GIMMS / AN EXAMPLE OF AN OPERATIONAL SYSTEM FOR COMPUTER CARTOGRAPHY

T C WAUGH and D R F TAYLOR
University of Edinburgh and Carleton University

ABSTRACT The computer is playing an increasing role in Canadian Cartography. Developments in the field of thematic computer cartography have been less spectacular than those in automated cartography. This paper describes an operational system for thematic computer cartography, GIMMS; now mounted at Carleton University. It is argued that the availability of systems of this type will help realize the potential of the computer in thematic mapping.

In 1973 a monograph entitled *Computer Cartography in Canada* was produced.[1] The studies in that monograph, although by no means fully representative of all the work going on, gave a glimpse of the increasing importance of the computer to Canadian cartography and since that time development has proceeded apace with several systems making significant progress.[2] Interest in the role of the computer has grown both in governmental circles, at the federal, provincial and local levels and in our universities but whereas progress in the field of *automated cartography* has been rapid, progress in *computer cartography*[3] has been less spectacular. This is perhaps somewhat paradoxical as thematic mapping was one of the first areas of cartography to which computer technology was applied. The first generally available computer mapping program SYMAP[4] was first available in the mid-sixties and it is interesting to note that without major enhancements it has remained the most widely used computer mapping program. (A comparison with SPSS makes an interesting contrast in this respect[5].)

The advantages of SYMAP are offset to a considerable degree by a number of deficiencies: it is a line printer based mapping program; it has virtually no data management facilities; and control is by fixed format numeric codes. Line printer maps, despite the enhancement methods used are inherently of low quality and the lack of data management facilities together with the fixed format numeric codes make SYMAP a relatively difficult program to use. Several systems designed in the 1970s such as EMDS[6], CMS[7], and GIDS[8] have attempted to solve some of these problems but it is only in recent years that they, or other more advanced cartographic systems[9] have become available.

T. C. WAUGH is Senior Researcher, Program Library Unit, University of Edinburgh, and D. R. F. Taylor is Professor of Geography, Carleton University. MS *submitted July 1976*

[1]LeBlanc, Aubrey L., ed. "Computer Cartography in Canada." *Cartographica* Monograph No. 9. B. V. Gutsell, Department of Geography, York University, Toronto, 1973.
[2]Taylor, D. R. F., ed. *Proceedings of Symposium on Geographic Information Processing*. Carleton University, Ottawa 1976.
[3]These two terms were used and defined in *Cartographica* Monograph No. 9. They are seen as being at opposite ends of a utilization continuum the extremes of which are (1) automated cartography – simply a faster, more efficient means of producing much the same products as conventional methods; and (2) computer mapping – a software rich technique producing unique cartographic products.
[4]Fisher, H. T. et al. *Reference Manual for Synographic Computer Mapping (SYMAP), Version V*. Laboratory for Computer Graphics and Spatial Analysis, Graduate School of Design, Harvard University, Cambridge, 1968.
[5]Nie, H., Bent, D. H., and Hull, C. H. *SPSS – Statistical Package for the Social Sciences*. McGraw-Hill, New York, 1970.
[6]Phaltz, J. L. and Milgram, D. L. *An Experimental Map Description System*, Technical Report 70-130, GJ-754. Computer Science Center, University of Maryland, 1970.
[7]Waugh, T. C. *The Choropleth Mapping System*, Report No. 7, Inter University/Research Councils Series, Program Library Unit, University of Edinburgh, 1972.
[8]Yan, J. "GIDS – A Geographical Information System" (Master's Thesis) Department of Computer Science, University of British Columbia, 1973.
[9]For an excellent concise description of the field see Peucker, T. C. *Computer Cartography* Association of American Geographers, Resource Paper No. 17, 1972 pp. 75.

