deficiencies is summarized.

KEYWORDS: transportation, cartography, raster graphics, microprocessor

INTRODUCTION

Interactive computer graphics systems have been used for some time for the display of geographical data. [1,2] While most of the use of graphics has been to display land use, population densities, etc., systems have been built to interactively display urban street maps. Such displays have many uses, including vehicle dispatching, fire dept. coverage, route planning, etc. [3,4]. Traditionally, display systems have been limited to large urban centres in which the considerable development and equipment costs could be justified. While the costs of hardware have been decreasing at a rapid rate, the availability of interactive street display systems is still beyond a very large number of potential users. A system utilized by a large city department would be entirely unaffordable to a small city, or a private enterprise such as a courier service. However, the needs of a small city or organization may not differ appreciably from a larger one.

This disparity has provided the motivation for investigating a cheap, stand-alone microprocessor based street display and navigation system which would be affordable to a significantly larger population than current systems. This paper presents the first steps towards the development of such a system. There are two major aspects presented here. First of all, the objectives of a display and navigation system are presented. Then, as a starting point in the development of a small, microprocessor based system, the suitability of a standard personal computer (an IBM PC) is analysed. In conclusion, the work that is needed to be performed to extend such a computer to be able to meet the objectives is presented.

OBJECTIVES

The objectives for this system can be split into two parts. The first of these includes the features to be provided by the display system. The second details the performance and desired cost of the system.

In terms of objectives for a street map display system, some features are obviously desirable. Ignoring practical considerations and the differing uses of such a system, a user would generally like to be able to display an area of the city centred around any particular point. He would, of course, like to be able to specify this point as a particular street address. A navigation facility allowing scrolling in any compass direction is also desirable. The map segment shown in Figure 1 demonstrates several other requirements. This map displays a 4000 metre by 4000 metre area of the City of Winnipeg. Several observations can immediately be made. With the resolution used, the display is too crowded. The major routes are difficult to pick out, and individual streets are difficult to identify. The particular area shown in this map is better than many areas in this regard due to the presence of several rivers, railways, and golf courses (the open areas). Yet, at the same time, for many purposes, such as bus route planning, or fire vehicle coverage, this display shows too small an area. Thus it is evident that some improvements to the display are necessary. One such improvement is to provide for selective zooming so that different magnification levels can be displayed. Another desirable facility would be to restrict the display so that many of the minor streets are omitted, or alternatively to highlight major routes. A labelling system to identify particular streets, traffic routes, and other points of interest is required.

Colour can add significantly to the usefulness of the display. In addition to providing a means for separating major and minor routes, it also provides a very strongly visible means for showing points of interest, such as fire stations, and for distinguishing rivers, creeks, and railway lines from regular streets.

All of these display characteristics have been identified and are present to various degrees in existing systems, such as one in use in the City of Dallas [4].

The particular objectives which separate the system being discussed in this paper from existing systems relate to performance and cost. In order that such a system be affordable to small scale users, there is a cost requirement that such a system be cheap. For our purposes, this is interpreted to mean that such a system should be available for under $10,000, and preferably for less than $5,000. (One particular application which has received some attention, that of having a route navigation system in a private automobile, has a requirement of costing under $1,000[5]). At the same time, such a system should not depend upon an outside large system for its operational needs (although it is expected that the initial data collection and preparation would be done on such a system). It is possible that some applications could use a portable system, which could possibly be mounted in a vehicle.

In terms of performance, the system is expected to operate in real time. For the purposes of applications such as emergency vehicle dispatching, it is necessary to have very small waiting times for requests such as displaying a particular area, zooming in, or scrolling. For the purposes of this project a maximum response time of three seconds has been assumed to be a requirement.

