THE EUROPEAN DIGITAL ROAD MAP MultiMap AND ITS APPLICATIONS

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ABSTRACT

This paper describes the European digital road map MultiMap, produced by the Tele Atlas group. First a concise introduction to the historical development of the product MultiMap, the corporation itself and the current status of MultiMap is given. The product MultiMap is then explained in details, including its data model, data content, data quality, data capture and updating concept. The integration of Photogrammetry into data capture is illustrated by the projects Switzerland and Austria, where orthoimages were used. On the basis of this open-structured high quality database MultiMap, various value-added GIS products can be developed for different applications like intelligent traffic management systems, Telecommunication planning and geo-marketing. A typical example is the production of navigable CD-ROM's for the in-vehicle navigation systems like Blaupunkt TravelPilot, Mercedes-Benz Autopilot and Audi navigation system. Other examples are the in-vehicle navigation system Blaupunkt TravelPilot, Multimedia travel guides, StreetNet, StreetMap and StreetPilot. Finally the future work is summarized with emphasis on the rapid completion of the digital road map for the whole Western Europe.

1. Introduction

The need for electronic mapping of European territory went back to the common pan-European R & D projects in the field Advanced Road Transport Telematics (ATT) like DRIVE I, DRIVE II (Commission of the European Communities) and PROMETHEUS (EUREKA), beginning from the middle of 1980's, in which Robert Bosch GmbH essentially participated. However, comprehensive large scale digital road maps were not available until May 1989, when Bosch launched its first in-car navigation system Blaupunkt TravelPilot IDS (Lippert, 1995). Since then this database, called MultiMap, standing for multi-purpose, multi-faceted, multi-information and multi-functionality, has being continuously improved and extended by Bosch.

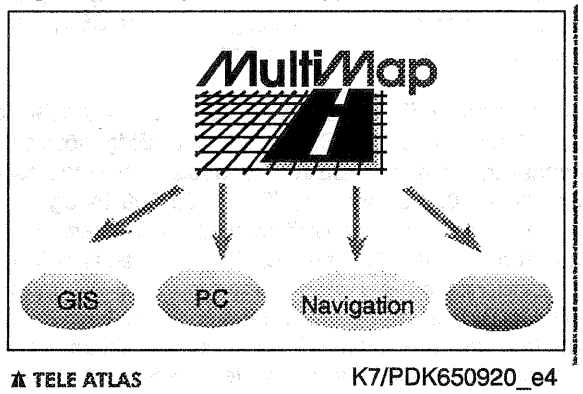
Recently with the rapid development of fleet and traffic management systems, emergency/accident warning and alarming systems, travelling planning systems (route, time, means), in-vehicle turn-by-turn navigation systems, GIS-application for environment evaluation and utility management, telecommunication, as well as geo-marketing, the demand on digital road data is increased greatly. In July 1995 a joint venture Tele Atlas Group was founded by Robert Bosch GmbH and the Dutch company Janivo BV, in order to speed up the collection of uniform digital road maps for Western Europe, develop value-added GIS products and finally market them successfully. In addition to three offices in Belgium, Germany, and the Netherlands, Tele Atlas has currently national offices in Austria, Switzerland, Italy, France, Denmark and Sweden.

MultiMap is an europe-wide uniform large-scale digital road map, produced by Tele Atlas. It contains extremely accurate up-to-date geometry and distance information, enhanced with a wide range of administrative, geographical and traffic information. MultiMap has an accuracy of better than 5 meters within metropolitan areas and cities/towns with more than 50 000 inhabitants and 25 meters outside these areas.

Up to now in Germany the interconnecting road network (ICNW) has been completely digitized. In addition the street network (STNW) in 13 metropolitan areas all towns with more than 50 000 inhabitants have also been collected. This covers altogether about 50% of the total population. In Austria and Switzerland, the ICNW and STNW in all metropolitan areas (7 areas for Austria and 10 ones for Switzerland) have been completely digitized. Digital road data for Belgium, Luxembourg, the Netherlands, Northern Italy and the most important municipal areas of France and the United Kingdom are also available. At the same time activities for collection of digital road data have already started for selected cities in Spain, Portugal, Denmark and Sweden.

