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Possibilities of object-oriented data base application in land information system

The geodetic law defines fundamentals of the prospective land information system. Construction of an information system may be based upon different designing assumptions. The purpose of this article is to outline the problems connected with the construction of information systems and presentation of the basis of land information systems designing using object bases. The article presents the elementary characteristics of systems currently in use and the advantages of object solutions. The suggested application of object bases to the construction of land information systems will be backed up by simple examples connected with the construction of an object model.

1. *Introduction*

The act of May 17, 1989, "The Geodetic and Cartographic Law" (Legislative Gazette No 30, item 163, with later changes), in its article 5 reads that "data in the land and building registration, in the land registration and other data in the state geodetic and cartographic register make up the basis for the national land information system to be establishment". The system is supposed to provide a basis for economic planning, land management, taxes, state statistics. According to clause 1 point 1 of the order by the Minister of Inner Affairs and Administration as of May 17, 1999 on specification of the kinds of materials that make up the state geodetic and cartographic register (Legislative Gazette No 49, item 493), "sets of maps and materials ans documents in the form of field documentation, registers, lists, catalogues, map issues and satellite photographs", should be regarded as such. Data comprised by the land are buildings registration, in accordance with clause 3 point 1 of the order by the Minister of Spatial Administration and Building Industry, and the Minister of Agriculture and Food Economy as of December 17, 1996 on the land and buildings registration (Legislative Gazette No 158, item 813) are computer data repertories in the form of main and auxiliary fiels such as: lists of entities, land register, building register, building file, list of seised, index of land parcel, index of addresses, archive of withdrawn record, book for claimed changes, land specification. The foregoing legal basis implies that the land information system is supposed to collect data and materials of different nature, a wide variety of persons intersted in land management, planning, tax leving and land administration being supposed to be the users of the system.

There are no detailed guidelines on what the system should be link, the designing basis it should be based on, what tasks it should accomplish and solve. The presented legal basis implies that it must be a large one, covering the entire area of Poland and different legal entities, however, at present it is difficult to accurately specify its users. There are quite a lot of them, those intersted in the issue are expacted to augment their number.

Each paper on land information systems is rather necessary and advisable. In the Geodetic Law (clause 7, paragraph 1, point 10) the following have been made obligatory tasks for the Geodetic and Cartographic Service: „initiation of scientific and research works in the line of classification and information standards, as well as application of information science methods in the national land information system". This article is supposed to meet that requirement; it is also meant to:

— outline the issues connected with the construction of information systems,
— describe current solutions and present thire merits and faults,
— suggest a new approach to designing of land information systems.

In the solution suggested herein object bases have been applied. The article presents the theoretical fundamentals of those bases. On the foregoing basis the authors will suggest and present the data model of a model of a land information system.

2. *The basis of information systems designing*

2.1. Designing of information systems — the classical approach

Software engineering deals with the construction of computer systems. An information system is a computer one of special functions: data collecting, arrangement and making them available. According to theory each information system breaks down into successive phases — starting from the designing phase up to complete accomplishment [3]. The life cycle of an information system is even spoken about [10]. According to the classical theory of software engineering the life cycle of an information system may be divided into elementary constructing stages:

— analysis
— designing
— implementation.

The first phase of the construction of information systems is the most important ne. According to the theory of software enginering it takes 75 per cent of the entire time of the accomplishment of a project. This stage will be collectively accomplished by information scientists and the future users. In appropriate works all the future users should be take into consideration, both the active ones, who work immediately on the formation of a system, an the "naive", whose knowledge of the system is next to none, yet they will want to use it in order to obtain necessary information (Fig. 1).

In the first phase the future users will specify their requirements:

— what they expect of the system,

— what functions the system is supposed to fulfil,

— what are the expected effects of the system.

Preliminary works should specify the thematic and qualitative range of collected information, certain form of the stored information and its source. A concept of the system shoul came into being [8].

Analysis is the most important stage of the construction of information systems, it is followed by successive stages connected with the design and applicationat a big rate.

