GIS and the dynamic phenomena modeling

Modelování dynamických jevů v GIS

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Abstract: Different aspects of the dynamic or temporal of GIS are very frequently discussed and we can register new approaches and applications in this field every week. This paper analyses the possibility of the selected approaches to contribute to the temporal data processing and gives the overview of the most basic ones. The author presented part of these results also at the Agrarian Perspectives Conference 2005 in the applied informatics session.

Key words: dynamic modelling, temporal analysis, dynamics evaluation, temporal space

Abstrakt: Různé aspekty dynamického nebo temporálního GIS jsou v poslední době velice často diskutovány a nové přístupy a aplikace se objevují každý týden. Tento příspěvek analyzuje možnosti vybraných nástrojů přispět ke zpracování temporálních dat a věnuje se některým aspektům těch nejzákladnějších. Autorka presentovala část tohoto tématu na konferenci Agrární perspektivy 2005 v sekci Aplikovaná informatika.

Klíčová slova: dynamické modelování, temporální analýza, vyhodnocení dynamiky, temporální prostor

Dynamical GIS

For GIS, as a tool of decision support, it is very important to incorporate and to be able to use the dynamics of objects and phenomena starting from the temporal database creation and finishing by the development of new approaches and methods focused on the analysis of the objects and phenomena around the temporal axis. Dynamically oriented system tends to introducing of the temporal state and development of the objects and phenomena. Mathematical model considers usually simplified assumptions and estimated parameters to be able to fulfil some practical conditions of the definite task domain. Using of this model for different range of tasks, it effects in the significant inaccuracy in different parts of evaluation and trend analysis and interferes with the stability of the model.

Apart from the fact that there are many difficulties with dynamics, modelling the geo-information processing tends to the temporal GIS (Claramunt, Thériault 1996; Claramunt et al. 1998). It means the system that has to its disposal not only the thematically oriented static picture of the service area but it will be able to use the regularly and systematically processed data from the point of landscape development, trends evaluation and behaviour modelling of all objects and phenomena and map temporal consequences.

Thanks to the Mobile Internet GIS, Mobile Web Map Services and Mobile Web Analytical Services that facilitate the acquiring of data, it is much easier to monitor and map the temporal states of the objects and phenomena.

ACCESS TO DATA

Mobile Internet GIS

It is a new solution that offers mobile Internet access to the data including their updated versions. The accessible technologies:
– GeoMedia Technology
– Mapserver.

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Mobile Web Map Services

WMS provide the transmission of maps that are composed under the demands and the transfer of map attributes is utilized. WMS works with the standard picture format (PNG, JPEG) specified by the set of input parameters even in the case when the partial maps come from different Web Map Servers.

WMS have the access to the raster data orthophotomaps. WFS (Web Feature Services) provide the access to the vector data.

Mobile Web Analytical Services

Web Analytical Services make possible to process and analyze spatial data through internet and mobile internet. This system increases the access to information for the management in the field of forestry, agriculture, regional development, environment protection and others. The mentioned technologies (Mobile Internet GIS, Mobile Web Map Services, Mobile Web Analytical Services) can significantly increase the processing effect because they make possible:

- to increase the speed of finding information (phase of collection)
- to increase the ability to analyse the large files of information (phase of analysis)
- to increase the effect of the context evaluation (top analysis)
- to increase the effect of the presentation (distribution).

The speed of the reaction is the critical factor of competitiveness, the amount of information sources and the amount of the potential important information included with them continually increases whereas the ability of people to absorb new information continually decreases. It means that the signification of intelligent information technologies expressively increases and the spatial temporal data analysis allowing spatial temporal evaluation of information opens the new possibilities for decision support.

TIME AND GEOINFORMATION

Temporal slices

The understanding of time and space as an integral reference brings a lot of problems with the necessity to solve them. The significant part of problems is connected with the temporal slices creation (Goldberg 2003; Huang, Shibasaki 2003) and consequently with the processing and analysis of temporal data, integration of dynamical models into existing global geographical environment. To generate temporal slices, it represents the interpolation of temporal layers and suitable integration into the spatial resolution (Cui et al. 1993; Huang, Shibasaki 2003). It is evident that the method of the nearest neighbour will not sole this task. Moreover, we have usually to our disposal only temporal fragments to describe the continually changing natural objects.