On the basis of this open-structured high quality database MultiMap, a special environment is established, so that we are able to create or develop numerous value-added GIS products for different applications in private and public sectors, with the possibility to integrate external data from other sources such as tourism information into these products (Fig. 1.1). At present, one of most important applications is the so-called „turn by turn" autonomous in-vehicle navigation. For this purpose a series of CD's, which have different data content and are appropriate for different customers circles, is designed and produced with selected information from MultiMap. Besides, our data have been used in the projects for traffic planning, management and information service. We are providing mobile telephone companies with basic data for their telephone network planning. Other applications such as fleet management, geo-marketing, electronic traveller guiding, desktop mapping, yellow pages, Internet on-line service and personal digital assistants (PDA) are conceivable.

Digital Road Map: Different Applications Fig. 1.1



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In section 2 the European digital road map MultiMap is explained in details, including its data model, data content (collected objects and their attributes), data quality, data collection and updating concept. The integration of Photogrammetry and Remote Sensing into GIS plays more and more important role in our discipline, which is also adopted in the production of MultiMap. The data capture by digitization of digital orthoimages is depicted and discussed, taking Austria and Switzerland projects as examples. In Section 3 several applications based on MultiMap are presented, which concern the production of navigable CD-ROM's for the in-vehicle navigation systems like Blaupunkt TravelPilot, Mercedes-Benz Autopilot and Audi navigation system, navigation system Blaupunkt TravelPilot, Multimedia travel guides, StreetNet, StreetMap and StreetPilot. Finally the future work is summarized with emphasis on the rapid completion of the digital road map for the whole Western Europe.

2. MultiMap - European Digital Road Map

2.1 Data Model, Data content and quality

In MultiMap the world is modelled with complex features, simple features and geometric primitives, which are topologically structured in 2-dimensional vector form, described by their attributes and, depending on concrete situations, connected by well defined relations. Geometric primitives are nodes, edges and faces which refer to the coordinate level and are basic components of topology. The simple features are on the next level and represent the semantical objects, which are either points, lines or areas. Finally complex features are aggregated from one or more simple and/or complex ones.

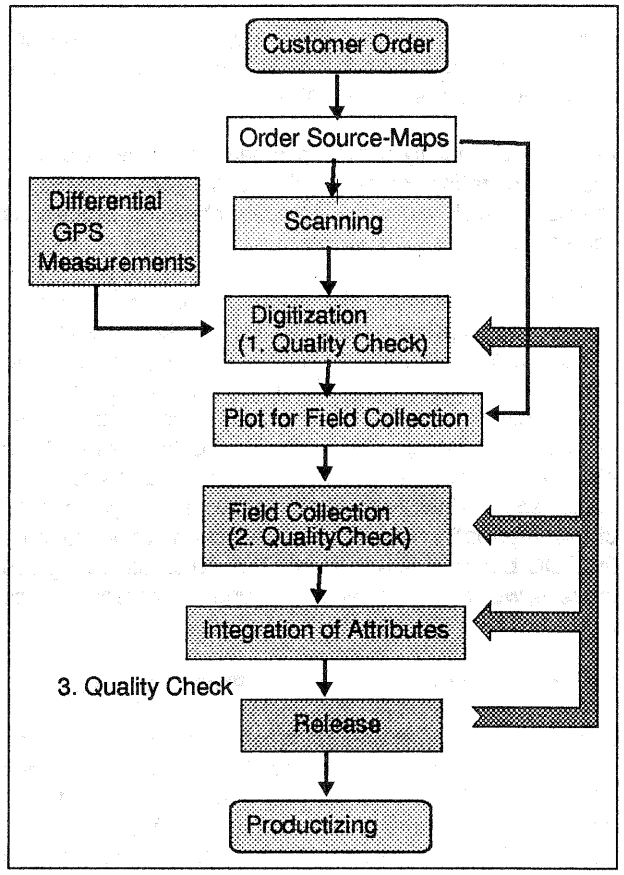
All traffic-related information such as roads, railways, political boundaries, waters, town centers, train stations and airports, together with their attributes and relations, is captured. Roads are classified and attributes like one way, banned turns, access roads, barriers, bridges, tunnels, over- and underpasses are collected additionally for them.