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The GIMMS system[10] is one such advanced system which is in full operation and readily available and the main purpose of this paper is to describe the system and outline its uses and potential. GIMMS is a large computer program for use in spatial analysis. The primary application is in the production of thematic maps utilizing a plotter (drum, flatbed, microfilm, laser etc.) as an output device. The system is a general purpose, integrated, user-oriented one which can be operated either in a batch[11] or interactive fashion.[12]

The system is general purpose in that it is, like SYMAP and other systems, not designed for any specific geographic space. It can deal with point, line, and area geographic zones and can relate both alphabetic and numeric data to these zones. Zone descriptions are provided by x, y coordinate pairs, usually by digitising from a base map. A point is a single xy coordinate pair, a line is a sequence of xy coordinate pairs and area zones may be described by area descriptions or by segment descriptions.

GIMMS is an integrated system and includes facilities for data input, checking, storage, retrieval, manipulation, and display. Thus the system provides most, if not all, of the common facilities required to process geographic data. In addition, there are program and file interfaces available to the more sophisticated user who wishes to do some of his own programming.

The major advantage of the system, however, is that it is user orientated. All of the functions of GIMMS are accessed by data command and there is no need for the user to do any programming, or even to be able to program. The data commands are, in effect, a language, which is designed to enable the user to express his instructions to the program easily. For example, the command

*TEXT POSITION = 3,2, HEIGHT = 0.6, TEXT = 'POPULATION DENSITY'

would, if given to the plotting or compilation modules, draw the text POPULATION DENSITY on the plot at the position 3 cms to the right and 2 cms up from the bottom left hand corner of the map. The height of the plotted text would be 0.6 cms. This command could also have been given as *TEXT 3,2,0.6, 'POPULATION DENSITY' and it should be noted that, for this command alone, there are 24 keywords that may be used to specify parameters some of which may be set by using a graphic cursor.[13] As the example shows, not all the parameters need be specified so that it is not necessary to know of the more complex facilities to be able to use the system. For example one of the parameters not specified in the above command is ANGLE. If the parameter ANGLE = 45 had also been specified then the text would have been inclined at an angle of 45 degrees to the horizontal.

The system is designed to be used in an interactive or batch manner. Some parts of the system are primarily batch orientated. For example, there is little advantage in inputting massive amounts of digitised information in an interactive manner, although

[10] Waugh, T. C. *An Introduction to a Geographic Information Manipulation and Mapping System (GIMMS)*, Research and Development Notes No. 9, Inter University/Research Councils Series, Program Library Unit, University of Edinburgh, 1973.

[11] Batch mode: submitting a complete job at one time which will be run on the computer at a later time and the results returned after that.

[12] Interactive mode: a job initiated by the user at a terminal with the user providing data from the terminal, usually interacting with the program.

[13] Graphic cursor: a device used to point at a position on a graphic display screen the position of which may be transmitted to a program being run in an interactive manner. The devices include thumbwheels, 'track balls', 'mouses', light pens, and data tablets.

it can be done. However, some of the checking features (e.g. *EXAMINE) are useful when used interactively. The *COMPILE module, for compilation design of thematic maps, is specifically designed for interactive use. Some functions should be run in batch mode as the computing resources required to run them are greater than that normally allowed an interactive user. Thus, where appropriate, a user may interact directly with the system and on other occasions may just give it a set of commands.

DATA INPUT

The GIMMS system recognizes two distinct types of data; geographic descriptions and data relating to these descriptions. These are input separately and are really only merged in the application modules, such as the plotting program. Geographic descriptions are either points, lines, or areas. Inputting point data and line data is straight forward; with one coordinate pair per point and a sequence of coordinate pairs per line. Area descriptions can be input in one of two ways. The complete description of each area can be input, that is the sequence of coordinate points completely surrounding the area, or area descriptions can be entered as segment descriptions which are then linked into areas. The major disadvantage of inputting complete area descriptions is that boundary segments between adjoining areas are input twice, once for each area. Since most graphic input is by using a digitiser[14] of some sort, then it is unlikely that the person digitising is accurate enough to record exactly the same boundary twice. This causes small gaps and overlaps along common boundary segments. The resolution of a line printer map is so low that these gaps are not noticeable. On a system that produces plotted maps, however, the capability of the human eye to detect differences in two lines which are supposed to be coincident is quite remarkable. This method of data input is therefore not cartographically acceptable except where subsequent processing is done to remove the differences. The MAP/MODEL system[15] uses this method of cleaning the image. The GIMMS system solves the problem by providing for segment descriptions as the preferred method of area descriptions. In this method, the areas are described as a series of common boundary segments and information is input indicating to which areas the segment belongs. Since each segment is only digitised once then there can be no gaps or overlaps. Another, and very important advantage, of the segment method is that topological checking can be done on the set of segment descriptions. Since the segments should link together to form areas then by attempting this (using the *BOUNDCHECK or *EXAMINE commands) errors can be found. If the attempt is successful then it can be shown that the descriptions are consistent, complete and correct. In addition, unlike the DIME[16] system which uses the same method, geographic consistency is checked since it is the coordinates themselves which are used for the checking procedures.

