A multi-level approach to the integration of traffic data within GIS

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1. Context and objectives

Recent changes in Information Technology have a major effect on the way in which systems are designed and used in many application fields. Geographical Information Systems (GIS) have now been adopted as a successful solution by a wide range of disciplines such as environmental planning, business demographics, property management and urban studies. Currently one of the most important challenges for GIS is to generate a corporate resource whose full potential will be achieved by making it accessible to a large set of end-users and providing successful solutions for decision makers. The potential of GIS includes the enhancement of local administration, more efficient management of scarce resources and new business opportunities for the nascent geographic information industry. One of the most promising challenging issues is the modelling of a cooperative traffic GIS that manages both static urban data and dynamic traffic flows information [Bargiela at al. 1999, Pursula 1998]. Such a system may provide an integrated geographical reference to the management of a traffic system leading to the improvement of the quality of transport systems [Claramunt at al. 2000].

However, current GIS software and interfaces do not provide the set of functions to make this technology compatible with simulation models used for traffic monitoring and management. The integration of GIS and traffic systems is likely to be a challenging and worthwhile objective for both user communities whose needs are not satisfied by loosely connected set of existing systems, and current static display and analysis functions of GIS. In particular, current forms of integration of GIS and traffic systems still use loose coupling methods such as passive file transfers and separate user interfaces [Laurini 1999]. This poor level of integration is often a result of the different model paradigms used within GIS and modelling systems [Egenhofer *et al.* 1999], and the fact that any integration solution often implies a re-design and re-implementation of existing software. Typically, the access to traffic data is restricted to engineers in traffic control centres. Recent advances include the development of graphic interfaces for traffic systems [Barcelo 1999, Dailey 1999] or traffic applications in the Internet that display traffic conditions on regular temporal basis [Feng 1999, Dailey 1999]. However the full potential and benefit of historical traffic databases still needs a closer integration of traffic system data in order to facilitate the integration of traffic data within urban management and planning studies, and the modelling of efficient route simulations required by the industry [Thériault *et al*. 1998].

This research proposes the design and development of temporal GIS (TGIS) that supports the real-time collaboration with a traffic system. Our objective is to investigate and to identify a reference database model that will favour an active collaboration, in terms of data exchange and task complementarities, between a Traffic System and a GIS.

Our research objectives include both the identification of relevant Traffic GIS functions and their implementation within a GIS computing environment. The traffic data component of our application is based on temporal traffic maps that provide successive snapshots of an urban traffic network at different levels of abstraction. Our implementation is based on the GRASS (Geographic Resources Analysis Support System) GIS software that gives a flexible software platform for the development of a operational prototype [Neteler 1998]. GRASS offers a large number of functions for the pre-processing, generation, and real-time visualisation and animation of traffic maps.

2. Multi-level Traffic GIS

The prototype implemented so far is applied on a traffic system in the city of Mansfield. The traffic component of our prototype is based on the SCOOT (Split Cycle Offset Optimisation Technique) commercial software designed to monitor traffic flows and automatically adjust traffic signals timing on a second by second basis [SCOOT 2000]. The distribution of traffic data towards our GIS environment is based on the DIME (Distributed Memory Environment) that receives incoming real-time traffic data, and provides an interface between software modules that execute on distributed computing nodes [Peytchev 1999]. This software has been designed to support client applications, it also provides a flexible interface to applications programmer. Real time traffic data received from SCOOT is pre-processed and then integrated into the GRASS environment.

We have identified a traffic data model that supports complementary levels of abstraction (i.e., level of cartographical detail and temporal granularity). It contains three levels of resolution with different levels of detail. The initial traffic data model contains the following levels, from the higher to the lower level of abstraction (Figure 1):

- The first level gives an overview of the main roads (linear representation of roads).
- The second level gives additional details on secondary roads (linear representation of roads).
- The third level provides an exhaustive two-dimensional view of the road network (surface representation of roads).

The third level of abstraction is reflects the monitoring level operated by SCOOT. The third level acts as the traffic data integrator. We plan to propagate traffic data towards higher level of abstraction using some aggregation mechanisms as proposed in [Valsecchi et al. 1999]. These aggregation operations are applied to both the temporal and spatial dimensions. Appropriate visualisations will be then generated and derived at each level of resolution.

This multi-level Traffic GIS is illustrated in Figure 1. Traffic data are presented using three scales, and at different levels of detail. The prototype supports the real-time update of these traffic maps. For example, the lanes of the crossroad presented at the first level of the Figure 1 are visualised using a lookup table that replicate the traffic conditions in function of time (e.g., degree of congestion, length of queue).