For data exchange (exporting and importing) the internationally accepted standard GDF (Geographic Data File) is utilized, which is an ASCII file containing geographical data structured in a standardized way (Claussen, 1995b).

The quality of the digital maps is the most important factor for all kinds of application and judged by the geometrical accuracy, topological consistency, correctness (of attribute values, object classification and object relations), completeness and up-to-datenese (Claussen, 1995a). Among all these parameters, the geometrical accuracy is most clearly defined, depending on scales, accuracies of source materials and on the production process, while the definition of the other parameters are more or less connected with uncertainty. The quality is determined by the statistical sampling approach.

2.2 Data capture and updating concept

Process Flow: Digital Map Production Fig. 2.1



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In co-operation with surveying and mapping authorities, official digital and analog maps as well as orthoimages in scales 1: 2 500 or 1: 5 000 (for STNW - street networks) and 1: 25 000 (for ICNW - interconnecting networks) are made available for data capture. Negotiation over buying source map materials for data acquisition is very complex as to the aspects of copyrights and specifications. In order to keep the number of negotiation partners as few as possible and start our projects without unnecessary delay, we looked first for organizations which have homogeneous map works covering large areas with the same scales and object sets etc. and fulfilling the quality requirements of

MultiMap. This means that the geometrical accuracy should lie in 25 - 30 meters in ICNW and 5 -10 meters in metropolitan areas.

The data capture is carried out manually (Fig. 2.1). Analog maps or orthoimages are scanned first. These digital raster data should be transformed in the MultiMap reference system and converted into the specified digitization image format, before they can be displayed on computer screens and then digitized. Available vector data can also be integrated into the digitization process, so that data capture can be speeded up.

On the basis of these data plots are generated for field data collection (FDC). Taking these plots with them, the field surveyors make site-the-spot investigations to collect necessary traffic-relevant attributes and to mark possible errors.The collected data are then put into the data base manually.

Differential GPS is used as a supplement measure for areas where available source materials are out of date or no up-to-date ones are available.

An individual quality checking is catered for every step in this vectorization process. For data base release, a specially developed strict complex checking process is carried out.

In order to ensure the high quality of MultiMap permanently, updating with high quality data should take place fast enough, before changes in reality occur again. Instead of collecting every piece of information ourself in a long costly process, relevant publishing houses, civil engineering offices, driving schools and taxi associations etc. are incorporated in order to obtain up-to-date high quality source data. Naturally it goes without saying that all of this information is verified, if necessary, on location by the FDC before it is added into the database. Using this process, we are able to release an updated database twice a year.

2.3 Data capture through digital Photogrammetry

In many cases digital orthoimages will be the best solution in terms of up-to-dateness, reality, accuracy and rich information, which are essentially vital for the MultiMap. A disadvantage compared to maps is that they don't carry notations like street names. Another shortcoming is that at the moment the costs of using Photogrammetry are relatively high.

Digital and analog orthophotos have been successfully used in our projects Austria and Switzerland respectively.

In Austria the department Land Topography of the Bundesamt für Eich- und Vermessungswesen (BEV) possesses different map works, which were suitable as source materials. For the street network outside cities the digital data from a BEV-database were used. This database is built with photogrammetric stereo-restitution method and currently further densified by the BEV. At that time only an ICNW was available in addition to objects like administrative boundaries, waters etc., so that further source materials were needed for data densification in metropolitan areas. For this purpose orthoimages (scale 1:10.000) in analog form were bought from the BEV, which were then scanned in our production.

