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Spatiotemporal Model for object geometry prediction and reconstruction in Hausdorff space to empower GI and environmental systems with a time synchronization tool

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ABSTRACT

Almost in all environmental studies, mainly in land use planning projects, natural objects should be assumed temporally. While temporal modeling oftentimes is interested in non-environmental planners specifically in a mobile object or rarely in temporal cadaster, environment experts themselves issue the idea due to additive thematic description for eco-objects or physical and less time temporal logical layers.

In environment studies according to nearly long lifecycle, it is not possible to collect all required datasets regarding unique time spots. Whereas deploying datasets without time interoperability in geometric structure leads to significant output errors even more than thematic ones, they should be synchronized.

Geometry post-diction, however, would lose data quality and in addition, is not usually possible according to data diversity but a prediction would cause both, overall data quality improvement through the synchronization and constructing unknown prospective of features' geometry.

In this paper, firstly based on similarities in environmental systems and Hausdorff space, a topological conceptual framework was planned in which let us find a practical solution to continuous geometric reconstruction on any arbitrary time closure.

Secondly, different predictor methods have been considered and suitable ones regarding geometrical changes were selected. Then based on practical objectives and suitable ontological concepts, a storage data model was designed capable of feeding prepared dataflow to predictor algorithms' entries.

"Mighan" Lake, in the middle of "Markazi" province of Iran, was then selected whereas in recent years, due to intensive desiccations, it has been shrunk and has considerable changes in its geometry. Under a stringent preparation flowchart, datasets regarding three different time spots in the past and newly acquired data for testing scope were handled and prepared.

Based on prepared models, ontologies, and predictor algorithms, software was implemented that uses functional language for the sake of decreasing process burden and simplicity in future development. Results conveyed acceptable matching between predicted and real object geometries as opened up new challenges to discuss and research more.

Key words: Engineering hydrology, Spatio-temporal objects, GIS Analysis, Automotive Engineering

1. INTRODUCTION

Thinking about the 4th dimension long ago was previously fired by computer science experts that innovated practical techniques for databases to store temporal data. (Babbage Institute, 1959), (Codd E F, 1970). Deploying temporal dimension in the GIS field firstly was aimed at the presentation level, combining with animations. (Chang S-K and Fu K-S, 1980). During the decade of 1980, the fundamental structure of the 4^{th} dimension in GIS databases practically was based due to developed software solutions. (M, 1985), (Aref W G and Samet H, 1991). Time-coupled architecture or integrated extra dimension structure, since then, affected new database designs such as what has been implemented in POSTGRES DBMS. (Stonebraker M and Rowe L A, 1986).

Although modeling space and time primarily was used for point-based objects and just for representation scopes, new trends towards analysis over polygon and linear-based objects beyond the previous motivations have been already begun. (Xu J and Güting R H, 2013)

Indeed, time and space are strongly interwoven as they should treat completely continuum rather than splitting them as 3 dimensions of space plus an extra dimension of time. Historically, the development of algebra and algorithms sourced from the Islamic law of inheritance led to precise portioning of space. Meanwhile, Calculus was developed to study the motion of objects under forces in time. (Brimicombe Allan, 2010)

It should be reminded that even 3-dimensional data has recently been added to GIS practical participation and there is still lots to do just manipulating 3 dimensions rather than 4^{th} dimension which intuitively differs from space.