The aims of the display system can then be summarized as follows. Given a data base representing the streets of an urban area, an area around any particular point can be displayed in a selection of different magnifications. The display can subsequently be scrolled in any compass direction. Some means for alleviating the crowding of the display of large areas is required. Particular features of interest will be highlighted and identified using a combination of labelling, and colours, as appropriate. The complete system should be stand-alone and reasonably portable and should cost less than $10,000, with a preferred cost of under $5,000.

SUITABILITY OF A MICROPROCESSOR

One of the most obvious ways of reducing the cost is to use standard off the shelf hardware components, which are in widespread use. Thus, as a starting point, a standard representative microprocessor system, the IBM PC has been used as the basis in experiments to determine those objectives which can easily be met, and those which will require more sophistication. A prototype system using a data base containing the entire street network of the City of Winnipeg has been constructed. This system provides for the display of an area around any selected coordinate, for scrolling in the four main compass directions, and for display in either of two magnifications. A third magnification displays the entire city, with a coloured box indicating which area of the city was previously in view. This allows the user to relate a particular displayed area to the city as a whole. In addition, colour is used to highlight rivers and railways, and labelling is

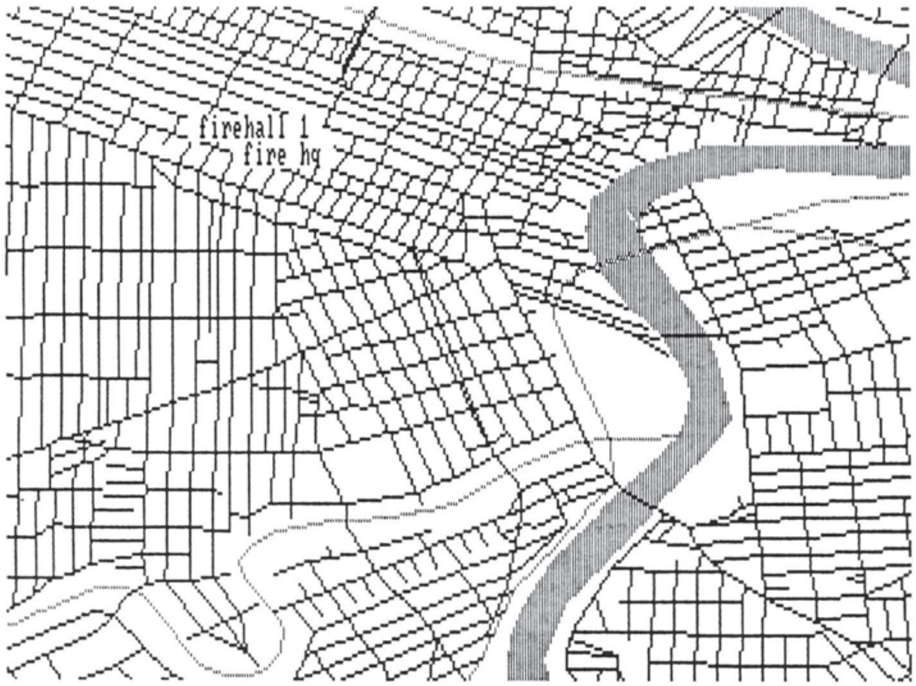

Figure 1

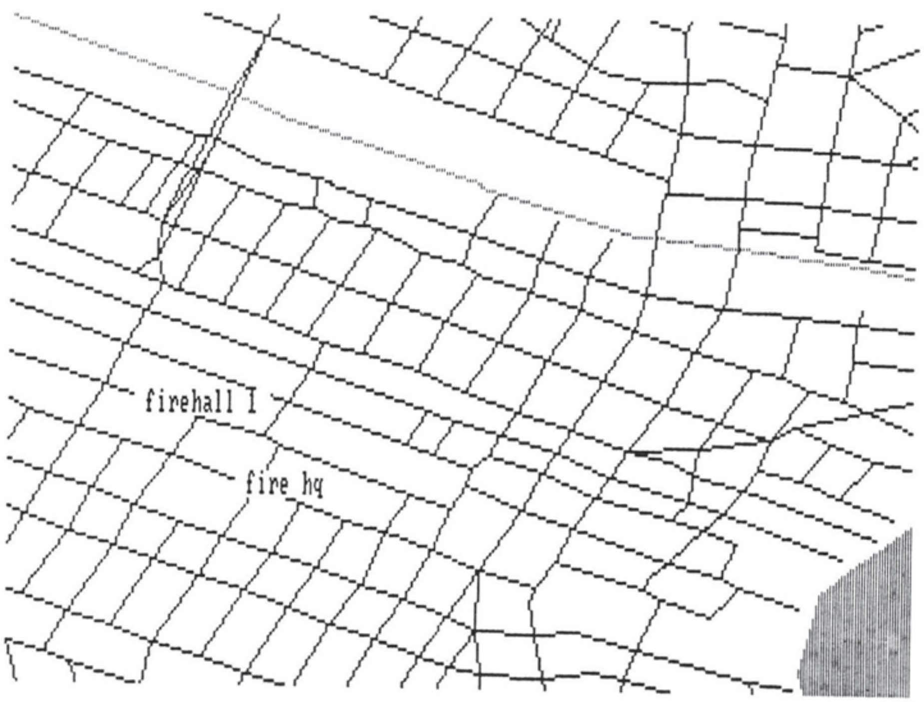

Figure 2

provided for selected points. The capabilities of the IBM PC as it pertains to this system will be discussed in terms of graphical display capabilities, storage space, and speed.

The IBM PC uses a standard colour monitor with either RGB or NTSC input. The standard graphics board provides either a 640 x 200 pixel bit-mapped display in monochrome, or a 320 x 200 pixel display in four colours. Other vendor's graphics display boards allow for more versatility with a 640 x 400 pixel display in 16 colours being easily obtainable. In the prototype system, only the standard IBM graphics interface has been used. Text can be displayed along with graphical information. With 640 x 200 pixels, textual material is displayed in a 24 line by 80 column format. IBM does not provide any facility for displaying text at an angle, and the resolution of the screen is insufficient to allow a user to provide such a facility in an effective manner. It is planned to attempt to provide angled labelling using the 640 by 400 resolution provided by other vendors.