It was more difficult to obtain source materials for Switzerland, since the Schweizerische Eidgenössische Vermessungsdirektion (SEVD) conducts only small scale maps (1: 25 000 or smaller). The 1: 25 000 topographic maps were applied for acquisition of ICNW. The large scale maps (up to 1:10 000), needed for data densification in metropolitan areas, are conducted respectively by the individual federal states (Kantone). In order to keep source materials for the planned metropolitan areas to be homogeneous, digital black & white orthoimages (1 meter ground resolution) were ordered with the company Swissair, which were rectified from latest photogrammetric flights.

These digital orthoimages were then transformed from the respective national coordinate systems into the MultiMap-conform reference system and converted into the special image format suitable for the on-screen digitization, before they can be loaded into our digitization stations for the vectorization process in our production.

The accuracy of orthoimages is usually strongly influenced by the used basic data like the quality of DEM. During the digitization cases were observed where the images didn't fulfil our accuracy requirements, so that additional sources (DGPS measurements, other map materials) were necessary. This problem was put down to the errors coming from the rectification processes.

In the Austria project, the digitization was made difficult because of bad quality of several images. These images can be divided into 2 groups: the one with bad photographic quality (contrast, disruptive pixels) and the other negatively influenced by unfavorable flight time (dense leaves, unfavorable sun position). This problem was not encountered in the Switzerland project.

With one meter resolution images, it was often very difficult to recognize some small details such as road markings and small streets. In future work resolutions of less than 0.5 meter should be applied.

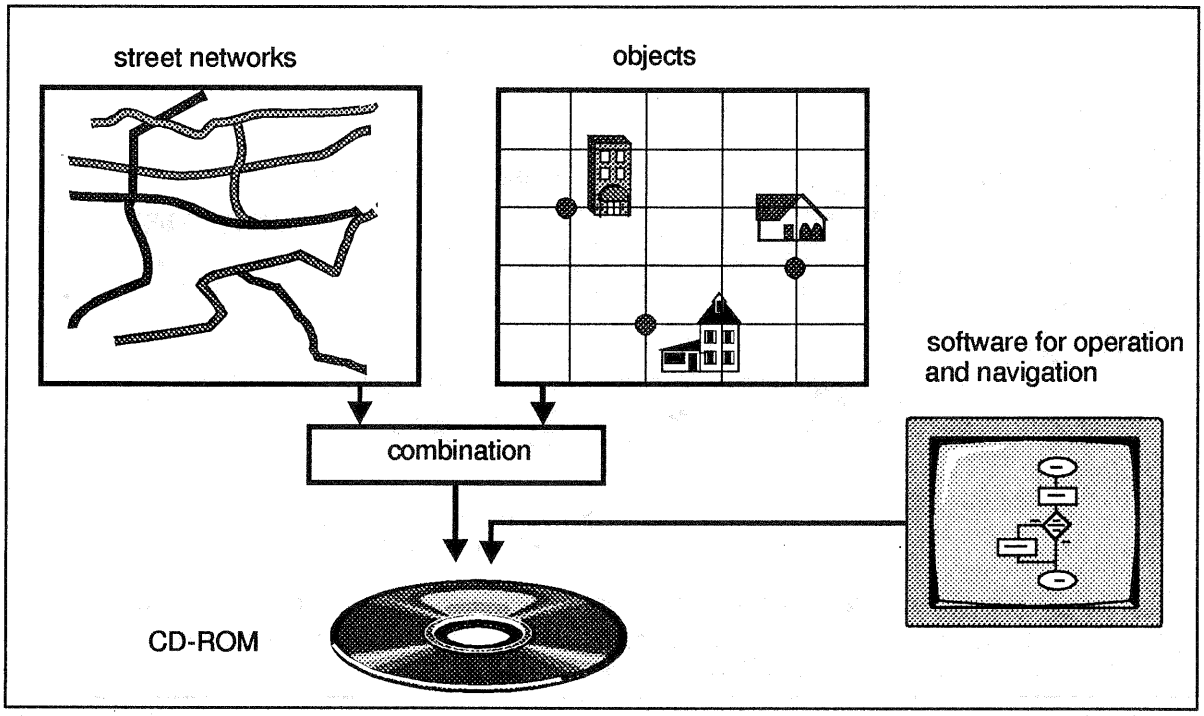
Photogrammetric materials are currently solely applicable large scale sources in Austria and Switzerland, owing to the up-to-dateness and lack of other economical alternatives. The same situation occurs partly also with the acquisition of digital road data in the Scandinavian regions.