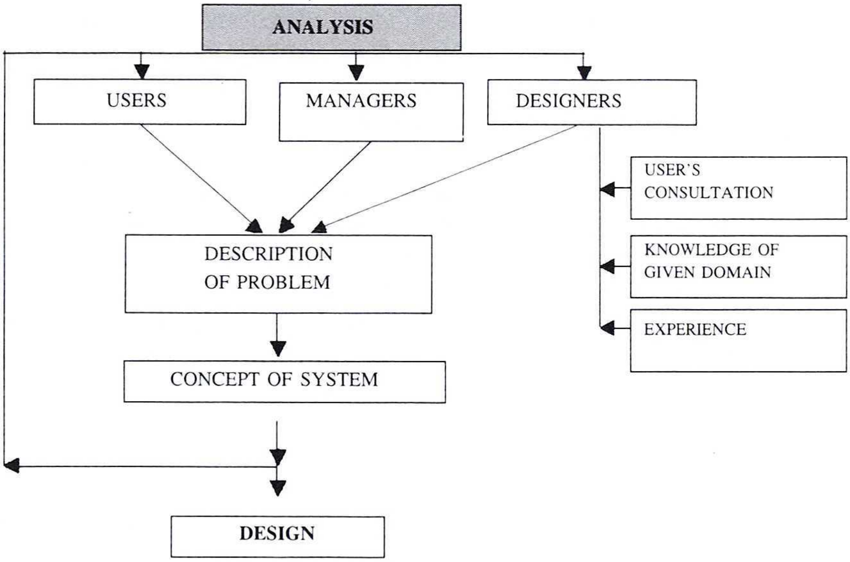


Fig. 1. Analysis at designing information systems

The preliminary experience on working with an information system is followed by successive stages connected with maintenance, corrections, improvement of the system. They result from the users' growing requirements, who after some time notice new possibilities and strive for the system to be improved. Systems based on the classical designing and constructing methods, after a number of corrections and improvements, every now and then are "killed". This will be manifasted by the fact that the system's possibilities become restricted through excessive growth of costs and limitation of methods assumed in the original desing. The killing of a system results in designing works to be started anew, with a quest for better solutions which will meet the users' augmented requirements. During designing works the existing experience, software structure and model structures are being used. Collected data will be transferred: to new solutions. This is the natural process of systems evolution, it will be going on for ever. The better the first desing is, the longer the life span of a system will be this is why the first constructing stage — analysis — is so significant. At present scientists and practicians are working on that first stage, setting up the theoretical basis of a national land information system. Bearing in mind that the first stage is so important, all efforts should be done to make the developed desing possibly best.

2.2. Designing of information systems — the object approach

Recently studies on object systems have been increasingly popular. New terms are to be found: "object designing", "object methods", "object technologies" [4], [5], [6]. They are connected with a new programming approach and result from a different modelling method, different analyzing, designing and implementation techniques. In object software engineering one may also distinguish three phases starting from analysis through design up to implementation, however, the "killing" of the system is not to be spoken about. This is due to the fact that an object system consists of independent modules which may be exchanged, improved, not destroying the system. There are no fixed limits in the first designing phase affecting the entire solution: if there are some, they pertain just to certain modules. The system may constantly develop, no new implementations being necessary.

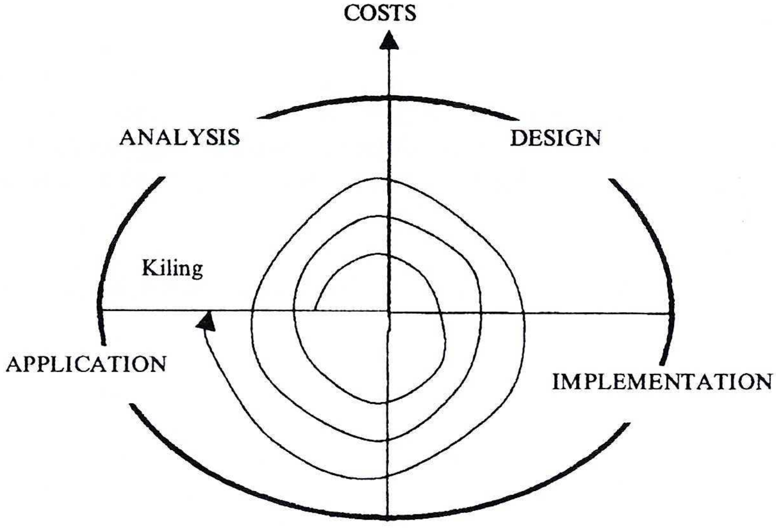
The life cycles of classical and object systems may be roughly presented in Fig. 2, which displays life cycles schemes: that of a classical system set forth by B. Boehm [13] and that of an object one, set forth by Coad [2] in the form of a baseball.

Every life cycle of the classical system is connected with the killing of it. The life cycle of the object system leaves hope for permanent modernization, even while using it. Corrections and improvements are possible at every stage of the life of an object system. While constructing a land information system which covers a large thematic scope and many useres, including those responsible for taking decisions, it is safer to base it on an object system guaranteeing for its undisturbed development. All the more, growing demand for various terrain data, quite undefinable at present, is to be expacted.