When the segment descriptions are correct, then the *AREAFILE command is used to create area descriptions from the segments. The area descriptions contain not only

[14]Digitiser: A device to record coordinates, usually from a base map.
[15]Keith, R. E. *Map Models: Concepts and Applications*, Bureau of Municipal Research and Service, University of Oregon, 1967.
[16]Census Use Study. *The DIME Geocoding System*, U.S. Bureau of the Census, Washington, D.C., 1970.

the x,y coordinates of the boundary of the zone but also the surface area of the zone, its centroid, and pointers to the zones surrounding it. This latter set of pointers is used to minimize drawing on the plotter and to provide sophisticated facilities, such as the ability to omit internal boundaries on a plot.

During the process of data input of geographic descriptions, the input coordinates may be transformed from the input coordinate system, usually digitiser table coordinates, to another set of cartesian coordinates, for example, National Grid or Universal Transverse Mercator (UTM) coordinates. This is achieved by establishing reference points for which the coordinates, e.g. UTM, are known. The system is informed of the UTM coordinates and the digitiser table coordinates of the reference points and can thus transform all subsequent digitiser table coordinates into UTM coordinates.

Data relating to the geographic descriptions is input in a manner similar to many survey analysis packages. For each zone a set of data items (values) are read for a common set of data elements (variables). The data items may be either numeric or alphabetic and several sets of data, from different sources, may be input during a run of the program.

DATA MANIPULATION

The system provides a range of manipulations, the most extensive of which are for the data relating to the geographic descriptions. Facilities are available to retrieve and manipulate both numeric and alphabetic data and to output values for use by the plotting modules or other systems. For example if the data elements POPULATION and AREA have been defined for a set of zones then the command

*FORM DENSITY = (POPULATION UPON AREA)

would create a new data element called DENSITY for the set of zones. The equation could also have been written (POPULATION/AREA) for those users more familiar with standard computing symbols. The manipulation may include conditional expressions as well as arithmetic ones. The command *FORM NOFSC = FOR (TOWN = 'HULL') SET POP TIMES 75.2/100) ELSE (POP *43.1/100) would create a new data element called NOFSC, which would have a value of POP*75.2/100 if the data item for TOWN was equal to the alphabetic string 'HULL', or would have a value of POP*43.1/100 otherwise.

The manipulations provided for geographic descriptions allow selective retrieval of zones, calculations of surface area and centroids for area zones, and centroids for line zones.

DATA DISPLAY

The system has a wide range of display capabilities. The display output is one of two forms, text display, and graphic display.

Text display comprises listing, diagnostics, and histograms. Listings of various values are printed at appropriate points, depending on how much information is requested. Throughout any run of the system, a series of diagnostic messages are printed to keep the user informed of what the system is doing. In addition, error messages are printed if an error occurs. Frequency Histograms of variables may be generated to help in the mapping process.

The production of maps and diagrams is the primary application of GIMMS and there are extensive facilities to allow the user great flexibility in the kinds of graphic output that may be produced. While the system may be used to produce diagrams, it is in the production of thematic maps that the system is primarily of use. Maps may be produced from point, line and area locational data banks. Point and area symbolism may be used to depict the values of data relating to geographic descriptions. Point zones may be depicted by point symbolism, such as squares, circles and other shapes, shaded or not. Area zones may be shaded or point symbolism, located at the centroid of the zone, can be used.