In general, the orthoimages proved to be effective in both projects. In order to improve our future working process, following points should be investigated:

- improve data exchange in digital form to avoid using analog source materials.
- install an improved method to increase photographic quality.
- use color orthoimages for the digitization process.

Navigations-CD: Principle Production Process

Fig. 3.1



- make full use of other information appearing in images for data collection (e.g. one way etc.) in order to reduce FDC work.
- alternatives to on-screen digitization (e.g. photogrammetric stereo-restitution, automatic or semi-automatic approaches).

3. Applications based on MultiMap

3.1 CD-ROM's for vehicle navigation systems

For the production of navigation CD-ROM's, the high quality data from MultiMap, together with the navigation software, are restructured and prepared through complex processes (Fig. 3.1). Additionally other information like data about tourism and entertainment facilities can also be integrated, as is done with the CD-ROM MERIAN *scout* from the tourist guides publisher Gräfe und Unzer. From these pre-prepared data a CD-image is generated and then burned on a CD. Such kinds of CD-ROM's are used in the autonomous navigation systems of Blaupunkt TravelPilot, Mercedes-Benz Autopilot and Audi navigation system.

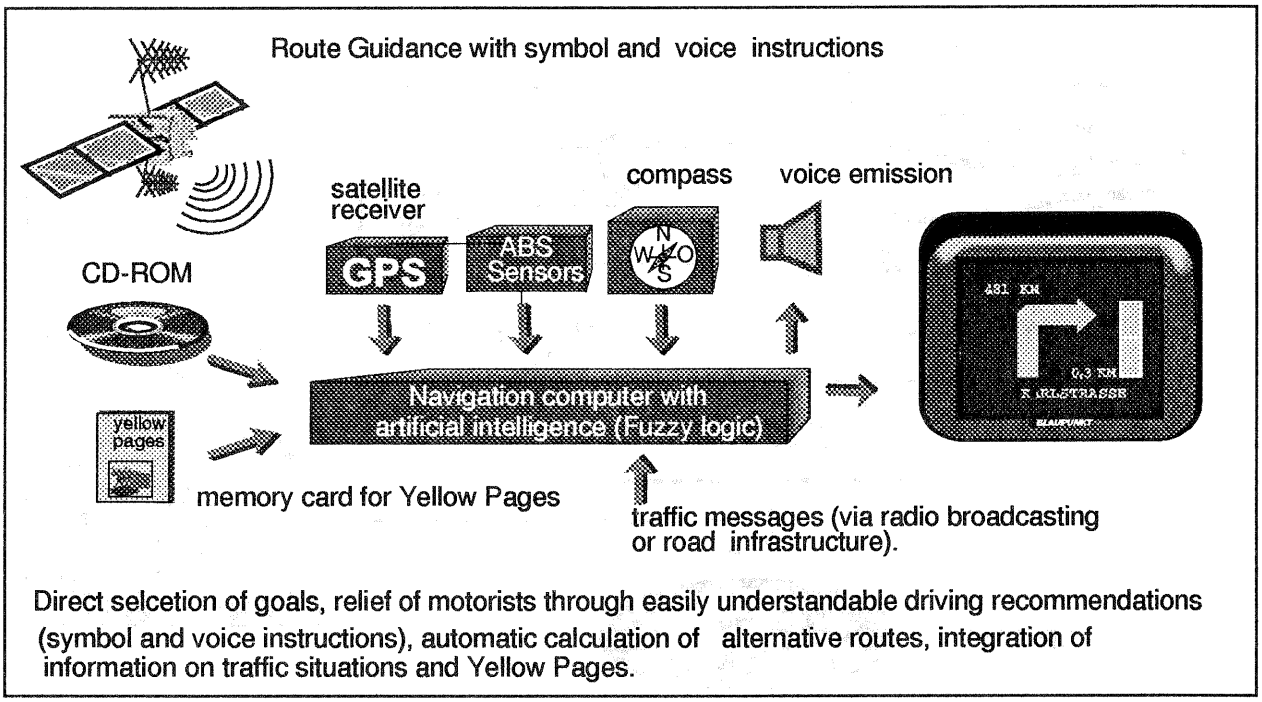
Currently CD-ROM's for Germany are available. On the basis of available data, the production of navigation CD-ROM's for Belgium, the Netherlands, Luxembourg, Great Britain, Italy and France or some of big cities in these regions such as London, Paris etc. are scheduled to be completed this year. From the middle of 1996 we will be able to supply complete CD-ROM's for Switzerland and CD-ROM's for 4 cities (Vienna, Linz, Salzburg and Graz) and motorways in Austria. By the end of this year complete CD-ROM's for Austria will be available. Under co-operation with data suppliers in USA, navigation CD-ROM's for several regions in North America are also in preparation. Test-CD's will be available in the 1st half year of 1996 for Atlanta and Detroit.