The maps in the accompanying figures were all prepared using the 320 by 200 4-colour format, since the presence of colour was found to greatly enhance the presentation of the map. The printed versions of the maps used in the figures in this paper provide a fairly accurate rendition of how the maps appear on the screen (although the colour information can only be approximated using grey-scale shading). The lines were prepared using a standard algorithm (Bresenham [1]) with no usage of antialiasing or dejagging techniques. Even with this, the resolution is acceptable, although the 640 by 400 resolution would undeniably provide for a cleaner looking display.

Labelling on such a small, cheap graphics system does present a problem. A monitor which fits into the desired budget is simply not capable of displaying much more than 640 by 400 pixels. This does not provide very good text presentation, as required on displays containing as much information as the maps shown. In Figure 1, the textual information obscures much of the detail in their area, although a different magnification, as used in Figure 2 does alleviate the problem somewhat. One option which does help the problem of providing labelling is to allow the user to selectively add or delete particular labels, and to provide small coloured markers, which identify the exact point that the label applies to.

In the prototype system, only the two magnification levels as shown in Figures 1 and 2 have been provided, although a complete city map showing the area last on display is also available. This feature, which is shown in Figure 3, is very useful after scrolling across sections of the city which do not possess natural landmarks has been performed. To be most useful, the ability to display in other magnifications would definitely be useful. For example, the area shown in Figure 1 is not large enough to show all of the fire halls which would send apparatus to a fire in the centre of the display. Displaying a larger area would require the removal of some of the detail for clarity.

To summarize the graphics capabilities of the IBM PC as they relate to this application, the following points can be noted. The display hardware used costs under $1,500 which includes both a colour monitor with RGB inputs, and a display adapter containing the memory needed to store the screen's pixels. The resolution obtained is adequate for most route following applications. Colour can be used to minimize the labelling problems which do exist.

