SMALL AUTOMATED CARTOGRAPHIC SYSTEMS

A. R. Boyle
University of Saskatchewan

Small automated cartographic systems have wide applicability for provincial, State, municipal and similar authorities, in application areas such as geology, soil science and forestry and also in individual departments of large mapping agencies. In fact they can be used where there is a need for a medium output of maps which need compilation by experts in a particular area of work. Many such groups have found that they cannot provide the necessary speed of response to demand by purely manual methods, and realize that it is now necessary to enter the digital age of mapping. It is only in this way that variations of map content and modifications can be made, without excessive individual effort each time. Special applications such as land use planning have also created an atmosphere of change.

The preliminary commitment is a serious one requiring a minimum financial outlay of at least $100,000. More importantly the commitment requires an acceptance of new ideas and methods by the present manual cartographers. However, it appears that the time is now ripe for change and manual cartographers realize that their skills are still essential, even if used in a rather different way.

The entities of a cartographic system are made up of digitization, storage, interactive display and edit, and drafting. All these entities require separate data control and are then bound together to form a compatible system. The initial financial commitment may be relieved by using contracted facilities for some of the entities. It is not possible to do this for interactive display and edit as that is the main interface between a digital system and the manual cartographic compiler; it must be in-house. Moreover, it must be one which can operate on data at very high speed, be very flexible and very easy for the cartographer to use. Without this facility the human control of the mapping is absent, or at the very best causes uneconomic production of overlay sheets, which have to be scrapped or manually corrected by pen and ink.

On the other hand, the digitization of maps and aerial photographs can often be subcontracted, and this will be advisable for many small users. It may also be possible to obtain data already digitized from other establishments. The subcontracting facilities are only recently emerging from the development stage, but can be reasonably applied to contouring and culture in photogrammetry and to pure irregular line data, such as for contours and hydrology, on existing map overlays.

The annotation of the lines digitized remains as a major amount of work for the user, but it can generally be most efficiently done in-house on an interactive display and edit facility.

Subcontracted work has until now generally been carried out by manual digitization methods, but the output is then not only expensive but may be unreliable. However, manual digitization will always be very important for point location data, and for updates and corrections too detailed to be done interactively on the display. It is thus recommended that a manual digitizing table should form a part of the interactive display and edit facility. Although the table need not have a very large work area; the integration of digitized data from part maps into a whole, is now a simple software procedure.

Although drafting is the entity in the system with the longest history, nevertheless serious organizational problems arise. Most users converting to digital methods have created a reputation for high quality mapping, and they are not prepared to allow this to suffer because of any advantages of automation. There is no need for quality to suffer, but, while adequate precision drafting systems are certainly available, they are expensive and require special facilities, as they draft with light-heads moving over photographic film. The cost of such a unit may well be two to three times that of the display system mainly because of the precision mechanisms involved.

It should be possible to use contract facilities for drafting, but these do not appear to exist as yet. There is definitely a need for centralization of this type of work as only a large user, or small users working in a group, could warrant the funding and upkeep.

At one time digitizing and drafting tables used specially constructed electronic directors. These have now generally been replaced by simple minicomputers which give greater reliability and flexibility; they are still treated by users as 'black boxes.'

An interactive display and edit facility needs a control very similar to that for a drafting table, but with very much higher operational speed. An operation that may take an hour in digitization or drafting must be completed within seconds, otherwise the cartographer will become irritated and prefer to return to his pen and paper methods. Such a high speed of control with the large amounts of data in cartography requires the employment of software in assembler language. It cannot be obtained by the use of a display terminal on line to a remote computer or by operating a minicomputer system in FORTRAN. Many developers have used FORTRAN because it was easy to write. It produced results adequate for research use, but much too slow for production. Bit-manipulation assembler routines take longer to write, but then control the data with an acceptable speed, so that a complete map may be drawn on the CRT screen, or modified, in seconds. Such systems are now available and can be treated as control 'black boxes' in the same manner as those for the digitizers and drafting tables.

The storage of cartographic data in small establishments is not really a problem and a magnetic tape library is usually adequate. Individual tapes are selected as required for a specific area, and these fitted to the appropriate controllers.

A proper cartographic system design must take care of the interconnection of the separate entities. This not only involves hardware but also software. Generally such software is of a computational character but may also involve programmed manipulation of the data (e.g. sorts and selections). These interconnecting programs may be run on any external computer or, if within the capability, on one of the control minicomputers. It is in such processes that the user may become involved in special program modification or additions to meet his particular needs. In general he will not be concerned with modifying the control programs except for such aspects as the possible addition of specific symbols.

The costs of the minicomputer controllers are so low compared with the peripheral devices and software that it is normal to apply individual controllers to each device and not attempt time-sharing with its attendant software overheads. The separate controllers are usually connected by interprocessor buffers or, if over a longer distance, by magnetic tape transfer. Telephone lines are usually too slow to handle the very large amount of data involved in topographic mapping. The system designer must check that data compatibility is maintained. He may decide to group a number of peripherals onto one controller, or it may be necessary to duplicate or triplicate some entities once the work load has been analyzed. It is not essential that all controllers be of the same type or make. However, if they are, then there are advantages relative to maintenance and to continued operation in the case of the failure of one unit.

