Yerach Doytscher
Department of Civil Engineering (Geodesy)
Technion-Israel Institute, Haifa 32000

Spatial Information Infrastructures in Israel: Toward the 21st Century

Abstract

In Israel, as well as in most of the Western world, there is manifestly increased awareness of geospatial information and its importance in the modern high-tech society. Many GI projects were launched in Israel during the past decade and efforts were invested both in data gathering processes as well as in the development of effective spatial hardware/software projects in the private, public and government sectors. In the past year a very clear trend could be discerned, leading toward the next phase of utilizing GI data, in which efforts are shifted from initial data gathering to processes of updating and improving the quality and accuracy of the data, and moving from initial launching of GIS projects toward improving the efficiency of spatial applications and expanding the community of geospatial information users in Israel.

Introduction

As everywhere else, mapping in Israel has been undergoing in recent decades a gradual transition from the field of graphics to the digital field. Three stages of this transition can be observed:

- Conventional (graphical) mapping.
- Computerized mapping.
- Geospatial information.

In the distant past, conventional mapping was completely based on field measurements and analog photogrammetric systems, with the output being ordinary paper maps. The transition to what is today called computerized mapping (or computerized cartography) began in the 1960's and 1970's. As analytical photogrammetry was introduced in Israel, the maps were drawn from digital data using computers and their peripheral equipment (e.g. plotters, digitizers). However, the end products remained the drawn maps rather than the digital files used in the drawing process.

Since the late 1980's and early 1990's we have been moving to the third stage (or generation) of mapping - geospatial information. At this stage, the purpose of digital mapping in Israel as elsewhere, is to construct geographical databases rather than drawing paper maps. Since the products are in digital format, special attention is devoted to geometrical accuracy on the one hand, and gathering of topological relations and descriptive alphanumerical information, on the other hand, as an essential part of the mapping process.

In the last decade many geospatial-mapping projects were implemented in Israel and many GIS databases established for a very wide range of applications. These applications range from small projects initiated by private firms, through medium scale projects initiated by municipalities and infrastructure companies, and up to national large-scale projects initiated by government departments and ministries. Most of the national large-scale projects are initiated by the "Survey of Israel" (SOI), the governmental agency responsible for geodesy, topographic and cadastral mapping and the National Geographic Information System.

Whereas in the last decade the main efforts in Israel were invested in defining the geospatial projects, the initial implementation processes and in the data gathering, in the last year the main trend has shifted toward issues of improving the quality and accuracy of the data and on establishing proper updating processes.

In the following sections several geospatial mapping projects are described, with the aim of providing some insight into the current work, future trends and accomplishments in the geospatial field in Israel.

Mid-Scale Topographic Infrastructure

The mid-scale basic topographic mapping of Israel was composed (until the beginning of the 1990's) of topographic maps at a scale of 1:50,000 (about 90 map sheets) that had been completed during a period of 20 years (1960's and 1970's). These topographic maps were of a graphical nature only, with a limited horizontal accuracy of 20-40 meters and a limited vertical accuracy of 10-20 meters. Based on the obvious disadvantages of digitizing these topographic maps as a possible source for an accurate and updated topographic database, SOI (in its role as responsible for topographic mapping in Israel) decided in the late 1980's and early 1990's to establish a national topographic database by remapping the entire country.

The new topographic remapping was based on black and white aerial photographs at a scale of 1:40,000. The geodetic control was provided by aerial triangulation, based on GPS measurements only and connected to the high order national geodetic control network. Several photogrammetric blocks composed of about 1000 ÷ 1200 photogrammetric models cover Israel. The mapping was carried out in the New Israel Grid system (ITM - Israel Transverse Mercator). Data acquisition was executed using analytical and digital photogrammetric stereoplotters, by private firms acting as subcontractors for SOI. These firms were (and still are) required to work according to very strict specifications and use a special Digital Feature Coding method. The achieved accuracy of the topographic mapping is 2 meters in position and elevation. The planimetric and altimetric features are collected into 11 different basic thematic layers of the topographic GIS (including geodetic control, hypsography, hydrology, buildings and infrastructure). Data received from the sub-contractors was processed employing very rigorous quality control at SOI (and returned to the subcontractors for corrections and completion if needed). Only material that had successfully passed all stages of quality control was integrated into the database.