Storage space and speed go hand in hand. The only possible way to achieve the desired three second response time for displaying an area and for scrolling is to store the maps in an unencoded form. Each map is stored in its display format, so that it can be displayed by simply moving it into the display adapter's memory. Even at this many hard disk systems do not have sufficient speed to retrieve the data quickly enough during scrolling. The standard IBM file system which partitions files into 512 byte segments can not be used since too many head movements are required to read in a map. Instead, each map must be stored contiguously on disk, and the disk controller has to be accessed directly to obtain adequate performance.

However, while it is just possible

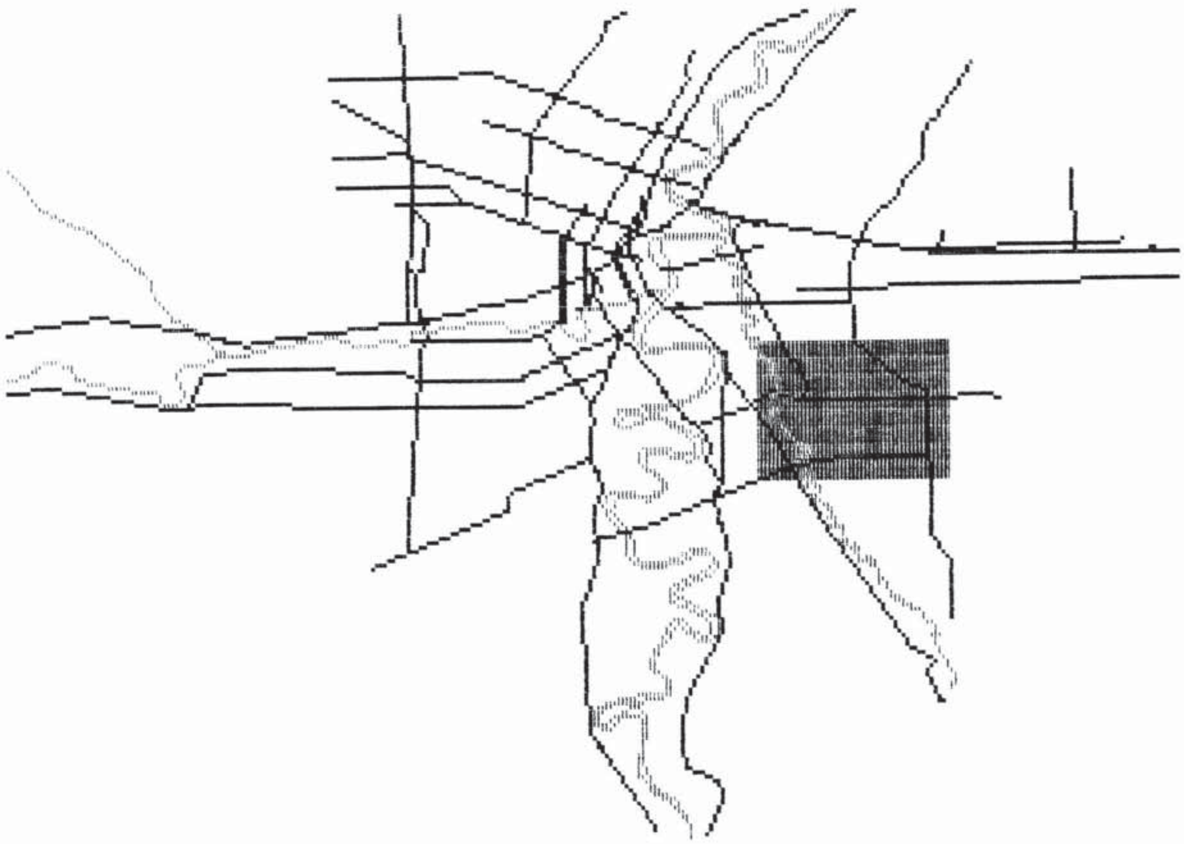

Figure 3

to achieve the desired speed in this manner, the maps occupy too much storage space. A complete 10 megabyte disk can be filled by storing only two magnifications of the city. Since the amount of disk space occupied increases as the square of the linear distance, larger cities would require significantly more space to store. Such large hard disks are too expensive for our budget constraints.

