Data Representation Dynamic Model for Distributed Urban IGIS

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1 ABSTRACT

In the article a dynamic distributed model of data presentation for creation of municipal economy distributed managment systems on the base of intellectual GIS technologies is offered. Decisions on submission of actual data for solving end users tasks, organization of data processing, data analysis, supporting interaction of various system components taking into account structure of municipal economy data and its great volume that meet modern standards are described.

2 INTRODUCTION

Hic et nunc (with lat. Here and Now). The modern computer user does not want to wait for a long time, does not want to enter initial data received from different places, does not want to look for a place where he (or she) can solve his problems. Information systems serving these users must comply with the principle of semper et ubique (with lat. Always and everywhere). Modern systems should not only provide decision support, but also a set of following possibilities. To extract necessary information from newly appearing data sources. To integrate information immedeately into existing information space. To transfer results to any place wherever a user can be. To predict his intentions and prepare the result in advance and with maximum quality. To such systems municipal services management systems undoubtedly refer. Functions that are carried out by the system are various and thus they are implemented in different subsystems. The majority of them have been developed during a long period of time, without any general idea or a plan. Because of functions distrubution and absence of the system management concept it is extremely difficult to provide hight quality solution of main tasks, such as rational use of city resources, coordination of city services work, safety of different types of human activity in conditions of dynamically changing situation. All this, finally, defines effectiveness of modern cities and megalopolises management. There is an objective need for development of a urban system that allows to integrate separate components by building a uniform data and knowledge space, and a need in universal tools for processing and analysis of continuously received diverse information. All this, finally, defines effectiveness of modern cities and megalopolises management.

3 GOALS AND REQUIREMENTS

The managment system of municipal services belongs to category of decision-making support systems. The main goal of such systems is to help users, that make decisions in difficult conditions, in complex and objective analysis of subject activity in the form of decision making process support [1]. Life cycle of a decision is a set of processes which are carried out from the moment of situation emergence to its permission. Life cycle of a decision consists of the following top level stages:

(1) Initiation – a stage that realizes the mechanism of decision making start point. As a cause for the beginning of the stage situation emergence is considered.

(2) Planning. Stage of decision making.

(3) Implementation. Stage of decision implementation.

(4) Assessment of results. Stage of implementation completion, analysis and storage of results.

At the same time several interacting cycles can be realized. New cycles are build on the basis of in advance prepared templates, but there is an opportunity to change the structure and contents of the cycle stages in dynamic when cycles are executed. The course of life cycle is considered as changes of state of the decision information model. As methodology of system development IDEF standards [2] are used.

For effective management of municipal services a system must be able to solve the following tasks:

(1) To execute continuous modeling of managed object; it allows at each timepoint to provide qualitative estimations of object current and predicted states for timely identification of various situations.

(2) To support interaction with various sources of information for maximum decreasing of the degree of uncertainty about managed objects states and providing results obtained by the system to other consumers of information.

(3) To provide adequate representation of information about managed objects states and about possible development of the situation to the user.

For the successful solution of the system tasks the following requirements are to be fullfilled:

(1) The system and all its components have to be distributed. Duplication of connections with information sources is to be provided for continuous obtaining of information. For operative modeling of unexpectedly arisen situations it is necessary to involve maximum amount of computing resources. To allow users working in various places client applications of the system have to function on various platforms, including mobile platforms.

(2) The system has to be adaptive. The main directions of system adaptiveness are defined by features of managment systems. First of all it is necessary to carry out newly arising tasks with minimum expense. Besides, depending on completeness, volume and features of analysed data the system has to apply various mathematical models. There also must be an opportunity to provide interaction with new sources of information in the shortest possible time at the expense of automatic information search that satisfies information requirements.

(3) The system has to be safe. It is necessary to provide mechanisms of the system stable continious functioning. The system has to reveal constantly internal and external threats and to use software and hardware solutions for effective prevention of threats and restoration of the system functionality and integrity. For this purpose a plan [3] has to be made. The plan is realized by aprocess that includs: analysis of functionality threats, updates of restoration strategy, adaptation of threats prevention and system restoration mechanisms, testing and state analysis.

The enumerated problems can be solved by the system at the expense of continuous situation modeling. The modeling is base on application of dynamic information model.

4 DYNAMIC INFORMATION MODEL

Dynamic information model reflects existing business processes of objects life cycle related to situations and allows to receive adequate estimates of situations at each timepoint. The situation is considered as a certain change in time and space of objects properties state and relations between objects that demand attention of the system [4]. Dynamic information model implements top levels of JDL model. Modeling is carried out not on the request of an operator, but continuously in case computing resources are available. Depending on degree of uncertainty of situation objects state and requirements to operationability more rough or exact mathematical methods are used. Methods can be applied if correct input data and parameters are defined [5].