The first blocks of aerial photographs were photographed in 1991. Feasibility of the project in large dimensions was established by mapping the first block. The project has been running since 1993 and is currently in its final stages. The estimated cost of data acquisition (data collection by the private firms and the quality control process by SOI) is about US $9-10 million. Considering the approximately 30,000 square kilometers mapped area of Israel, the cost of the primary established topographic database is about US $300 per square kilometer.

The accuracy of the collected data within the topographic database is equivalent to a scale of 1:5,000 in traditional mapping. The mapped features according to the specifications meet the demands of the 1:10,000 traditional maps. Based on these figures, two cartographic products are being proposed by SOI:

(i) Upon request, by defining detailed look-up-tables, "work maps" at scales of 1:5000, 1:10000 and 1:25000.
(ii) A standard new basic national topographic map series at a scale of 1:25,000 has been in preparation during the last few years.

It is worth noting that in June 1998 the new "Israeli Regulations for Surveying and Mapping" were published. The Israeli surveying and mapping regulations that are published periodically (at a ten year cycle) are in fact a statute, and all surveying and mapping activities are to be performed accordingly. The regulations contain the principal standards for surveying and mapping methods, measurements and data processing. Based on the new regulations and their new standards (control network, topographic mapping, classification of DTMs according to quality and accuracy, classification of mapping products as to GI topological standards and so on) the technical specifications of data gathering processes within the topographic remapping project have been changed in several instances of the data gathering processes. Currently, the topographic database contents cover more than 50% of area of Israel, whereas the rest of the country is in the final stages of mapping – with the mapping process itself completed and the data undergoing quality control. It is estimated that the topographic database will be completed by the end of the year and cover the entire area of Israel.

Recently, following a very detailed study dealing with the appropriate process for an effective and continuous data updating of the topographic database, the SOI has announced its

solution for ongoing updating of the topographic database. The solution is based on the following principles:

- Updating the topographic data will be based on black and white aerial photographs at a scale of 1:30,000 up to 1:40,000.
- The geodetic control, as in the initial mapping process, will be provided by aerial triangulation, based on GPS measurements only and connected to the high order national geodetic control network.
- The updating photogrammetric process will be carried out only by using first order digital photogrammetric 3D workstations. The mapping process will utilize the superimposition abilities of the existing digital photogrammetric workstations for presenting the vector data of the (current) topographic database against the background of the (new) photogrammetric models in order to identify the changes manually.
- A special software package was developed by the SOI, aiming at defining the appropriate procedure for gathering the updated geographical features. As most of the photogrammetric software packages are oriented more toward mapping processes rather than toward updating processes (issues such as not being able to preserve the original ID of the spatial features through the updating process), the SOI opted for a solution consisting of the self development of a special software package able to address the specific problems and issues concerning SOI's topographic data. The software package is available as an updating tool for use by all SOI's subcontractors.

At the moment, the updating process is planned to operate on a four-year cycle in the populated zone of Israel (the northern part) and on a ten-year cycle in the less-populated zone of Israel (the southern part). Based on the detailed research, SOI estimates the costs of the updating process to be in the short term in the range of about 70% of the initial mapping cost. It is assumed that the updating cost will drop within one year of actual updating process to a range of about 30% of the initial mapping process.

Simultaneously with establishing the updating process, efforts are being invested in the development and establishment of a process for preparing 1:50,000 scale topographic maps.

Large Scale Urban Mapping Infrastructure

In a joint initiative by the telecommunication and electric companies ("Bezeq Israel Telecommunications Corporation" and "Israeli Electric Corporation") and local municipalities in Israel, a multi-informational detailed urban mapping project was launched in the early 1990's. Intended to cover most urban areas of Israel, the project is aimed at preparation of data for geographical information systems that were constructed at these two infrastructure companies and the local municipalities in Israel.

Very detailed specifications (the Urban Specifications) defining the contents of the map and the technical description of the mapping requirements were prepared. The accuracy of the data is equivalent to maps at a scale of 1:500, and is defined as 10-15 cm. in height and 25-30 cm. in position. About a hundred separate classes of features were defined for the basic mapping (planimetry and altimetry), a similar number for features defining the telecommunication elements and for features describing the electricity network elements.