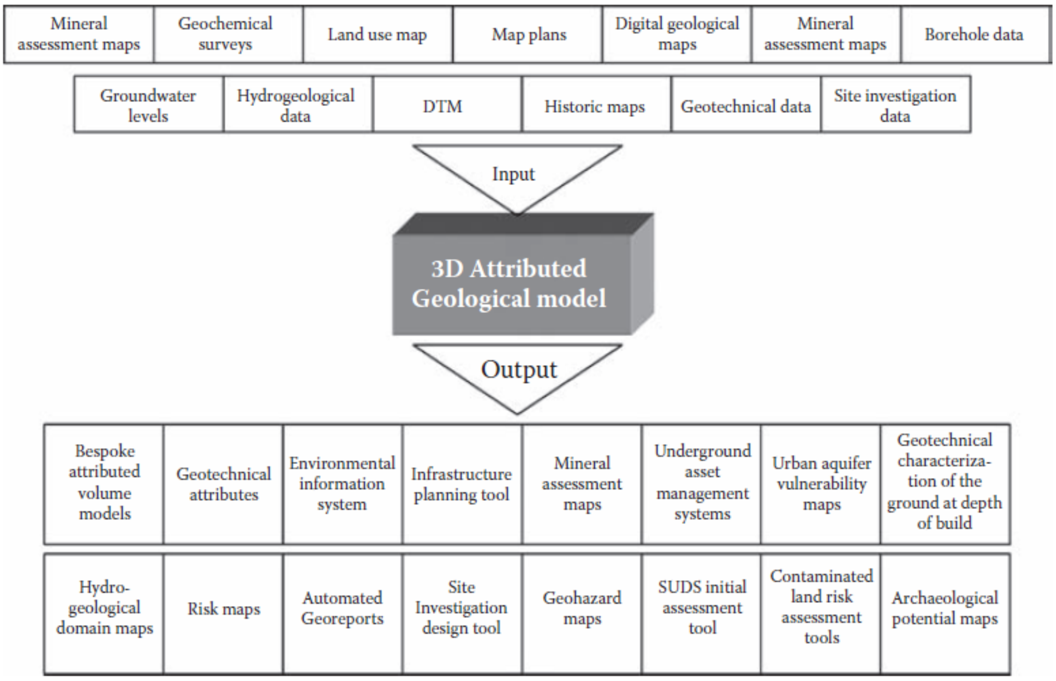


Figure 1. Several 3D product objects based on input data by the British Geology Survey

The figure above illustrates several inputs and their consequence outputs of 3d modeling project which has been conducted by the British Geology Survey to form a 3d model that concerns the hydrological and geological structure of Britain. (Royse, K.R., Rutter, H.K., and Entwisle, D.C., 2009)

In the context of environmental studies, furthermore, almost all phenomena subjected to models treat according to the time. In the other words regardless of defined ontologies, any environmental object exhibits variable properties and even behaviors according to its location on the space-time dimensions (Maroufan, et. al., 2019; Kryukova, et. al., 2021).

Although dynamic thematic properties of objects are very important to simulate systems, and it has been covered in many pieces of research (Brimicombe Allan, 2010) but very few have noticed to dynamic nature of spatial object properties. Indeed, almost all natural objects have dynamic and variable borders too. Such floating nature of object borders critically affects the whole thematic and all the other consequent behaviors. Therefore, it is vital to care about it even more than other objects' aspects.

Mobile objects as a point e.g., have been studied well deep in all aspects while few objects in nature act as points. In addition, most cases assume to earn position via sensors online or due to recorded files. This differs from what happened in nature.

Meanwhile, besides the development of integrated GIS and environmental modeling software, there is a crucial need for something more than temporal storage of the observed location of objects. How to deal with variable objects located in the context of space-time dimension, revolutionary from the other system simulation aspects. In environmental issues, of course, there are more to be worried about.

In land-use planning studies which are among the most important environmental activities, according to study lifetime which is usually spanned between 2 to 5 years that would be very difficult or impossible to set time interoperability among different data sources. Consequently, whenever two different datasets with two different time validities, each regarding different time closures, are processed together, result output won't be able to pass accuracy tests. (Heuvelink, G.B.M., 1998)

Eventually, it was planned to develop a Spatio-temporal model, which can be applied not only with point-based objects but also linear and polygon-based ones. Besides the ability to store spatiotemporal objects, such a model should endow potent processes to objects with unstable borders or even mobility.

Furthermore, to solve the time interoperability among different interwoven datasets associated with spatial analysis, it is necessary to develop a predictor module that has been expertized to synchronize and adjust different objects' borders to the time of the process.

2. Related Works

A basic simple model categorized different properties of an object into 3 main groups including space, time, and attribute as a cube. (Sinton, D.F., 1978) Sinton described how the dimension of the cube interchangeably could be fixed, measured, and controlled. It means among time, space, and attributes, one should be fixed, one should be selected and the other one is surveyed.