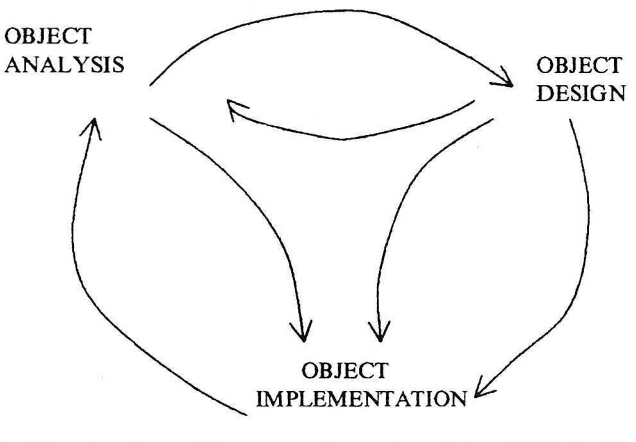
3. *Data bases*

3.1. Data bases and the data model

An computer information system consists of its data base and software. Data are being collected in data bases in an orderly way to be managed by means of software. At present relational data bases are most popular (75 per cent of the market). They are the main element of classical information systems. Every now and then author's



a) Example of the life cycle of the classical system (B. Boehm's spiral model)



b) The life cycle of the object system (baseball model set forth by Coad); correction of the system possible at every stage

Fig. 2. The life cycles information systems based on different programming techniques: a) relational solutions, b) object solutions

data bases (approx. 20 per cent of the market) are also to be found. Recently studies on object data bases (approx. 5 per cent of the market) have being met more often. Object bases are applied to the construction of object information systems.

Differences between those bases lie in a different data model. In each of them data are recorded in a certain specific way. Data are generally known to be stored in the form of objects; a set of attributes explicitly identifying and describing an object is kept in a base. If a more rigorous definition is to be arrived at, one should note that in relational bases the data model comprises three kinds of elements: objects, atributes and relations. In object bases the model consists of objects, the latter being defined by means of attributes and methods.

3.2. Current use of a data base in local land information systems

A large majority of local land information systems currently in use based on two types of data bases, graphic and descriptive bases. Land information on objects is divided into the so called spatial data and descriptive data. Division of data into spatial and descriptive parts is connected with the traditional division of information according to the graphic presentation of an object upon a map and preservation of descriptive data in the form of field documentation, registers, lists, etc. Graphic bases are built on the basis of graphic program prepared for different platforms, descriptive bases being based on textual author's or classical bases. Data management within systems that divide information into two differenty operating bases is more difficult. Two bases should be referred to; on the other hand, while data updating, integrity of information should be in mind.

There are also available systems based on data bases which collect spatial and descriptive data within a single base, it is difficult, however, to record in them data of a single object in a single coherent way. This is due to the fact that objects of a single type are often characterized by a different number of spatial attributes, e.g. parcels are defined by a different number of boundary points. If so, a problem arises: how to record information on parcels in a single record. In relational bases [1] this might be solved by dividing descriptive and spatial information. Descriptive data should be recorded in one table, spatial data to be recorded on another one. The record of data on a parcel, bounder lines and boundary points within a relational base may provide

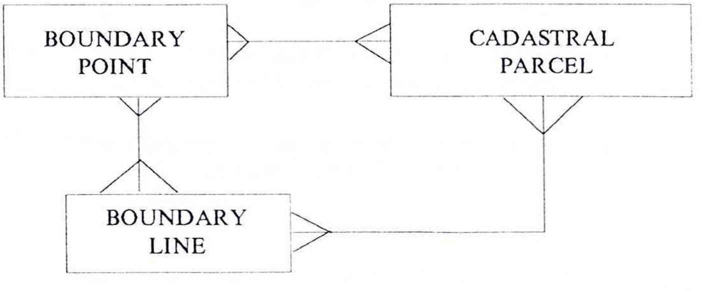


Fig. 3. Many — to many relation showing links between boundary points, boundary lines and cadastral parcels

an example. One boundary point may be used in a spatial description of a few parcels, yet the parcel itself will be spatially described by means of many boundary points. If information on bonduary lines is added to that, a complex description of the situation may be obtained what is presented in Fig. 3.

The occurring here relations between bonduary points, bonduary lines and parcels (many-to-many relationship) can be accomplished in relational bases, however, spatial information (e.g. information on a parcel) will be obtained in an indirect way. The presented example shows the complexity of classical solutions, as it is impossible to record information on a single object at a single place of the base.

The existing land information systems contain also materials in the form of photographs, documents, numerical documentation, mark descriptions and other materials covering the geodetic resourses. They cannot be recorded in the form of tables, yet, part of them are suggested they should be attached to objects by means of reference attributes. They are kept in separate files. Such a solution make it more difficult to independantly manage those data.

The foregoing problems point out difficulties while accomplishing a simple data model in relational bases currently in use, therefore simpler solutions should be looked for. Will object-oriented systems based on object-oriented bases facilitate the accomplishment of that difficult task?