For each of the types of symbolism a wide variety of options is available. For point symbols for example, shape or size can be selected; whether the symbol is to be shaded can be specified, as can the offsetting of the symbol from the centroid. Figure 1 shows a simple shaded map and Figure 2 shows a map sheet with 5 maps to illustrate a theme. The system allows multiple maps to be drawn on one map sheet. These maps may overlap, such as a road network over a shaded map, or a series of point maps overlaid, or they may be separate. Figure 3 shows some of the range of symbolism.

The facility of scaling the map and 'windowing' may be used to produce insets, at a larger scale, of congested areas of the map. Figure 2 shows the scaling capability of the mapping module and if the scale is adjusted to produce a large scale then all map output drawn outside the frame will be 'windowed' (clipped), that is, not drawn. The user may window any part of the map sheet so by drawing at a large scale and windowing a specific part of the map sheet, then a different scale inset may be produced.

Thus multi-map sheets, with extensive scaling, positioning and windowing capabilities and those with multiple symbolism may be produced. The system also has the capability of producing a variety of multiple component point symbolism, allowing the depiction of up to 20 variables in one point symbol.

In addition to having the facility to produce single or multiple maps, with single or multiple components at a variety of scales, the system also provides extensive facilities for the addition of ancillary information such as text for titles, etc., keys, north arrows, and the addition of any line work to enhance the map.

The system provides facilities for multi-colour maps and colour separation maps. Multi-colour maps, or rather maps using more than one pen (they may be different line thicknesses, rather than different colours), may be produced in two ways. If the shading is to be in different colours, or combinations of different colours, and the user has access to a plotter with a multiple pen turret then a multi-colour map may be produced by specifying the pen for each shading overplot. If only one pen is available at the time then the *MAP command must be given several times, once for each colour, and the *PEN command used to change the pen between the different *MAP commands. Colour separation maps are produced by using the second method and also separating each *MAP command by a *NEWMAP command which causes the separation of the elements into individual map sheets.