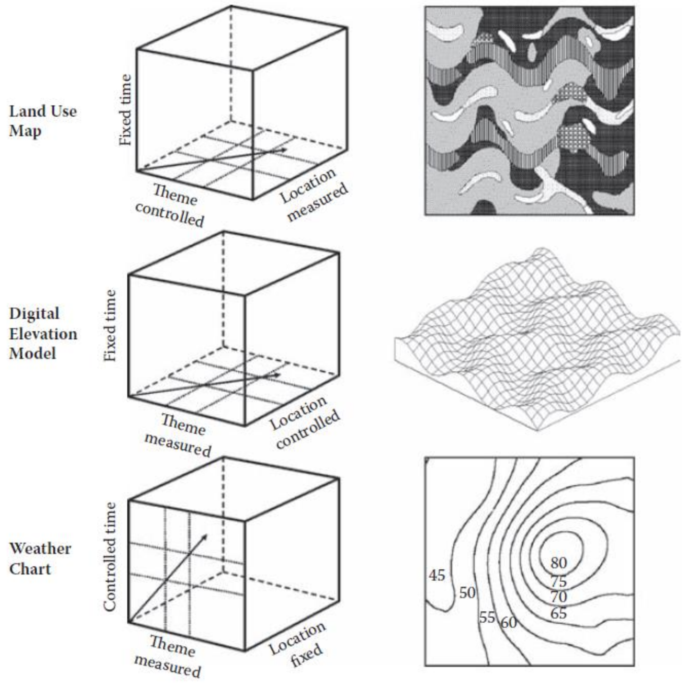


Figure 2.3 main folds of GIS Geodata: Thematic, Location and Time

A serious Temporal GIS model was launched by issuing temporal conceptual models. (Langran G and Chrisman N R, 1988). Since then, Spatio-temporal data models have been developed according to different applications. Each model is proportion to application and thus has its ontology. Simulated interaction in such models mainly arises from different aspects. While some focus on the mobility of objects, others express on event domains, some on tasks, and the others take the movement itself.

By expansion of Spatio-temporal interests, now it is possible to recognize a different group of models. A primary classification was proposed according to data nature; Raster based, Vector based, or a hybrid approach. (Peuquet D J and Duan N, 1995), (Claramunt C and Thériault M, 1996), (Tryfona N and Jensen C S, 1999). An interesting classification includes six different groups: (Yuan M and Stewart Hornsby K (eds), 2007) process-based, changed-based, event-based, activity-based, time-stamped, and movement-based.

In more recent research, six elements have been emphasized to define spatio-temporal objects. These elements point to movement, mutation, extent, attribute, evolution, and finally location. (Bothwell J and Yuan M, 2011).

Altogether if all efforts during the last 3 decades are considered, then some general trend in Spatio-temporal modeling would be distinguished among different opinions. The simplest modeling is pointing out to snapshot time perspectives (Armstrong M P, 1988), simple time stamp (Hunter G J and Williamson I P, 1990), delta time correction vector (Langran G, 1992), object-oriented approach enhanced by time (Worboys M F, 1994), domain-based modeling (Koncz N A and Adams T M, 2002), models with special focus on events (Worboys M F, 2005), process-based model (Goodchild M F, Yuan M, and Cova T J, 2007), event-based modeling concepts (Worboys M F, 2005), semantic-based models (Zheni D, Frihida A, Ghezala H B, and Claramunt C, 2009), models which are based on features (Maldonado Ibañez A and Vázquez Hoehne A, 2010) and among the latest works, are those which are controlled by ontology concept. (Gantner F, Waldvogel B, Meile R, and Laube P, 2013)

Integration of time to current static GIS was pursued by so many to simulate the realized modeling in GIS. Whereas GIS is the joint appealing point for different sciences and is used to model the real state of phenomena to support their research areas, providing the system with the real dynamic status of an object is emphasized. To achieve a Temporal GIS, geography, computer science, and also information systems together have been utilized. (Time Biography, n.d.)