4. *The theoretical basis of object-oriented bases*

4.1. Introduction

Object bases are those in which different data from different sources can be collected. The entire information on the form of objects may be stored in one system in them. Representation of a conceptual model onto the scheme an object data bases follows the natural way. The features of object bases, such as hierarchic data structure, inheritance, encapsulation, specialization, aggregation, polymorphism facilitate data modelling. The data structure of object bases may consist of objects of optional size and optical complexity, regardless of their current state and storage carrier. This makes it possible to store the spatial and descriptive data of objects in a single record. Object bases may store data of optional structure, optional format, all we need is just to define them in the form of objects.

Once the diversity of data included in a land information system is know alongside the manifold character thereof, it seems that application of object-oriented data bases and object-oriented systems connected with them enables the constrution of a system which would manage all those data. Such a system should guarantee for its long life becase of the possibility of its constant development.

4.2. The object model

Organization of a data is the most important element of object information systems. Data are stored in object form in this kind of bases. Definition of the objects that make up the so called object model should be the first stage of the formation of object-oriented information systems. The object model this is description of reality by means of objects (entities, subjects, objects) [11]. In object-oriented bases objects will be defined by their properties and behaviour (Fig. 4). Properties will be described by means of attributes [4]. An object's behaviour — this is a set of methods (operations, procedures) which may be activated for a given object. Each object should be discriminated by means of the accepted identifier, it should be independent and appropriately protected by the assumed methods.

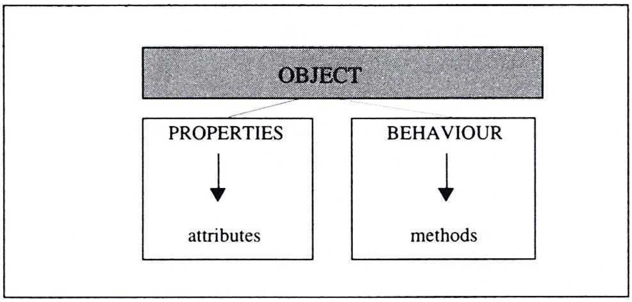


Fig. 4. Description of an object consisting of attributes and methods

Construction of an object system requires objects to be arranged, grouped in classes, subclasses, divided into types. A class is a set of objects which have the same inner structure, the same atributes and the same methods. A type of objects is a set of objects which have the same characteristics. While assigning objects to certain classes and types, an arranged objects model is being created; in object bases this a hierarchical model (Fig. 5). The accepted data structure in an object model provides the basis for the system. It should take into account:
— thematic division,
— structure of objects,
— relation between objects.

An appropriately designed structure should model reality in an arranged manner. A class is a set of objects. Objects of a single class are characterized by the same attributes and methods. Inheritance defines the kind of hierarchy between classes in which a subclass inherits after one or many superordinated classes (superclass, overclass). In order to make designing easier, it is possible to set up a class which is an object. It may extend the hierarchic structure of an object model, facilitating at the same time the arrangement of its structures. It is set up to extend a certain class to the end of its subclasses to be obtained. This procedure is called aggregation — specialization [5], [11]; it has been show in Fig. 6.

There are also other features of object bases such as: association — it makes it possible to combine objects, polymorphism — it enables inherited methods to be substituted by different ones, abstract data types. All of them facilitate the constructing process of an object data model.