Thematic maps are produced by the *PLOTPROG module which is usually run in

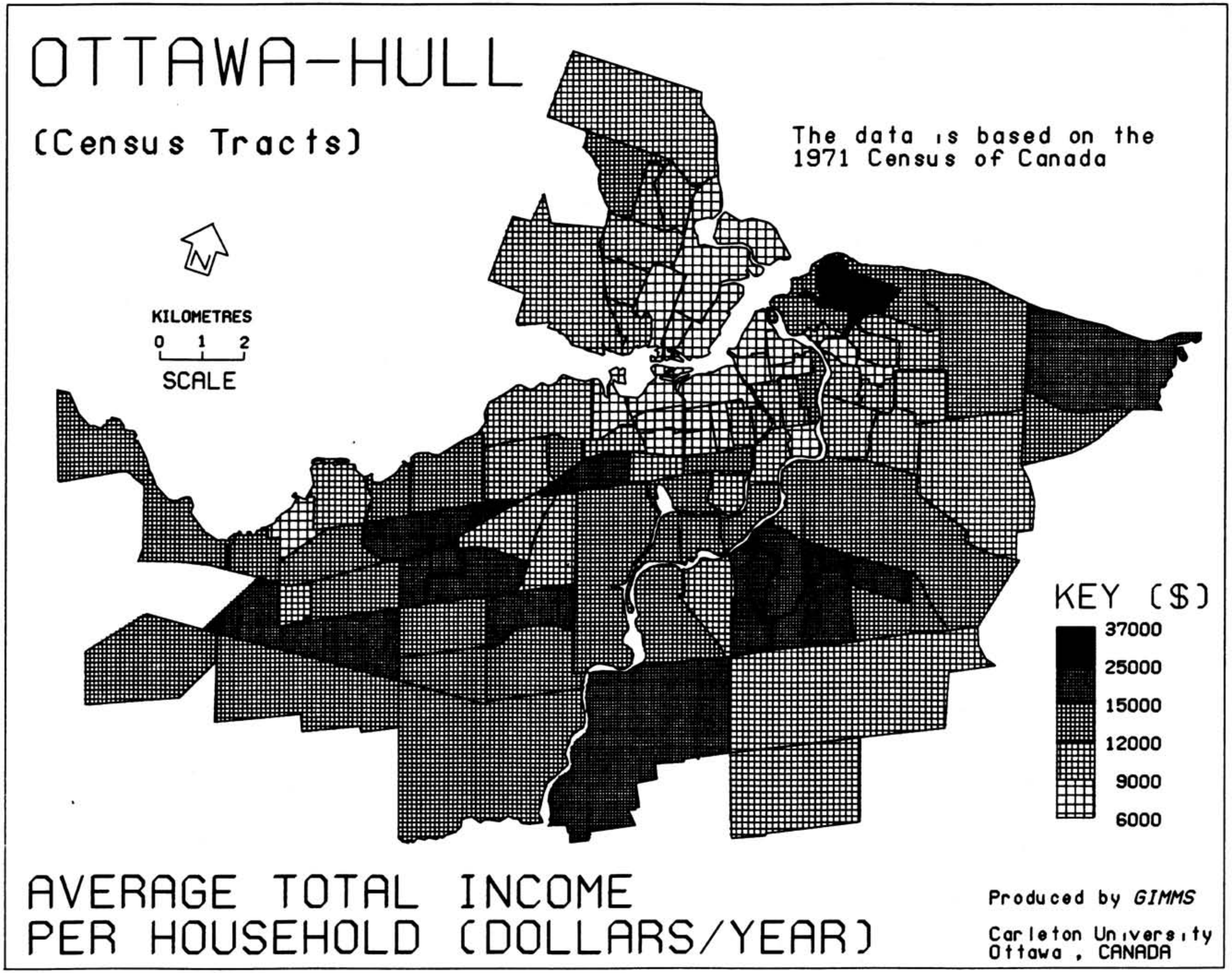

FIGURE 1. *An example of a simple shaded map.*

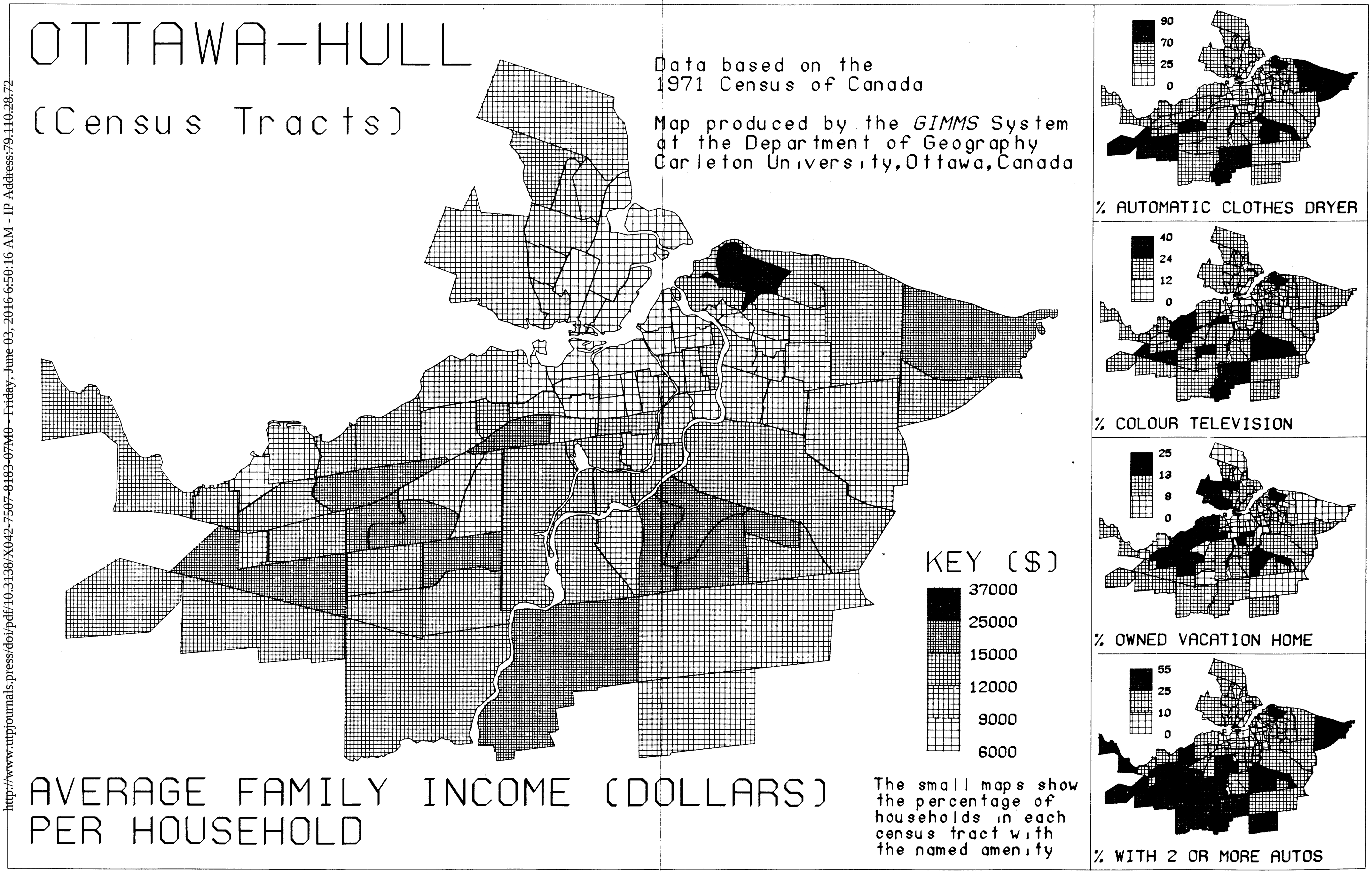

FIGURE 2. *A multiple map sheet.*

a batch mode to produce maps on a plotter thus giving hard copy. The module may be run interactively thus producing maps on a graphic display screen but any hard copy produced from a screen is usually (with some notable exceptions) of poor quality. However prior to the actual production of the map with value symbolism, the design of a map may be done interactively. The system provides facilities to design a map using the *COMPILE module and, using a graphic display screen and a graphic cursor, the user can create a design for a map, modify it until it is suitable, and then store the parameters so that they can be used by the *PLOTPROG module.

The facility to let the designer use his ability to point, using the graphic cursor, and to see the results of a change immediately, free the designer to design, rather than measure or guess. Thus the design of a map may be created and finalised in minutes rather than the days that the process of producing plotted test maps take. In practise, using this kind of system, maps *are* designed, and not just thrown together. This is the kind of facility that enables cartographers to become users of computer systems while retaining the design ethos that computer systems have not in general promoted, or even allowed. The actual design is done by manipulating zone outlines, text, keys, north arrows, grids, frames and any linear or point information required for the map. Position, size, and content are the main parameters to be created; and usually position, and occasionally size, are set by the graphic cursor. After the design is finalised, the commands necessary to produce this design are deduced and can be stored for later use.

USES

The system may be used for several purposes of which the primary ones are production, research and teaching. The system may be used to produce thematic maps for publication. If a set of maps of the same collection of zones is to be produced then the system will almost certainly be cheaper than by manual means. After a skeleton map has been produced by the compilation system, then many maps of different distributions may be produced with little effort. Therefore as the number of maps on one base goes up the average effort per map goes down. Small changes to a map are made very easily, such as changing scale, position within the map sheet, type and amount of text, shading parameters, class intervals, and so on. Thus it is much easier to experiment than with manual systems and the cost of an experimental map is quite low after the initial overhead of data input.

One major advantage of the system is that, due to its ease of use, a researcher can produce maps for analysis without draughting support. This provides facilities for people, involved in analysis of geographic information, to include the map in the analysis process and with a little extra effort, produce finished maps to illustrate the results of the analysis. It also allows basic research on cartographic design when used in the interactive mode.

Due to the system's range of facilities and ease of use, it can be a powerful teaching tool. Not only can elements of cartography be taught using the system but also aspects of geographic analysis, geographic information systems and use of computers. The interactive capability of the system is of particular value in teaching and as a teaching tool for cartography GIMMS is unique.