The multi-sources for the mapping were defined as:

- New photogrammetric mapping;
- Full completion of the photogrammetric mapping by field surveying;
- Maps and plans of the Bezeq Israel Telecommunications Corporation and the Israel Electric Corporation;
- Verification and field survey of the telecommunication and electricity features; and,
- Full field survey for gathering the relevant alphanumeric data according to the Urban Specifications.

The Urban Specifications also defined precisely, in respect to each element (feature), the extent of mapping required as well as its sources:

(a) Photogrammetric mapping only (without any completion by field survey);

(b) Photogrammetric mapping followed by full completion by field survey;
(c) Existing maps.

The Urban Specifications also facilitates various combinations of the different sources for specific features.

The complete project covering the urban areas of Israel (roughly 3% of the country - about 1000 square kilometer) was divided between several private photogrammetric firms. The main characteristics of the project are:

- Structure and specification precisely defined;
- Separate accuracy requirements for the different mapping stages (photogrammetric measurement, conversion of "as-made" infrastructure maps, etc.);
- Highly detailed quality control processes;
- Combined mapping topics (planimetry and altimetry infrastructure, telecommunication, and electricity);
- Combined information from different sources (new photogrammetry, existing maps, and field survey); and
- Relatively large scales of execution (one of the largest mapping projects in Israel).

The project is based on black and white aerial photographs at a scale of 1:5,000 ÷ 1:7,000 while using first order analytical and digital photogrammetric stereoplotters. The geodetic control is provided by aerial triangulation, based on GPS measurements only and on a high order national geodetic control network. From practical aspects the project is based on the Cassini-Soldner projection – the Israel grid in use since the 1920's.

The project moved from the planning stage to execution within a very short period. Until now, mapping of more than 75% of the urban areas of Israel (about 750 square kilometers) has been completed, and mapping of the remaining urban areas is planned to be completed by the end of next year. The estimated cost of the data acquisition (not including hardware, software and developing applications) is about US $20-25 million.

Concurrently with the ongoing process of completing the mapping of unmapped urban areas, an updating process was recently launched with the aim of beginning the updating of the mapped urban areas. The updating procedure is aimed at remapping areas in which at least three to five years have passed since completion of the initial mapping. Within such areas is Jerusalem – one of the first municipalities to be mapped in the mid 1990's – where the updating process will be completed within a very short time (planned for the end of this year). The updating process is once again based on new black and white aerial photographs at a scale of 1:5,000 ÷ 1:7,000. By using first order analytical and digital photogrammetric stereoplotters and superimposing the features of the previous mapping process (all the planimetric information as vectors) onto the new photogrammetric models, it is easy to identify and measure the changes, and update the database. Based on economic and practical factors it has been decided that the updating process will be based only on photogrammetry without any completion by field surveying, thus concentrating only on updating the buildings and roads/streets layers. The current plans are to institute a three to five year updating cycle for all the urban areas in Israel.

Cadastral and Zoning Infrastructure

The Israeli cadastre is based on the Torrence method (Registration of Titles) where land parcels are measured and documented by means of field books and maps. Licensed surveyors carry out the measurements and the supervision and approval system is handled by SOI. Moreover the SOI, being the governmental agency responsible for cadastral mapping in Israel, is the keeper of the cadastral information archives and handles all relevant documentation (analogue maps, field books, and so on).

The existing cadastral maps have the following characteristics:

- The Israeli cadastral mapping system began in the 1920's during the British Mandate and is still in the process of settlement of land rights (currently cadastral settlement covers about 95% of the area of Israel).
- It is of a graphic nature, with about 14,000 cadastral blocks (maps) containing nearly 1,000,000 land parcels. The areas still lacking cadastral settlement will probably be subdivided into an additional 2,000 cadastral blocks.
- The cadastral blocks were and are still being prepared at different scales ranging from 1:625 to 1:10,000.
- The internal graphic accuracy of the cadastral map is assumed to be within a range of 0.5 ÷ 0.8 mm.
- The relative accuracy of adjacent cadastral blocks is much poorer, as a consequence of the measuring techniques employed during the last 70 years, and as a function of the low accuracy of the Israeli control network until 20 to 25 years ago.

At the beginning of the 1990's SOI decided to establish a national cadastral database. Neither the completion of a new cadastral mapping, nor the recalculation of the existing maps were feasible within a realistic time period and at an acceptable cost level. Consequently, the cadastral database is based on the existing cadastral maps by a process of scanning and semi-manual digitizing of the graphical information. Based on this process, the national cadastral database is digital in form but graphical in accuracy, and it is therefore used for general planning, land information or management, but not for renewal and reestablishment of the land parcel boundaries.