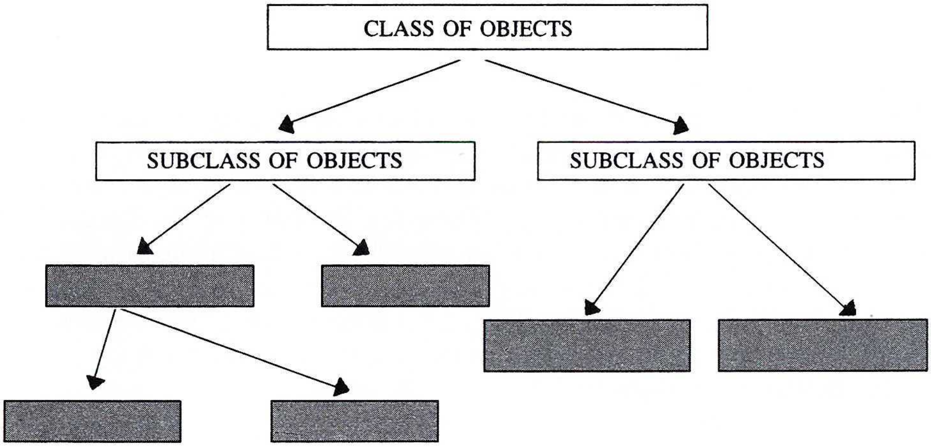


Fig. 5. The hierarchic structure of an object oriented data base

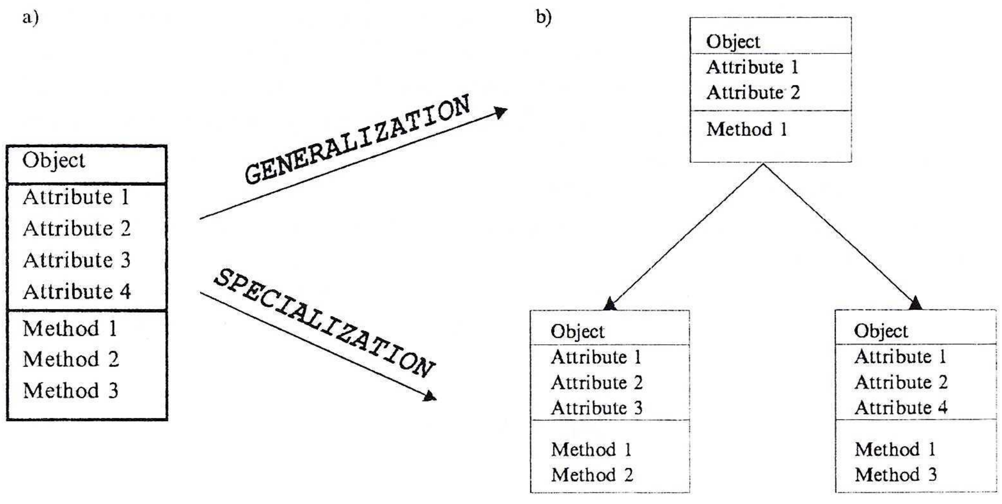


Fig. 6. a) An overclass (generalization) and two classed (specialization) having been isolated from a single class; b) diagram of objects of different classes depicting inheritance of attributes and methods

4.3. The kinds attributes of classes and objects

In object-oriented bases an object will be defined by its properties and behaviour. Properties will be defined by means of attributes. There are attributes of different kinds (Fig. 7):

— class attributes,
— object attributes,

and also:
— simple attributes,
— complex attributes.

Class attributes pertain to particular object classes; they are inherited by all subclasses and objects of a given class or subclass. Object attributes are object attributes of a single class. Simple attributes are descriptions of objects by means of the assumed elementary types [4], [5]. These are attributes in the form of a text, number, string, data. Simple attributes are recorded in a data in the form of columns in a table. Reference to an attribute comes about by means of the usual relation "object-attribute". Multimedial attributes are also regarded as simple ones.

Alongside simple attributes there are complex ones, from among which the following will be distinguished:
— reference attributes,
— multi-value attributes,
— computable attributes.

A reference attribute makes it possible to combine objects of different classes. Its value belongs to the set of identifiers of the objects of a certain class. On the basis of reference attributes a relations between objects of different classes comes into being.

A multi-value attribute will be conceived as a collection in the form of lists, files, tables. It assumes a certain value from the existing collection. A multi-value attribute may be used as a simple one.

A computable attribute is the one whose value is not stored within an object; it will be calculated at the moment it is referred to. A certain procedure computing its value is connected with it.

There are definitions of other attributes to be found in literature, such as: optional attribute, default attribute, common attribute. The list does not exhaust all po-

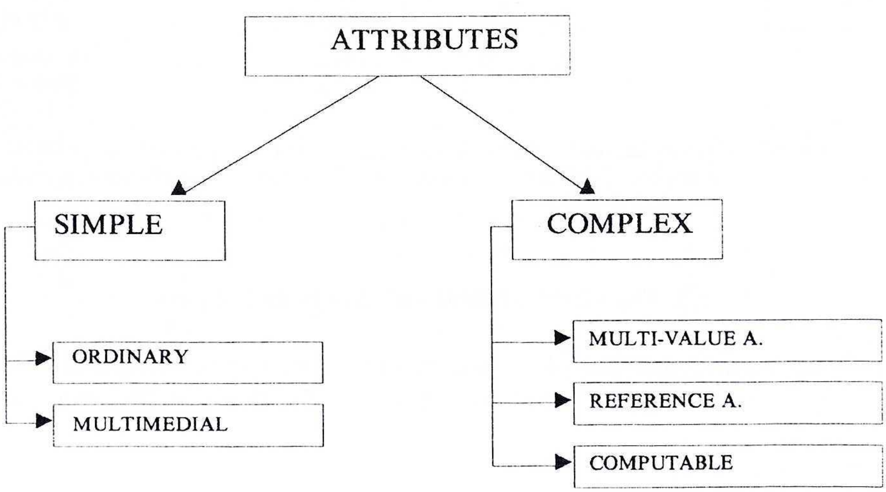


Fig. 7. Kinds of attributes occurring in objects bases

ssibilities, there are many different kinds of attributes, as well as many manners to combine them [12]. Each attribute must have a type assigned to it, which is a linguistic expression or a certain semantic structure specifying the kind of the values that may describe the object.