Many encoding schemes exist for reducing the amount of storage space required [6,7]. However, the lack of a sufficiently powerful processor and the large amount of data per display combine to give unacceptable decoding times. The best encoding scheme for a street map is to store the endpoints of each straight street segment. Using this technique the entire city map for Winnipeg can be stored in less than 150,000 bytes. This is small enough to fit in main memory and an external and expensive hard disk would not be required. This particular encoding scheme has the additional advantage that labelling and colouring information can be attached to individual street and river segments. However, even if the unreasonable assumption is made that all the line segments for a given area can be located quickly, the time taken to draw a map such as in Figure 1 is excessive on a machine such as an IBM PC.

This is the major problem with the use of a cheap stand-alone microprocessor system. In order to obtain a very good response time, the cost constraints are exceeded, since a large hard disk is required. A system can be built within the $5,000 cost figure, but the response times, particularly for scrolling, are too large.

A SOLUTION

In order to keep the cost low, and to provide the maximum flexibility, it is desirable to store the map data in its original form as a set of line segments. This provides the highest compaction level and allows the attaching of street related information, such as street names, types of street (major vs. minor streets), etc. The problem then is that decoding the information to produce a bit-mapped display simply is too time-consuming.

The following is a way, using some special hardware additions to the IBM PC, of acheiving acceptable response times without an exorbitant cost. The first part of the problem is to identify those line segments which appear in an area of the city to be displayed. One approach uses an associative memory technique based on work done for relational data bases implemented in disk hardware [8]. In these systems (several of which have been constructed) extra logic in the form of comparators is added to a disk drive so that as the data rotates under the disk read head comparisons can be performed simultaneously to determine if the data is to be selected or not. By having several such comparators all working in parallel on different disk tracks selection of a set of records satisfying a given condition can be done very quickly. The second part of our problem is to map the selected line segments to pixels and to clip the portions which are outside the display area.

Figure 4 show the overall outline of an I/O board to be constructed and plugged into the IBM PC's bus. The endpoints of all the line segments are stored in a memory area which appears at the top of Figure 4. This memory is not part of the regular IBM PC memory, but rather is internal to our display peripheral. Since the street data is non-volatile, read only memories can be used to construct the segment memory. For a city the size of Winnipeg, an array of 128K bytes is adequate.

Whenever a map is to be displayed, each line segment is placed in turn on an internal segment bus. This bus can be made wide enough to accomodate a complete line segment (i.e. both endpoints) at once. The segment bus is read in parallel by a set of "n" pixel generators (3 such pixel generators are shown in Figure 4). Each one of these pixel generators has the responsibility for decoding and clipping all of the line segments for a particular section of the display. The pixel generators place their output in a dual ported display memory which can be read by the main processor in the IBM PC for direct display on the screen. By increasing the number of pixel generators a larger degree of parallelism can be achieved.

At the time of writing this paper, this display peripheral has not yet been constructed. Current plans are to use a 128K byte segment memory, a 64 bit wide segment bus, and two pixel generators, each consisting of an INTEL 80186 processor with 2K bytes of memory. The 80186 processor has been chosen due to the small number of support chips required and its ability to perform arithmetic on 16-bit quantities. It is hoped that a prototype can be built for under $1,500.