Dynamic information model is based on three subsystems (Fig. 1).

(1) Subsystem of static information model. The subsystem is intended for providing access to business objects. It contains all set of objects, their properties and relations between objects [6]. The model is constructed on the basis of ontologies.

(2) Subsystem of business processes. The subsystem is intended for organization of decisions life cycle. It allows describing and carrying out sequence of interacting tasks. Interaction between functions is provided by making changes in business objects. It is build according to Business Process Definition Metamodel [7].

(3) Modeling subsystem. The subsystem is used for building models that reflect managed objects states and allows making estimates of situations development. Models are represented in a form of business process scenarios. Modeling subsystem contains two components:

(3.1) Simulation modeling subsystem. One of the subsystem’s tasks is visualization of progress of spatial distributed business processes. The subsystem represents business logic platform providing uniform integrated framework for managing rules, working streams and processing events. As an example of such framework Drools [8] can be considered.

(3.2) Mathematical modeling subsystem. The main objective of the subsystem is organization of a cycle of situations assessment at the expense of use of scientific based mathematical concepts and heuristic algorithms. The cycle represents a process of organization of interacting methods performance (the output data of one is input for another) that solves the task of identification and quantitative assessment of the situation.

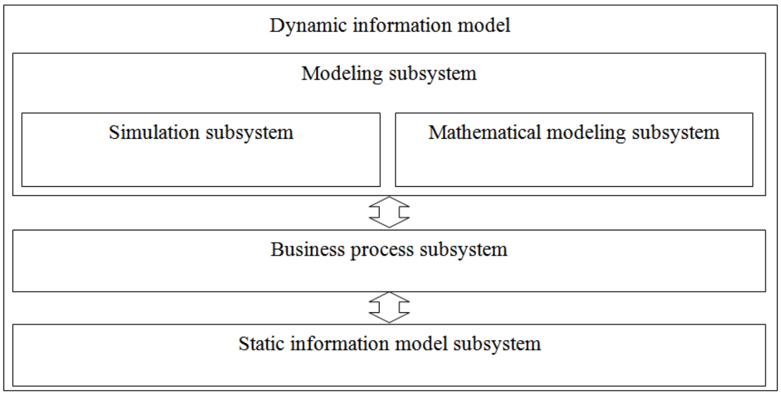

Fig. 1. Structure of dynamic information model

4.1 Static information model

The base of static information model is a unified model of information presentation (UMIP) [9]. The model provides access to all business objects that are used in applied business logic of the system. The structure of the model is based on the known principles of object-oriented paradigm. UMPI is a structure of entities describing subject domain in a form of a set of classes and objects, each of which possesses a set of properties that characterise them. A class represents a description of set of objects with similar behavior inherited from parent classes and extanded. These objects are called instances of a class. Objects of a class are described by a set of properties. For each property following characteristics are usually defined: name, type and value. Instances of classes are objects possessing all properties defined in a class. An object can belong to several classes and, respectively, it possesses all characteristic properties of the classes. Each property (object property or class property) has a complicated structure that contains: property unique identifier, property name, property description, set of property values. Property value can be multiple and single, contain simple data and links to other objects. Key types of objects of static information model are given in Fig. 2.

4.2 Business-process model

The subsystem of business processes defines an order of business functions execution. The subsystem allows describing and carrying out sequences of interacting functions. Interaction between functions is organized by modifying business objects. Process is a basic element of life cycle stages. It represents a set of interconnected tasks aimed to change a decision information model. Processes implement a unified interface providing methods to process and analyze input and output data, management and control mechanism and mechanism for interaction with other processes. Business processes are built on the basis of the following elements and relations connecting them:

1. Objects of management flow
1.1. Activities
1.2. Events
1.3. Gateways
2. Relations between objects of management flow
2.1. Flow sequence
2.2. Flow message
2.3. Association
3. Objects of life cycle products
3.1. Main product
3.2. Management product