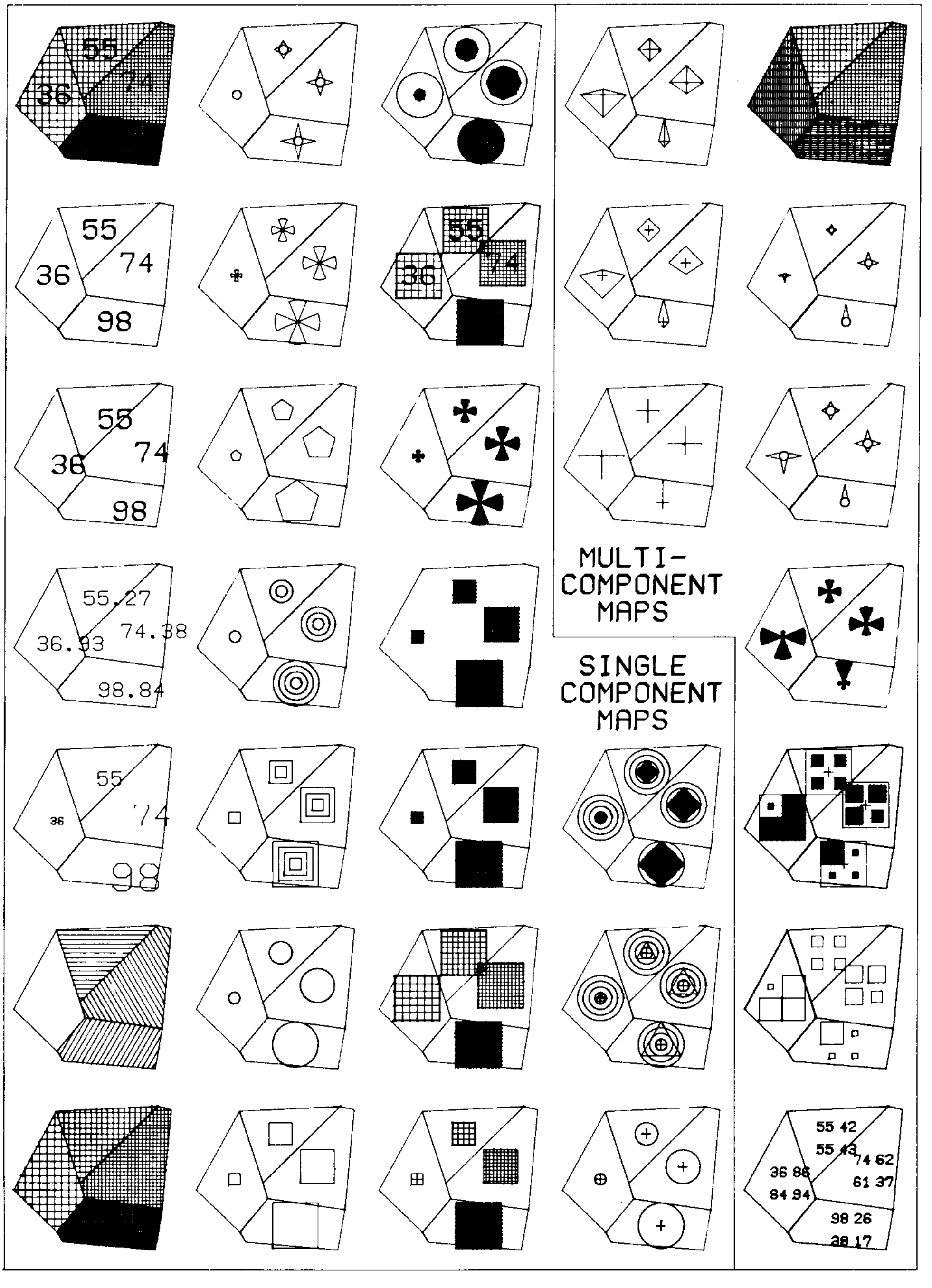

FIGURE 3. *Examples of some of the symbolism available in* GIMMS.