4.4. The dynamic model of objects

Behaviour of classes and objects will be defined by means of methods (operations, producers). Definition of a method consists of declaration and body [4]. Declaration — this is the name of the method that described an operation carried out by means of a given method. Body — this is a series of commands in a programming language. Method call comes about by means of the name of a method. Methods cause that an object model is an live, dynamic one; they also make it possible to specify the components of a model. What we speak about is a

— dynamic,
— functional

model; the two make up a whole to create an object model.

The dynamic model will be conceived as interrelation between objects which are used while designing the methods of a dynamic model. Methods provide the basis for those models, enable objects to be interrelated. By means of methods an object may refer to other ones. This will be made use of while defining complex attributes of the reference and computable type. The dynamic model determines the usefulness of a system.

4.5. The functional model of objects

The functional model — these are the methods of the functional model (system's input and output external functions and producers). Users most often come across the functional model while working with an information system. It is the functional model that determines the quality of their daily work. These are usually methods which it possible to:

— input data,
— delete data,
— carry out analyses,
— query the data base,
— arrange data.

By means of methods and classes new objects and classes might be created, it is also possible to carry out operations on objects, e.g. select objects of certain attributes. Object methods make it possible to change the definition of an object, e.g. through attributes being added or changed. A correct desing of a model of objects model and its components guarantees for the system being constructed to be successful.

5. *The exemple object-oriented model in land information systems*

5.1. Introduction

Construction of the model of a land information system is difficult due to the fact that it is supposed to collect all object — data, materials presented at the beginning of this study. These data are diversified, their character being remarkably manifold and heterogeneous, they cover areas of different sizes and there is a lot of them. Herein a tentative presentation of certain elements of the object model might be set forth, it will pertain to selected objects. This will imply presentations of the philosophies of object-oriened bases. A more detailed discussion is not supposed to be the subject-matter of this study.

Standard manual K-1 define elementary objects on the surface of the Earth, group them in the so called sections of the contents of a map, specifying among other things categories of objects belonging to: control networks, boundaries and lands, buildings, communications. While constructing an object model, one may use the systematics suggested in the obligatory standards and understood by those who are interested in the issue. In agreement with this assumption three is accepted that sections of map contents are clases of objects. Objects types are geometrical types of objects described also in K-1, e.g.: a point object, object in the form of a generalized segment, object in the form of a generalized open chain of linear segments, generalized closed chain-polygon. Such assumptions having been done the section of the contents of a map "boundaries, lands" makes up a single object class. Within the assumed class subclasses may be specified, e.g.:

— boundary points,
— boundaries (state boundaries, boundaries of a province, distric, commune, bounds, class of soil, land, parcel,
— parceles,
— lands,
— class of soil contours,
— bounds.

For each subclass of objects the internal structure of the fields of its record-attributes and methods making up a dynamic and functional model (of internal and external functions) will be defined. Data on each object will be stored in a separate record. Attributes characterize objects' properties. These may be simple attributes in the form of numbers of a certain type, text picked out from a certain dictionary, or in the form of an optional string of characters. For example, each boundary point is an object. Particular boundary points, as objects differ from one another in respect of some attributes. The elementary numerical attributes of a bonduary point are:

— number of a point,
— coordinate X,
— coordinate Y,

— coordinate *H*,
— accuracy of determination.

Descriptive attributes may be also assigned to each boundary point; they inform on:

— point's marking way.
— surveying documents on the basis of which the point has been determined.

It is up to the authors of land information systems how record fields assigned to objects will be defined and named, and what values they will assume. Some simple attributes of the multimedial type may be for inst. the image of a boundary point set-out site sketch, digitall photograph showing location of a point.

The straight section between two adjacent boundary points — this is a boundary line. It is an independent object. By means of attributes it is possible to describe what kind of boundary it is: boundary of a parcel, bounds, land. The code of an object, define in K-1, may be an attribute which clearly identifies the kind of boundary. Other attributes may inform on whether it is a disputed boundary, the accuracy it has been determined with, what boundary points it is based on, and what structure it determines. The cadastral parcel, agricultural land, class of soil are geometrically similar objects. They differ in respect of other properties, therefore their records should differ in respect of fields of descriptive attributes. A parcel is a coherent land area, closed in cadastral boundaries and strictly described spatially by means of coordinates of boundary points. Let us discuss the example of parcels, how they can be presented in a data base. Each parcel is presented in a separate record of the base. A parcels elementary attributes are its number and numbers of successive boundary points. The list of boundary points describing the parcel must be one of the attributes that spatially describe the parcel. It has been assumed that boundary points are independent objects. This implies that some elements of the set of objects which are boundary points define the geometry of a parcel. There is a relation between objects-boundary points and objects-parcels similar to that between bounadry points, boundaries and lands.