3.3. Information product

4. Associations of objects

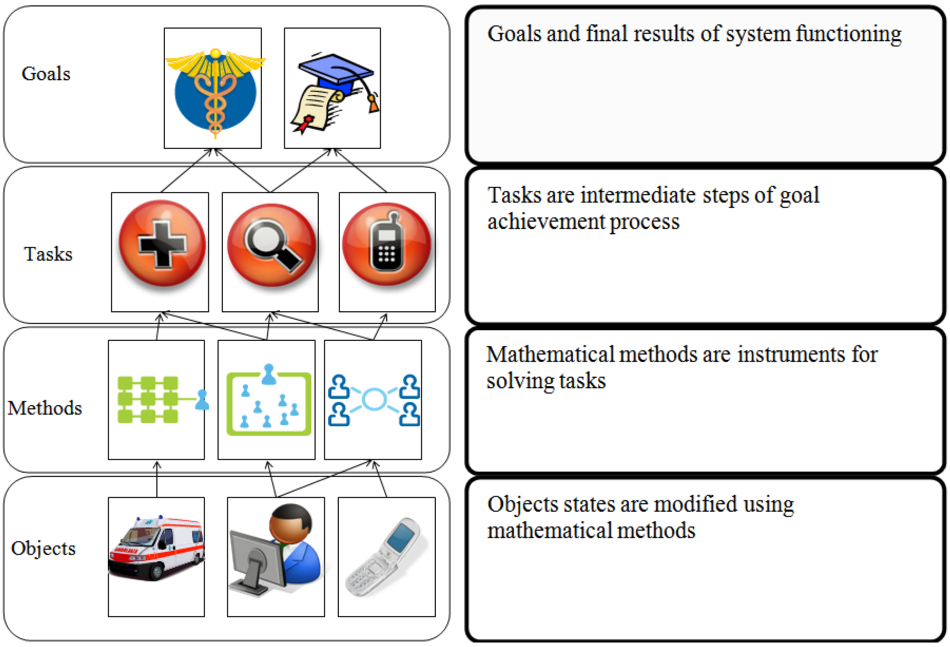

Fig. 2. Objects types of static information model

Activity is a basic element of a business process. It is an operation of generation, modification of state and destruction of life cycle products. Activities can be executed sequentially or in parallel, they can be dependent and independent.

Event is an element of process management that impacts on a process flow. Two types of events are considered – external and internal. External events are caused by factors that are outside of a process model. Internal events are results of changes in a management product state.

Gateway is an element that defines dependences in activities sequence. Using gateways consecutive and parallel activities are defined, selection of activities execution sequence is supported.

Flow sequence defines relations between activities and events connecting them in one sequence of activities. Flow sequence set describes an order of activities performance.

Flow message defines external actions which lead to event generation. It is a relation connecting management product or external object and an event.

Association is a relation connecting set of objects that is not an interaction or management relation.

Product is a result of activities execution. It is a container that changes its state while performing activities. It must match the information model of the product.

Information product is a product, which state does not influence a decision life cycle course.

Management product is a product a defined states of which can cause occurrence of internal events.

Main product is a result of performance of decision life cycle. It is an object generated in the beginning of decision life cycle. Main product can be considered as management product.

On the basis of dynamic information model decision-making support system is developed.

4.3 Modelling subsystem

Modeling subsystem supports two modeling approaches – simulation approach and mathematical modeling approach. Simulation approach assumes definition and execution of simulation scenarios [10]. Scenario can be formally defined as an algorithm that is a sequence of stages and solutions. Algorithms can be executed by expert systems. Stage is an aggregate of elementary actions executed sequentially or concurrently. Solution is a point where the process flow can alter to one or another direction depending on some conditions emerged at the given moment. Scenarios can alter the state of the information model objects. Scenarios are represented as texts written in special scenarios' language, and scenarios repository is a documentary data base. An aggregation of developed scenarios is considered as a part of knowledge base.

Mathematical modeling subsystem is aimed to process large volumes of heterogeneous data, including quantitive and qualitive data, as well as measurements time series. Data can be successfully (at the desired time and with the desired precision) processed only if automated adaptive data processing approach is used, that means that processes are built in dynamics taking into account all available related information. For building adaptive processes on the base of IGIS two components are required. The first essential component is a library of algorithms that must be sufficient for solving user problems. It is also necessary to provide possibility to performed algorithms in an automatic mode. To support automatic execution of algorithms functions for defining algorithms input parameters and functions for results estimation must be defined. The second component is a library of exploratory data analysis algorithms that provide additional priory information about structure and characteristics of the data being processed. It is used together with the knowledge available to system for selecting algorithms for building processes. Both components include a wide range of statistical and data mining algorithms.

5 INFORMATIONE INTERACTION MODEL

Effectiveness of decision-making support system significantly depends on possibility of interaction with external information sources for the maximum decrease of degree of uncertainty about managed object and possibility of trasfering results of tasks solutions to the place where a user is located. In modern conditions there is a huge number of various systems potentially capable to be suppliers and consumers of necessary data. There is a number of problems that have to be solved. The first problem is that initially interaction of all these systems was not supposed. The second problem is the organization of the optimal (on time and cost) route of information passing. The third problem is that suppliers of information can be switched off, faulty, occupied with solving other tasks. To overcome the specified problems the system has to be designed in the following way.