In practice, it will be necessary to create different dynamical models with respect to the different approaches how time is considered. For example, 3D model (Goldberg 2003) – see Figure 1 – can be used to the processing of temporal data sets. This model looks to be very simple but the processing and storing of the temporal layers of the observed area have to solve the problem of changing class, which the object belongs to with the accounting of temporal and spatial continuity (Figure 2).

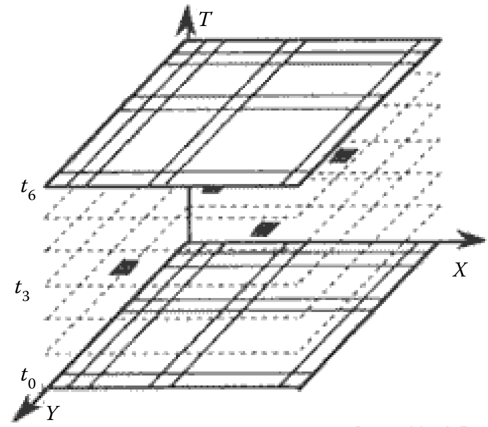


Figure 1. 3D spatial-temporal model

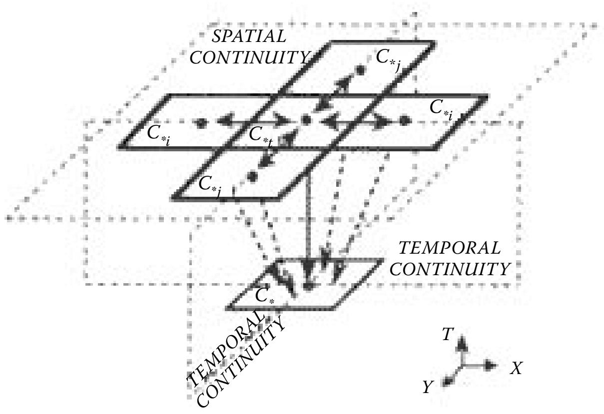


Figure 2. Spatial-temporal relation of belonging to the class (pixel-oriented concept)

There are two types of methods for the selection of class where the temporal object belongs:

– the estimation of time of the change using the distance from the class boarder
– the estimation of the probability of belonging to the class using structural model focused on some class property – expansion, contraction or others.

The first one is highly dependent on spatial temporal relations between classes surrounding the analyzed pixel.

Temporal-spatial relationships

For the creation of different models, it has to be clear in the basic temporal and spatial relations. It looks that very practical for these purposes are Allen temporal operators (Allen 1984) that define relations between the temporal intervals.

Time is considered to be a continual valuable, T is the set of measured times that corresponds to the set of real numbers and I is the set of temporal intervals.

Let i is the temporal interval from I,

$$i = \lfloor t_1, t_2 \rfloor$$

where

$$t_1, t_2 \in T \quad t_1 < t_2 \tag{1}$$

The relations between the temporal intervals of the type: *before, equal, meets, overlaps, starts* and their opposite operators (Claramunt et al. 1998) are arranged in the Table 1.

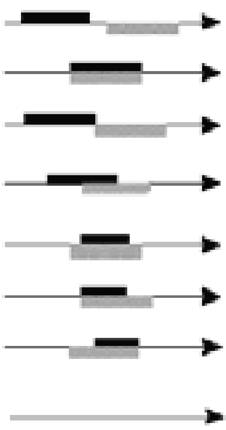
In the similar way, it is possible to introduce the spatial relations in a two-dimensional space. The basic relations like: *touch, inside, covered, overlap, disjoint* between two objects r_1, r_2, where $r°$ and ∂r note the interior and border of the object r (Table 2).

On the base of these considerations, it is possible to create temporal space and to define objects

$$e_1(r_1, i_1), e_2(r_2, i_2), \dots e_n(r_n, i_n) \tag{2}$$

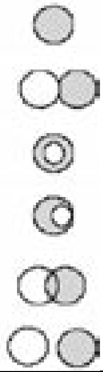
and the concept of interior and border of the interval. Than the algebra can be built for two-dimensional space where the axes are spatial and temporal relations.