Most of the activities in ting time to objects emerged from usual daily individuals' activities. E.g. it would be a simple routine to lay a schedule for everyone and act according to it. But it would rise to prominence when it is tried to model this plan not only by deployment of a kind of inventory fold but also by an object model diagram in the context of the object-oriented environment. (Stewart, 2013)

The digital environment includes some kinds of calendars with different time granularities. (Ashiru O, Polak J, and Noland, 2004) (Adnan M and Watling D, 2011). The goal of such activities was to develop such temporal model which can store temporal events for digital calendars while storing locations explicitly without scoping for spatial analysis. Such models would be interpreted as just temporal models in contrary with ontology-based models which have the capabilities to emerge reasoning for both types of conflicts; spatial or temporal. (Stewart, 2013). Such modifications would be able to optimize spatiotemporal connections between events and individuals.

Such activities primarily were tracked as human activities patterns and movement behaviors. (Kwan M-P, Janelle D G, and Goodchild M F, 2003), (Dodge S, Weibel R, and Lautenschutz A K, 2008), (Shaw S-L and Yu H, 2009). Then, lots of efforts have been done to execute primary research with applications (e.g. where a specific person would reach a specific time) that have been covered with titles such as space-time prism and so on. (Miller, 1999), (Timmermans H and Zhang J, 2009).

About 3 to 5 years ago, a trickle was fired to start time-space joint activities which are conducted by a group of individuals. (Neutens T, Versichele M, and Schwanen T, 2010)The result of such efforts now can be observed in a vast group of mobile applications. Others extended such efforts with more interesting applications such as the price of the trip, time of the trip in joint activities within urban areas. (Fang Z, Tu W, Li Q, and Li Q, 2011). To afford it, computational models were developed significantly to serve synchronized joint activities. (Neutens T, Versichele M, and Schwanen T, 2010), (Fang Z, Tu W, Li Q, and Li Q, 2011).

To develop more efficient models, some used multiple ontological temporal models at different scales which are connected. (Duce, 2009), (Yang L and Worboys M, 2011). They used three different temporal ontologies as domain, application, and task ontology which were crossed by three other classes to reasoning changing in the schedule. Such applications were able to modify individual schedules via "move up", "get closer", "postpone it", and such these terms. While the most focused on stationary objects, the challenge for the scholars was about moving objects such as demonstrations and parades.

In recent activities, scholars have focused on applications that are based on the enhancement of individual physical locations. (Yin L, Shaw S-H, and Yu H, 2011). Such applications, search the individual activities throughout the space-time looking forward those methods, one can affect his environment even much more than his presence lonely.

Although general top-level ontological frameworks were used in different applications, some develop more specified ontologies such as domain and task ontology that have been designed for indoor and outdoor (I-Space, O-Space) applications. (Yang L and Worboys M, 2011).

Some other research held on fundamental ontology as DOLCE and have tried to add a plan ontology to its foundation as DOLCE+DnS which focuses on the task, their sequential manner, and controls which should be applied to that tasks. This ontology refers to some tasks, roles that can be distributed among persons, and at least one ultimate goal. Of course, some others have tried to extend DOLCE using Information objects. Information object is a social object which can be felt in different ways by different persons. (Gangemi A, Borgo S, Catenacci C, and Lehmann J, 2004).

In contrary to what has been done in joint applications, mobile applications, have a stronger focus on personalized and contextualized spatial responses. (Yu S and Spaccapietra S, 2010). Their challenge is to form ontological models to provide the users with spatial and dynamic information. In such applications, context awareness is an important key that must be taken into account.

The other trends were started on new concepts such as agent-based models (Bennett D A and Tang W, 2006), spanning lifetime (Nixon V and Stewart Hornsby K, 2010) and graphs idea (Del Mondo G, Rodríguez M A, Claramunt C, Bravo L, and Thibaud R, 2013).

A proposed methodology to support scheduled events and switching among those events, includes three main classes, one for planned activities, the other for schedule itself, and the last for fixed scheduled events which are located by application. Planned activity includes event name, start and end time, and date. The schedule contains, event owner, duration, and event owner. The fixed schedule contains all, of course without any invention and planned as well as possible. It is possible to have some persons at the same time manage schedules too. (Fang Z, Tu W, Li Q, and Li Q, 2011). This has been done accordingly based on triple ontology works together; domain ontology relates to realm and location of events, task ontology which indicates events in space-time, and of course an application ontology for scheduled activities. Such ontologies would be easily taken from Basic Formal Ontology (http://www.ifomis.org/bfo/, n.d.).