Lets connsider a set of existing information nodes. A node carries out one business function. Business function can be realized on the base of information that is available in the node or is received from any other node. It is important to note that quality of such information can be different. A knot can have information necessary for other knot for executing its business function. Such information is received from sensors that are connected with the node or is earlier received from other nodes. A node can transform information when new information is received, make harmonization, integration and merge of data [11]. A node can transfer information to any other node connected to the supplier node by channels. Nodes and channels can be switched on or switched off, be occupred solving other tasks. For information transfer, storage and transformation certain resources are spent. It is necessary to organize information exchange between knots so that spent resources for business function execution with necessary quality will be minimized (Fig. 3).

Resources consist of the following costs and times parameters with defined weights (quality of information and probability of the corresponding task solving is taken into account):

(1) building rout for information transfer;

(2) information transfering;

(3) information transformation;

(4) information storage;

(5) possibilities of a node.

Weight coefficients are recalculated for each node proceeding from success of the previous operations.

Dynamically changing routes of information passing between nodes can balance system loading and provide its fault tolerance.

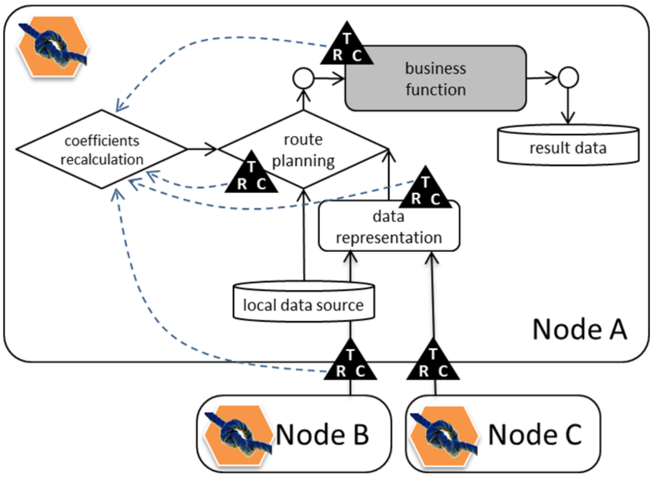

Fig. 3 Information interaction of nodes

6 SYSTEM STRUCTURE

Decision making support system contains following components (Fig. 3):

(1) Management organization component;

(2) Mathematical methods library;

(3) Simulation and modeling component;

(4) Situations management component;

(5) Component for support of external relations and interactions;

(6) Settings and audit component;

(7) Decision information model access bus.

Functional subsystems are realized in the form of program modules that interact only with decision information model access bus.

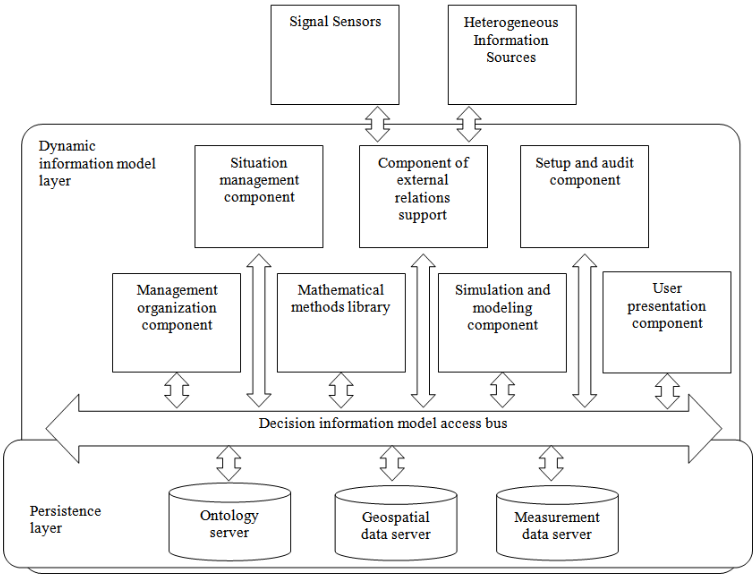

Fig. 3. System structure

7 CONCLUSION

Application of dynamic information model of data presentation along with intellectual GIS technologies for development of municipal economy distributed management systems provides:

(1) Integration at information level of various subsystems, each of which solves one or several tasks of municipal services management. It will allow creating a uniform system of municipal services.

(2) Access to the actual data on municipal economy in conditions of dynamically changing situation at the expense of continuous data acquisition from all accessible data sources and operative data processing.

(3) Possibility of making full and objective analysis and estimation of situations, arising in the sphere of municipal services, and also formation of well-founded decisions on situations management at the expense of application of mathematical and simulation modeling methods.

(4) Convenient working environment for end users due to using GIS technologies.

It is suggested to develop municipal economy distributed management systems on the base of ONTOMAP [11] System that is Surveillance & Recognize Systems for information Support and Automation of Activity Information Centers` Staff that is based on IGIS technologies and nowadays is efficiently used in naval bases, command and information centers.

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