3.2 Navigation system TravelPilot

The Blaupunkt TravelPilot is an autonomous in-vehicle navigation system, which works completely independent of any infrastructure such as induction loops, electronic beacons or cellular mobile phones (GSM), because all data and sensors necessary for positioning and navigation are installed in the vehicle. The important components of such a system are: a navigation computer, a GPS-receiver, a CD-ROM with data and software, ABS-sensors, an electronic compass, a loudspeaker for acoustic output of „turn-by-turn" driving instructions, and a LC color screen for visual display of maps, street name, driving instructions, distance to destination, route-list, GPS-status and other additional information (Fig. 3.2). The vehicle's motions are registered by wheel sensors and an electronic compass. The current position of the vehicle is determined from incremental changes of distance and direction by means of dead reckoning method. Position deviations accumulates depending on the distance travelled, because the accuracy of the sensors and applied method is limited. Hence positioning has to be improved. This is done through a process of map-matching, which means that dead reckoned position is compared to a digital vector map stored on a CD-ROM in the disk drive of the on-board navigation computer. GPS-signals are used for the calibration and stabilization of this positioning and matching process or positioning in areas where no digital maps are

TravelPilot
Vehicle Information System with Route Guidance

Fig. 3.2



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available. In this way locations can be improved continuously. The resulting position is shown to the driver as a symbol, together with a map representation in the background on a vector display.

The route finding function calculates the optimal route from the current position to a desired destination. For this purpose a weighted graph is built from the road network, where edges are road segments which are often called links. These links are ranked according to different criteria. The most important criterion is the travel time per link, derived from its length and road class. Travelling durations are further influenced by the traffic regulations (e.g. speed limits etc.), and number of turns, traffic lights and complex intersections. The „turn-by-turn" driving instructions are derived on the basis of the determined optimal route. If the driver doesn't follow the recommended driving instruction at some location, the system calculates at once a new optimal route from this location to the desired destination. range / medium-range two-way communication between the infrastructure and drivers). In regions, where no infrastructure is available, autonomous vehicle navigation systems are put into use.

The further development is to integrate the information from telephone directories such as yellow pages and messages about the actual traffic situations into the route finding and guidance process.

3.3 Multimedia travel guides

When combined with information about catering, tourist attractions, cultural sites and events, MultiMap forms the open basis for extremely useful and attractive multimedia travel guides, with which one can plan his trips or cultural outings at home comfortably, before he really starts. He will be accompanied on his voyage through Europe by these guides, if they are installed on portable or hand-held PC's. One of this kind of products is MERIAN *screen* from the tourist guides publisher Gräfe und Unzer.

3.4 StreetNet, StreetMap and StreetPilot

StreetNet and StreetMap for Europe build different subsets of MultiMap. StreetNet is of high data quality with detailed information, 5 - 25 m geometric accuracy and finer road classification, therefore is suitable for GIS-application and fleet management. StreetMap is of standard data quality with less information, 25 - 100 m geometric accuracy and gross road classification and is thus conceived for desktop mapping and geo-marketing.