Table 1. Temporal operators – temporal intervals



i_1 before i_2	End (i_1) < Begin (i_2)
i_1 equal i_2	Begin (i_1) = Begin (i_2) ∧ End (i_1) = End (i_2)
i_1 meets i_2	End (i_1) = Begin (i_2)
i_1 overlaps i_2	Begin (i_1) < Begin (i_2) < End (i_1) ∧ End (i_1) < End (i_2)
i_1 during i_2	Begin (i_1) > Begin (i_2) ∧ End (i_1) < End (i_2)
i_1 starts i_2	Begin (i_1) = Begin (i_2) and End (i_1) < End (i_2)
i_1 finishes i_2	End (i_1) = End (i_2) and Begin (i_1) > Begin (i_2)
time line	time interval i_1 time interval i_2

Table 2. Spatial relationships between two objects in 2D



r_1 equeal r_2	⇔	$(r_1° \cap r_2° = r_1° \cup r_2°) \wedge (\partial r_1 \cap \partial r_2 = \partial r_1 \cup \partial r_2)$
r_1 touch r_2	⇔	$(r_1° \cap r_2° = Ø) \wedge (\partial r_1 \cap \partial r_2 \neq Ø)$
r_1 in/contain r_2	⇔	$(r_1 \cap r_2 = r_1) \wedge (\partial r_1 \cap \partial r_2 \neq Ø)$
r_1 covered/cover r_2	⇔	$(r_1 \cap r_2 = r_1) \wedge (r_1 \neq r_2) \wedge (\partial r_1 \cap \partial r_2 \neq Ø)$
r_1 overlap r_2	⇔	$(r_1 \cap r_2 \neq r_1) \wedge (r_1 \cap r_2 \neq r_2) \wedge (r_1° \cap r_2° \neq Ø)$
r_1 disjoint r_2	⇔	$(r_1 \cap r_2 \neq Ø)$

Source: Claramunt (1998)

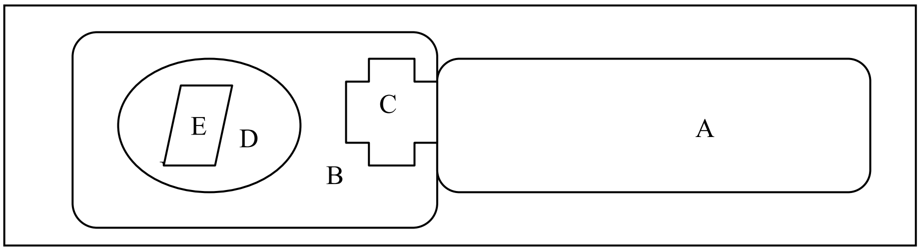


Figure 3. Spatial objects

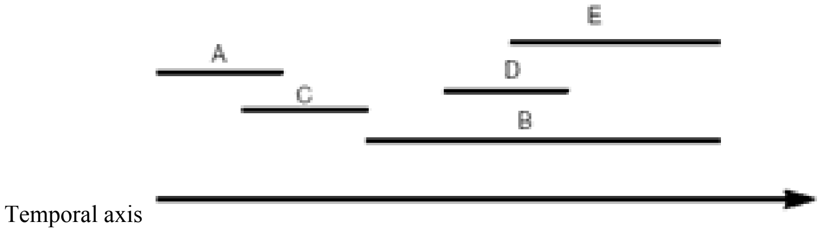


Figure 4. Temporal relations of objects A, B, C, D, E

See the example on Figure 3, 4 and corresponding Tables 3, 4 and 5.

Table 3. Spatial relations

	A	B	C	D	E
A	equal	touch	touch	disjoint	disjoint
B	touch	equal	cover	contain	contain
C	touch	covered	equal	disjoint	disjoint
D	disjoint	in	disjoint	equal	contain
E	disjoint	in	disjoint	in	equal

Table 4. Temporal relations

	A	B	C	D	E
A	equal	before	overlaps	before	before
B	after	equal	follow	contain	finished
C	overlay	meets	equal	before	before
D	after	during	after	equal	overlaps
E	after	finishes	after	overlay	equal

Table 5. Relations in the temporal space

	A	B	C	D	E
A	TOT	DISJ	TCH	DISJ	DISJ
B	DISJ	TOT	TCH	CN	OVL
C	TCH	TCH	TOT	DISJ	DISJ
D	DISJ	IN	DISJ	TOT	CVR
E	DISJ	OVL	DISJ	CVR	TOT

The identification of relations in the temporal space makes it possible to analyse the object transmissions in space and time.

CONCLUSION

The concept of temporal space is the great contribution to the modelling of spatial temporal relations of geo-objects and can be incorporated into the frame of the observed neighbourhood and change specification as touch spatial as well as temporal relationships investigation. Very probably it will be necessary to create specialized spatio-temporal models (May Yuan 2004) for the selected classes of tasks with the defined demands for objects with highly dynamical behaviour.

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