5.2. An example of the dynamic model

The dynamic model — this is for example combination of objects by means of methods (proceducers, internal functions). It defines relation between objects (Fig. 5). Thanks to those relations it is possible for example to calculate the area of a parcel on the basis of the attribute that comprises the numbers of its boundary points. In such a case methods must bring about the set of boundary points to be called and appropriate procedures to be applied. In object bases such functions are wides in definitions of complex attributes, e.g. these might be computable attributes. The value of the area of a parcel is not stored in an object, it will be computed the moment this object is referred to. This is a rather perspective solution; if coordinates of boundary points change, the geometry of a parcel will be automatically updated.

5.3. The functional model

The functional model will be defined by methods (procedures, external functions) which make it possible to update, correct and use the collected information. A graphic programme (CAD) output with an option to obtain a map whose contents depend on the need, should be the elementary external function. External functions to be used while checking the topology of a digital map (e.g. areas of parcels of certain attributes to be summed) may be described upon the objects of a single class. By means of such functions it is possible for example to check whether the area of a bound calculated on the basis of bonduary points complies with the sum of the areas of all the parcels belonging to that bound. Fig. 8 presents the records of exemplary objects: boundary points and a cadastral parcel with the external and internal functions described upon them.

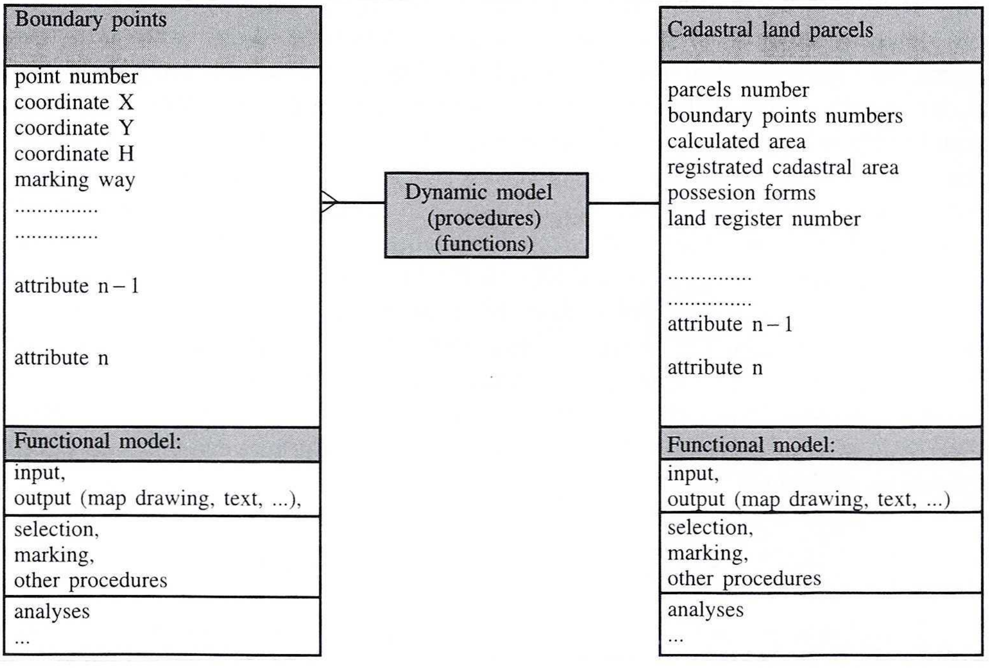


Fig. 8. Exemplary fragment of a model of objects, the dynamic and functional models having been distinguished

5.4. Final remarks

The foregoing choosen and illustrated mechanisms of object-oriented systems pertaining to the objects of a digital map show that the said systems are capable of managing land information. Information on land, objects in those bases will be recorded in a single data module. It is not necessary to divide information into graphic and descriptive data, as it is generally done in systems designed at present. All object data are collected in the form of attributes; by means of methods it is possible to manage them and obtain the graphic visualization of an object upon a map.

A land information system — these are not merely the objects of a numerical map; this is a large data set specified within a legal basis: material, documents, data files aerial photographs and other documents. All the foregoing materials should be approached as objects, thus they should be included in storage and management out of the information system.