It should be stressed that the use of the term 'small' does not in anyway infer a reduction in quality or flexibility of product; those may well be enhanced. It is merely related to a user with relatively small volume of work.

To this stage, only pure cartography, generally of a topographic nature, has been considered. However, there are now many groups involved in thematic mapping. In some of these the precision and detailed mapping requirements may be reduced, but there is often a greater degree of computation required; in some case, in fact, only the largest computers will suffice. In such cases the small cartographic system described here, becomes a highly intelligent terminal making repeated references to the larger computer. In other cases, much of the computation work can be carried out on one or other of the minicomputer controllers as these devices are now becoming powerful in computation and work well in high level languages.

As much work as possible should be carried out in-house. Experience has shown that a program working slowly on an in-house machine is normally cheaper and often preferable from a turn round time to a similar program used on a central computer facility. There are of course limits to these possibilities, but few appear in the cartographic processes.

The Graphic Systems Design and Application Group at the University of Saskatchewan and the writer, have been involved in developments as described here since 1960. The first system, in the United Kingdom, involved specially designed electronic directors for drafting and digitization, as minicomputers were not then available.1/ The second, for the Canadian Hydrographic Services, proceeded on the same lines, but with the much more reliable minicomputers as controllers, other computational programs being run on IBM or CDC machines.2/ Since that time the Group concentrated some three years of effort on interactive display manipulation of cartographic data 3/, and interactive manual digitization.4/ The last two years have been concerned with aspects of control manipulation of attributes of points, routes and areas and this work is still progressing.5/ 6/ An overall review of the present state-of-the-art is given in footnote 7.

Software development before 1970 did not require great speed of operation; reliability was the most important criterion. The work on interactive display and edit of cartographic data, however, soon showed that ease and flexibility of handling cartographic compilation was not enough, but that speed was essential for true interaction. There is a very big difference between an 'interactive' and a 'query and answer' system. Very few new manipulative facilities were actually created after the first year of work; all the subsequent work was concerned with ease of use and speed of operation. This involved the design and often redesign of the data format (it is in fact a multiple format system), the directory system, and the recording of cartographic changes made so that the user had complete control to remake changes, and then even change those again, as often as he needed. A speed of response of two seconds was always the aim and in most cases this was attained, even though such computations as changing projection from longitude-latitude to Mercator might be involved. Some programs were first written in FORTRAN to check out the operation usefulness and then converted to assembler to obtain speed. It was easy to change line descriptors, point labels, positions and shapes, and complex routines were written to give greater and greater simplicity of use in polygon manipulation and line-to-line end and T junctions, for example. For later processes lines might have to be reversed in direction or groups of data selected for particular uses. Some changes were to be relative to the databank, and some to special output for a specific map. It is a fast and powerful control and can operate as a self-standing system connected to any user's own system. The internal control formats are only matters of interest to a specialist in such control programs; the user normally only sees the data in an IBM-or industry-compatible I/O format.

Some of the programs developed by the Graphic Systems Design and Application Group are treated by others as purely computational, e.g. 'scale and rotate' and projection changing. The computational approach on an external computer was used for some years, but it was expensive to run and often created appreciable errors and, moreover, errors which increased as scale increased--a most unfortunate happening. After some time of irritation at these processes, these programs were rewritten to become ones which were called 'incremental mosaicing,' a process very similar to the cartographic manual methods but of much higher resolution. It was found that these programs would run easily in a minicomputer and as a result were low cost. The accuracy stayed constant at all scales without round-off or other errors.

Concepts similar to those used in cartography were then applied to the manipulation of attribute data relative to locations, routes and areas. The display thus became an emryonic Geographic Information System terminal; only those aspects which could be regarded as 'control' have so far been developed by the Group. The aim is to fill a need for the supply of information in a presentation which can easily be assimilated by the planner, who would then use his own mental modelling processes. There has so far been a complete avoidance of any aspects of computer modelling and true, complex, computation. Processes such as statistical manipulation of data and overlaying of polygons are on the dividing line, and can be treated in either way depending on circumstances. In all the control aspects developed, speed of response, flexibility and ease of use have been paramount guidelines. In many cases the system can be self-standing for a normal planner, but whenever referral to a larger computer is required the system can then act as a very intelligent terminal. In all its analyses of attributes, the basic background cartographic display manipulations play a most important part, and full use is made of those facilities.

The latest work of the Group is concerned with increasing the availability of low-cost and easily handled massive storage of data, so that this can become an integral part of the control system. This not only provides a capability for faster access but makes confidentiality control very much easier and more definite--this, of course, is now most important when socio-economic data is being examined.

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