Since 1993, cadastral block maps have been digitized by private subcontractors. The process is subdivided into two steps. The first deals with separate cadastral blocks. These blocks are prepared for digitizing by the SOI - including verification of control points, updating and adding missing municipal boundaries etc. As mentioned, subcontractors handle the digitizing process, following which the digitized cadastral blocks are transformed to the new Israeli Grid system (change of projection and datum). The second step is the matching stage, where adjacent cadastral blocks are readjusted (in terms of edge matching and rubber sheeting) in order to create a seamless cadastral database. The process is concluded with very careful quality control (of geometrical correctness).

As mentioned previously, out of the 16,000 cadastral blocks, 2,000 blocks are still in the process of settlement of land rights. The remaining 14,000 blocks are contained within the current cadastral project. At the moment the transformation process regarding 2,000 out of the 14,000 cadastral blocks has been finalized and the blocks are part of the cadastral database. About 12,000 cadastral blocks have been digitized (the first step of the process), with most of these past the edge-matching stage and in the quality control stage. It is assumed that by end of the coming year, cadastral database will contain all areas that are past the process of settlement of land rights. The total cost of data acquisition of this project, so far, is estimated to be in the range of US $10-12 million.

The current cadastral database is, as mentioned, in digital form at a graphic accuracy level. Thus, a distinction should be made between an updating process of the current cadastral database and an improvement process. Regarding updating of the database, two sources are available for continuous updating of the cadastral database. The first is re-digitizing block maps that were changed (after the changes were made and drawn on them) according to the standard procedures. The second source, more a completion process rather than just an updating process, is digitizing the new cadastral blocks in areas where the process of settlement of land rights is being completed. Both sources are planned to be used immediately after completion of the existing data gathering process.

Based on the relatively low accuracy of the current cadastral database on one hand, and on the non-statutory validity of the graphical cadastral information, the SOI is planning to upgrade the cadastral database in the future to an improved analytical cadastral database. As a solution for the problems of the current graphic cadastre an analytical cadastre in which the location of each entity is unequivocally determined by the state plane coordinate system will significantly reduce the inaccuracies and discrepancies inherent in the cadastre. The data of the analytical cadastre will thus constitute a spatial information system defining the

statutory land division. The analytical data is planned to be used for renewal and remarking parcel boundaries – a process that contributes to the improvement of the quality and accuracy of the cadastral information. At the moment there is only a general scheme and some initial steps toward the analytical cadastre. There are two alternative approaches to the issue - "passive" and "active" attitudes. Based on the 1998 "Israeli Regulations for Surveying and Mapping", all new cadastral blocks resulting from the process of settlement of land rights are accurate enough on one hand, while on the other hand they are being prepared digitally for recognition as an analytical cadastre. Moreover, the partial or total re-parcelization of existing cadastral blocks is nowadays measured and prepared according to the new regulations and therefore can be also regarded as an analytical cadastre. On the average, around 100 new cadastral blocks (out of 2000) are being prepared annually, in addition to 1,000 - 1,500 partial re-parcelization of existing cadastral blocks. In the "passive" attitude, without any special processes, within a period of 25 to 30 years, the current graphical cadastre will be replaced by the new accurate updates, thus forming the analytical cadastre. Due to the importance of an accurate cadastre and its economic significance an "active" attitude is considered by the SOI, in which a special governmental budget (estimated at the moment at several tens of millions of dollars) will be allocated, enabling to complete the upgrading process by the year 2010. The final decision is to be made within the next few months.