Objects grouped in classes, subclasses, make up the image of an object model. The section of the model shown in Fig. 9 might be an example of such a model. The

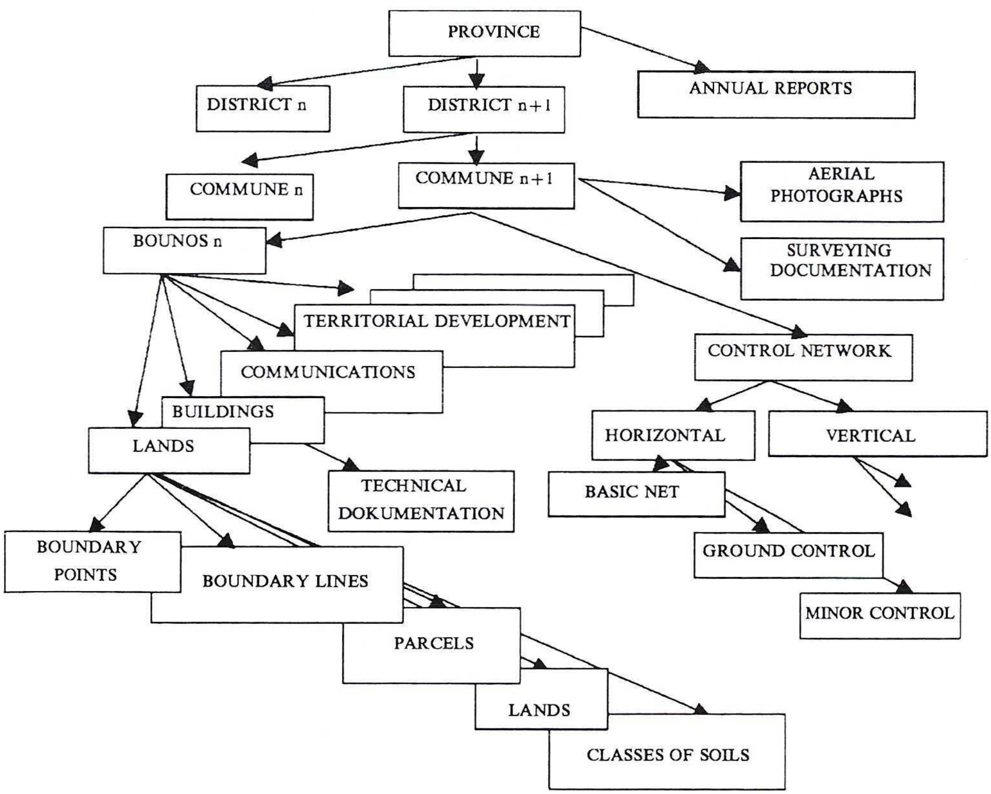


Fig. 9. Exemplary fragment of model of objects in a land information system

presented fragment of an object model comprises the materials which are hard to manage in relational bases: geodetic documentation, aerial photographs, annual reports. Relation between objects should be presented by means of more detailed schemes, alongside the definition of methods that make it possible to apply the system to tasks imposed by the geodetic law. According to how a system has been designed, such will be the possibilities of the use thereof for the needs of land management, statistics, spatial planning and land administration. This is a work for a large team, with the use of computing tools applied to analyses of object systems.

6. *Calculations*

The purpose of this sudy was to outline the problems conected with the construction of land information systems. The disadvantages of currently used relational solutions have been presented; it has been show that it is not possible to record spatial and descriptive attributes (e.g. linear and surface objects) at a single place of the base, thus it is necessary to divide information on a single object into different tables. Besides, in relationship bases it is not possible to manage the data that are difficult to record in the form of tables (e.g. aerial photographs, documents, mark descriptions). Bearing in mind the fact that systems based on relationship bases undergo the classical life cycles, thus more general solutions must looked for. Object systems based on object bases be applied to the land information systems currently constructed, which I have tried to prove herein. The works on an international standard, currently in progress, concerning spatial data modelling, have been specified by standard ISO/TC211 [9]; they advise object bases to be accepted as the platform of the information system.

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Możliwości zastosowania obiektowych baz danych w systemach informacji o terenie

S t r e s z c z e n i e

W prawie geodezyjnym określono podstawowe założenia projektowanego systemu informacji o terenie. Budowę systemu informacyjnego można oprzeć o różne podstawy projektowania. Celem pracy jest przybliżenie problemów związanych z budowaniem systemów informacyjncyh, oraz przedstawienia podstawy projektowania systemów inforamcji o terenie w oparciu o bazy obiektowe. W pracy zostaną przedstawione podstawowe cechy systemów aktualnie wykorzystywanych i zalety rozwiązań obiektowych. Zaproponowanie zastosowania baz obiektowych do budowy systemów informacji o terenie zostanie podparte prostymi przykładami związanymi z budowaniem modelu obiektowego.

Ельжбета Левандович

Возможности применения объектных множеств данных в системах информаций о местности

Р е з ю м е

В геодезическом праве определены основные положения проектировнной системы информаций о местности. Структуры информационной системы можно основывать на разных основах проектирования. Целью работы является приближение проблем, связанных с изготовлением информационных систем, а также представление основ проектирования систем информаций о местности с применением объектных множеств данных. В работе будут представлены основные черты систем использывающися в настоящее время и преимущества объектных решений. Предложенные применения объектных множеств данных для изготовления систем информаций о местности будут поддержены примерами, связанными с изготовлением объектной модели.