SYSTEM OPERATION

The GIMMS system is a large computer program written in FORTRAN. It is installed on various machines in the U.K. and Canada on IBM 360 and 370 series, ICL System 4 and Xerox Sigma 9 computers. The full system can be run in from 160 K bytes to 240 K bytes depending on the machine and operating system. Some major subsystems can be run in less than 100 K bytes. The system can be run in a batch or interactive mode with provision for system prompts and interrupts where appropriate. While the system is an integrated system it may be considered as a set of subsystems. In fact it may be split up and run as a set of subsystems. For example, the geographic description input and checking system may be used to input and check area descriptions and then output the results for input to SYMAP. Geographic descriptions may be input from other systems and the *PLOTPROG module may be used to produce thematic maps. The *DATMAN module may be used as a data manipulation package for other systems (e.g. SYMAP). These, and other uses, allow the system to be used in an environment that has no need for the total system.

The system is interfaced to several graphics software packages, notably the GINO-F graphics package,[17] and various versions of the CALCOMP basic software. If a user does not have access to one of these packages then the system will produce a text file of plot commands (pen, x, y) which may be post-processed by the user to produce graphic output by whatever means is available. The only drawing routine that is used is one routine which draws a straight line with the pen raised or lowered.

HISTORY

The GIMMS system was developed over a period of several years, primarily at Edinburgh University, but development was originally started at the Laboratory for Computer Graphics, Harvard University in 1969. Extensive additions and modifications have been made at Carleton University during 1976, primarily in the interactive parts of the system. Further information on the system may be obtained from: The Director, Program Library Unit, 18 Buccleuch Place, University of Edinburgh, Scotland, U.K.

CONCLUSION

The GIMMS system is one of a new breed of application systems for thematic mapping and is an important addition to the Canadian cartographic scene. The system is fully operational at Carleton University and has also been mounted at Statistics Canada. It provides a wide range of facilities with ease of use and produces maps of relatively high quality. It is hoped that this kind of system will produce the impetus to advance thematic mapping well and truly into the computer age. It is a concrete operational example of some of the potential of computer mapping outlined in 1973.[18]

[17]CADC. *GINO-F Reference Manual*, Computer Aided Design Centre, Cambridge, England, 1974.
[18]Taylor, D. R. F. "The Canadian Cartographer and the Computer: Present Trends and Future Challenges," in *Cartographica* Monograph No. 9, York University, Toronto, 1973. pp. 1–9.

RÉSUMÉ L'ordinateur joue un rôle de plus en plus important dans les services canadiens de cartographie. Les améliorations apportées en matière de cartographie thématique automatisée ont été moins spectaculaire que dans le domaine de la cartographie automatisée. Cet article décrit un système d'utilisation de la cartographie thématique automatisée, appelé le GIMMS, actuellement installé à l'université de Carleton. On estime que ces systèmes, une fois disponibles, aideront à utiliser au maximum les possibilités de l'ordinateur pour l'établissement de cartes thématiques.

ZUSAMMENFASSUNG Der Computer spielt eine wachsende Rolle in der kanadischen Kartographie. Weiterentwicklungen auf dem Gebiet der thematischen Computerkartographie waren jedoch weniger eindrucksvoll als in der automatisierten Kartenherstellung. Der Artikel behandelt ein erprobtes System für thematische Computerkartographie – GIMMS, das an der Carleton Universität Ottawa in Betrieb ist. Der Verfasser argumentiert, dass die Verfügbarkeit von Systemen solcher Art die Computerleistungsfähigkeit für thematische Kartographie voll ausnutzt.

RESUMEN La computadora tiene un papel más y más importante en la cartografía canadiense. Los adelantos de la computadora en el campo de la cartografía temática han sido menos espectaculares que aquellos en la cartografía automatizada. Este trabajo describe un sistema operacional para la cartografía temática con computadora, GIMMS, actualmente instalada en la Universidad de Carleton. Se argumenta que la disponibilidad de sistemas de este tipo contribuirá al reconocimiento del potencial de la computadora en la cartografía temática.