Simultaneously with the cadastral data gathering process handled by the SOI, a zoning data gathering process was initiated by the ILA (Israeli Lands Administration). ILA is the governmental agency responsible for handling, marketing and leasing the lands owned by the state (about 92% of Israel's lands, lands with different levels of state ownership). The zoning project is aimed at converting about 25,000 large-scale and mid-scale master plans from a graphical format (paper maps) to a digital format (a GIS database). Based on the relatively poor geometric accuracy level of the master plans, and the significant geometric contradictions between the plans, particularly in the overlapping areas of the master plans, it has been decided to apply only a separate-single map approach to the digitizing process. Thus, the technical specifications define the digitizing process as conversion of each of the master plans as a separate map. Due to these specifications, each master plan in digitized (actually scanned and semi-automatically vectorized), and then transformed to the state plane coordinate system based on the cadastral database as a relative background, this without any attempt for correlation or adjustment between the master plans. This method was chosen in order to come up with a practical and reasonable process in time and cost terms. The alternative approach where all master plans would be merged and adjusted to one continuous database would result in a better product – continuous, homogeneous and more accurate zoning database, but due to the technical and financial aspects it has been postponed. At the moment the process is still in its initial stages, where only about 8,000 out of 25,000 master plans have been converted to digital form. It is an ongoing process, the digital master plans have not as yet been inserted in the zoning database and the conversion process of the remaining master plans is planned to be completed only within the next 2-3 years.

The Commercial Sector Infrastructure

During the last few years, in addition to establishing the nation-wide geospatial databases described in the previous sections, many other commercial geospatial projects were initiated and launched within different sectors in Israel. These projects are basically GIS applications based on the nationwide geospatial databases. Among these projects are:

- The three Israeli Cellular Phone companies established GI projects based on the SOI's "Mid-Scale Topographic Infrastructure". Generally speaking, there are three groups of applications based on the "Mid-Scale Topographic Infrastructure": (i) subdividing the area into separate cells and optimizing their location; (ii) correlating the Cellular Phone failures to the GI data and handling the technician service; and, (iii) analyzing data from the Israeli Census Bureau on the background of the "Mid-Scale Topographic Infrastructure" as a marketing tool.
- All Israeli cable TV companies are managing their customer base against the background of the "Large Scale Urban Mapping Infrastructure" in urban areas and the "Mid-

Scale Topographic Infrastructure" in rural areas. They are handling their linear cable network as a GI database, optimizing their technician service, and so on.

- Several of the Israeli major banks are using the "Large Scale Urban Mapping Infrastructure" and the demographic information from the Israel Census Bureau in order to analyze client distribution versus branch distribution, as well as facilitating a geographical marketing analysis.
- Few of the Israeli nationwide networks (such as pharmacies and supermarkets) employ the "Mid-Scale Topographic Infrastructure", the "Large Scale Urban Mapping Infrastructure" and demographic data from the Israel Census Bureau in order to enable a client-focused marketing analysis.

Besides these commercial GI projects, it is worth mentioning several other geographical databases or products. Among these are:

- A nationwide orthophoto layer covering almost all of Israel was prepared three years ago by a private firm from 1:40,000 colored aerial photographs. The orthophoto, which is practically equivalent to a 1:10,000 topographic map, was prepared under the technical guidance of the SOI, and is being used by private engineering firms, government agencies and municipalities. Its new version of the nationwide orthophoto coverage will be prepared by late 2000 or early 2001. At the moment, the ongoing updating process is planned for a three to four year cycle for the populated zones of Israel.
- A medium-level nationwide DTM was prepared few years ago by a government agency (the Geological Institute of Israel) based on 1:50,000 topographic maps. The DTM is characterized by elevation points that are organized on an evenly spaced 25-meter grid. As the vertical accuracy of these topographic maps is estimated in the range of 10 to 20 meters, the DTM is being widely used for low and medium accuracy level GI projects.
- A new high-level nationwide DTM was prepared photogrammetrically in recent years by the SOI from aerial photographs, concurrently with the "Mid-Scale Topographic Infrastructure" database. The DTM is characterized by a high vertical accuracy of 2 meters, and being composed both of elevation points organized on a 50 meters evenly spaced grid and of all topographic discontinuity lines (break lines and form lines). As this high accuracy level is much more costly than the previous medium-level nationwide DTM, it is being used only for high accuracy level GI projects such as rectifying aerial photographs, non-photogrammetric GIS updating processes, etc.

Summary

During the past decade, Israel has advanced from the graphical mapping era to the digital and geospatial information era. Many geospatial projects were launched, and the main efforts were invested in data gathering processes within all private, public and government sectors in Israel. These projects are prepared at different levels of accuracy, scope and budgets, and are aimed at fulfilling the increased needs for GI data in a very wide range of applications in Israel. Entering the 21st century, efforts in the past year have shifted toward issues of improving the quality and accuracy of the geospatial data, primarily the establishing of appropriate updating processes.