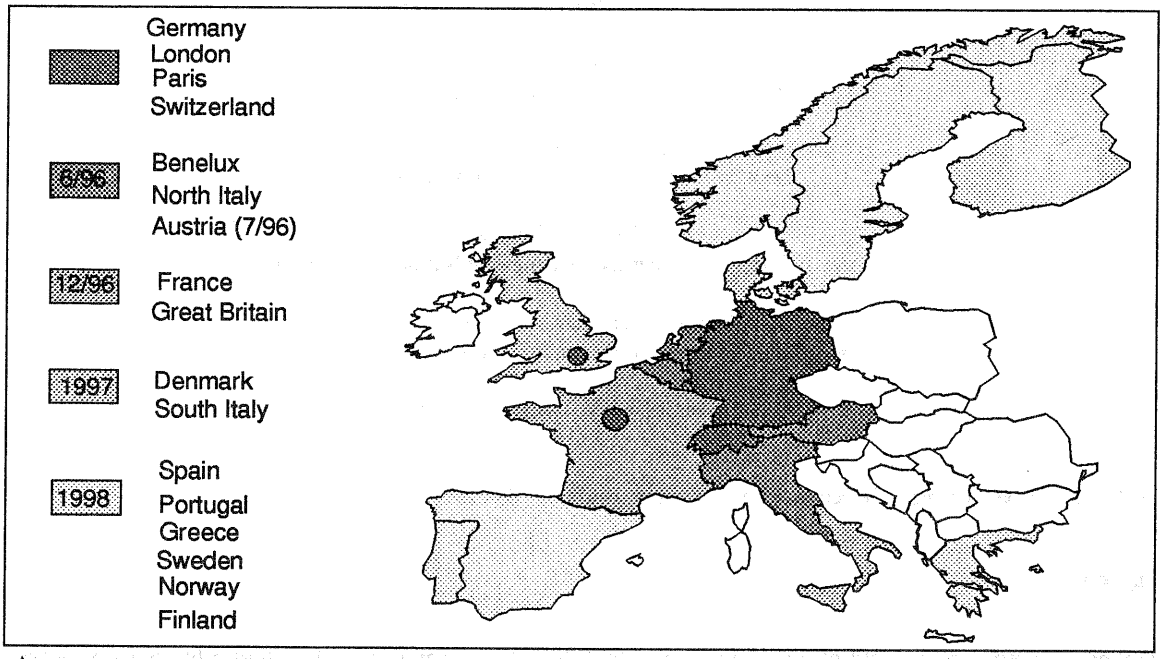
StreetPilot is a route planning program for DOS/windows, containing digital data from MultiMap. It can calculate routes from city to city and street to street with detailed path description and clear map display. It can be extended with following additional modules: GPS positioning, object management, geo-coding through a DDE interface, DAS hotel and restaurant guide, train time table of federal railways (Bundesbahn) and network version.

4. Conclusion

The future work is to complete digital road maps for the whole Western Europe by the end of 1998 (Fig. 4.1). We will market the existing products and develop new MultiMap products. Our effective approaches of quality controlling on

Digital Road Map: Completion of European Data Bases

Fig. 4.1



source data as well as intermediate and end products will be reviewed and extended from time to time.

Photogrammetry is an important approach for data acquisition, because of the previously stated advantages, which certainly need to be exploited fully in our future data acquisition process. Besides advanced data acquisition approaches should also be investigated. The suitability of space images (e.g. using MOMS data) for our purpose will be closely observed in terms of quality and costs, although at the moment it is not applicable as long as 1 meter resolution data are not available under operational circumstances.

Another task is to maintain, update the existing databases and fill them with further details, for instance collection of data for towns/cities with less population than 50 000, put more traffic relevant attributes like house numbers, different kinds of driving restrictions (especially time and vehicle-type related ones) and so on. Meanwhile the production of navigation CD-ROM's should be brought into line with this development of the MultiMap data base. Another development is the introduction of the digital traffic broadcasting RDS-TMC (radio data system - traffic message channel) in Germany and other European countries, with which both MultiMap and navigation systems must keep step.

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