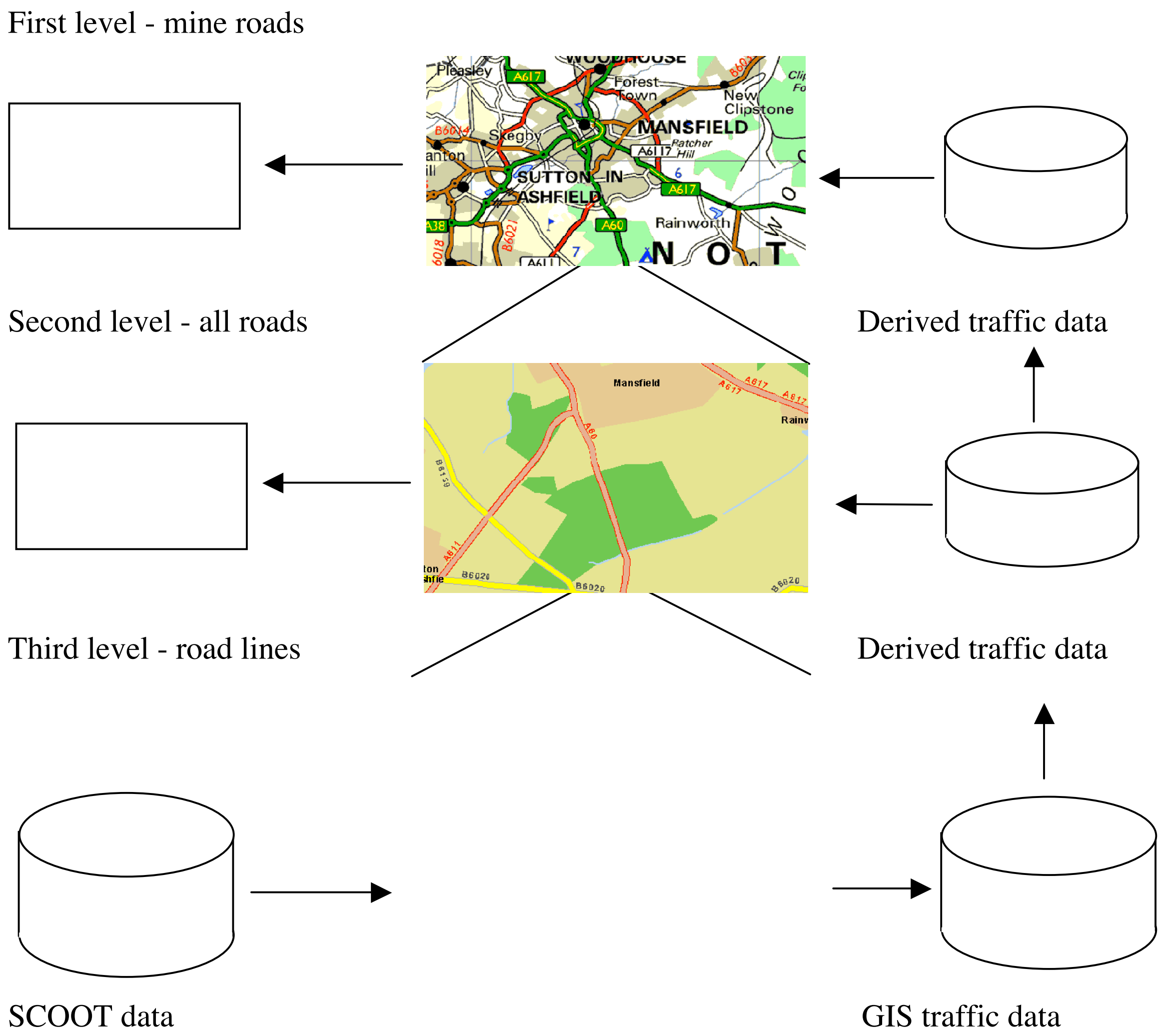

Fig. 1.: Traffic GIS database

This Traffic GIS covers a wide area of interest for the transportation community. The first level - the main roads - is relevant for an analysis of regional traffic patterns. The second level - all roads - provides a view on local traffic conditions. Finally, the third level gives a precise representation of traffic conditions at the crossroad and lane levels. These traffic maps can be also stored for further analysis, analysed with additional environmental data, and also connected to tier applications such as shortest path applications.

3. Conclusion

This prototype develops a multi-level traffic GIS that supports the processing and visualisation of traffic conditions at different levels of abstraction. It is based on a computing environment that facilitates the real-time acquisition and distribution of traffic data. The GIS-based prototype offers a flexible support for the visualisation of traffic conditions with their geographical context. Its potential needs further research in order to take advantage of the multi-level approach, and to identify spatial and temporal operations that support the propagation of traffic data towards the different levels of abstraction. Further research will also investigate real time visualisation techniques, analysis of traffic patterns, and the distribution of traffic data towards the Internet.

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