CONCLUSIONS

The suitability of a microprocessor based display system using an IBM PC can be summarized. A prototype system capable of displaying any area of a city and capable of supplying labelling and colour highlighting has been built. This system provides an adequate quality of display, but is limited in only being able to display two magnifications, in being able to scroll in only four compass directions, and in using excessive storage space in order to achieve response time goals.

A summary of a display peripheral capable of solving the above problems has been given. Such a device would allow for general scrolling, zooming, with acceptable response and storage space. A complete stand-alone system should be constructable for close to the $5,000 desired cost.

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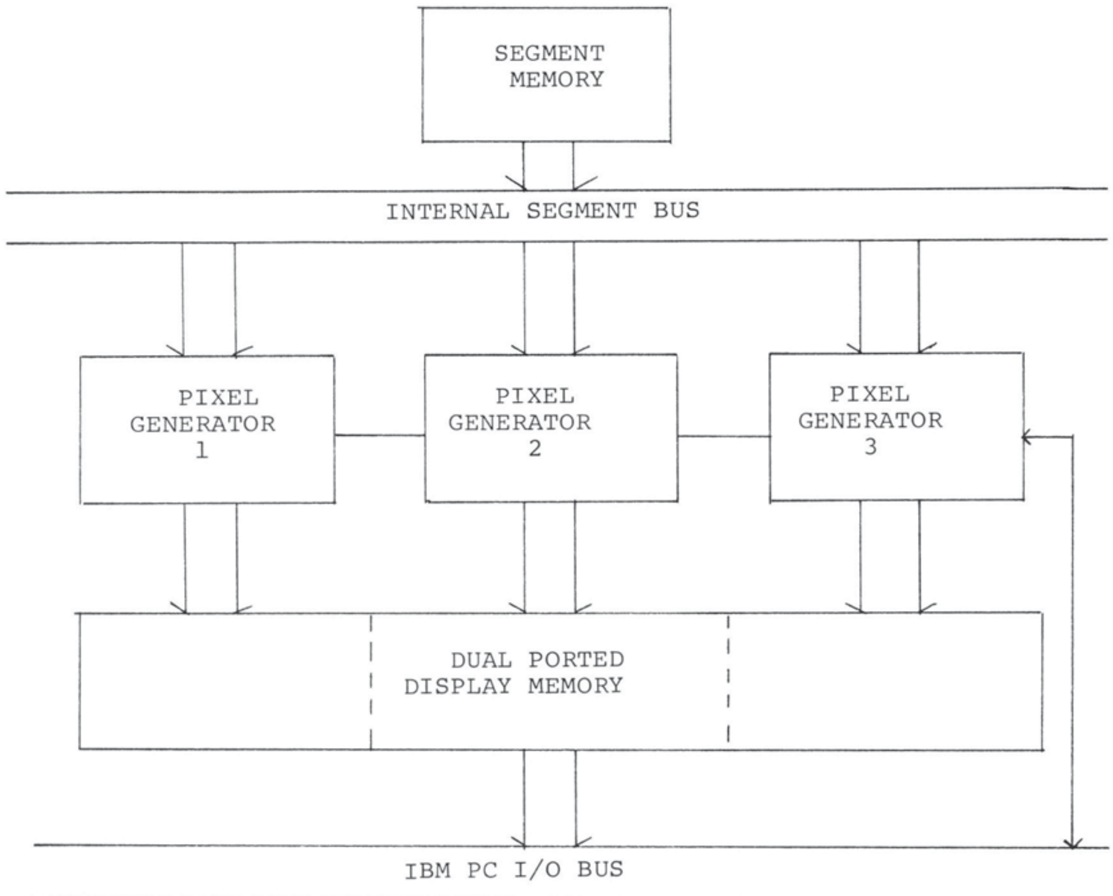
SEGMENT MEMORY
INTERNAL SEGMENT BUS
PIXEL GENERATOR 1
PIXEL GENERATOR 2
PIXEL GENERATOR 3
DUAL PORTED DISPLAY MEMORY
IBM PC I/O BUS

Figure 4

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