3. Proposed methodology

The solution consists of a conceptual model of three main blocks, work concerning each other. These are data-providing networks, Spatio-temporal storage, and simulator blocks.

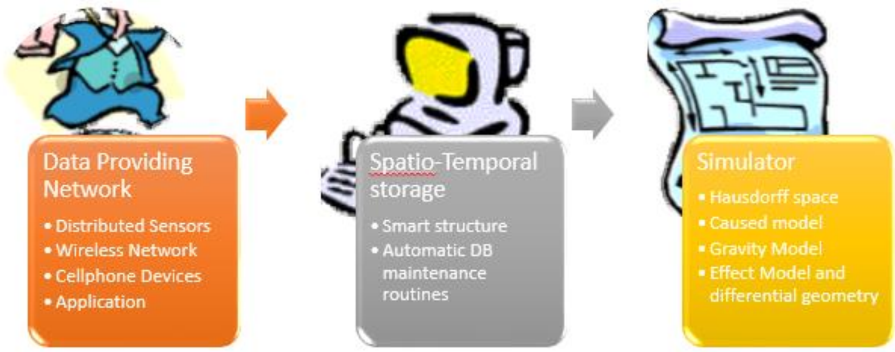


Figure 3. Overall proposed Spatio-temporal model includes 3 block divisions

In an object-oriented simulated environment, any object contains its specific properties and behaviors include geometry. The main geometry type, regardless of the intrinsic nature of objects, would be inherited from the point type. Therefore any object type will occupy a unified or more location in domain space.

In the real world, all objects are continuously changed on the time dimension. Of course, almost every object's specifications are altered but by different time sequences or intervals. We can define a space, contains all different object properties as its dimension, but by now, it is preferred to focus on just geometry instead.

Geometry displacement in each object has its reasoning, which would be interrogated in the context of a causal model. In such modeling issues, an inventory of all affluent parameters are enlisted and then their impacts are simulated via proper tools.

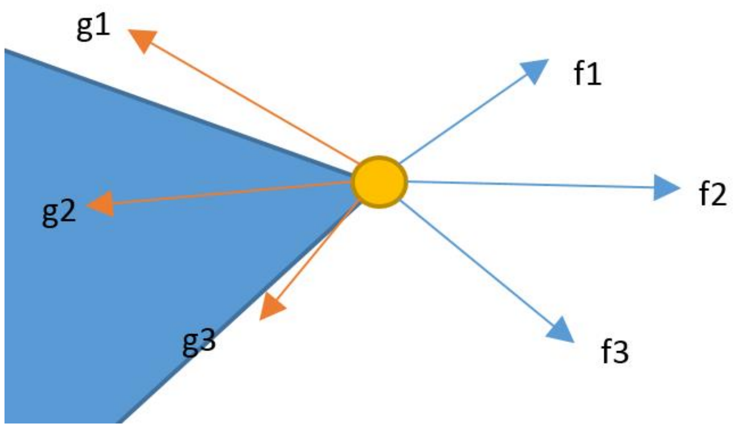


Figure 4. Each object vertices are under the effect of internal and external forces

Any of the effluent parameters form a movement vector, as is shown in the above picture, the final movement will emerge from primary composer vectors.

It is also possible to mime the behavior in one upper abstract level deploying the gravitational model. Nevertheless, developing mentioned structure would engage so many scientific and technical problems.

The other solution, the effect modeling concept, focuses on miming real movement vectors. In this methodology, displacement vector reasoning is ignored, instead it is tried to simulate its movement via the geometric solutions.

Different algorithms including, SOM, EM, Growth, Genetic, CFP would be examined against real data points. Then a new approach is proposed according to the nature of real phenomena. Curve studying in differential geometric space would best fit desired but the problem arises somewhere else.

Indeed continuum movement curve of an object does not obey the regular simple form of a curve, and therefore the differential structure is necessary. In addition, any tangent can predict object geometric location just a few times sequential after the precise acquitted point. Therefore a set of located precise points as constraints to control the behavior of any individual curve is vital.

In a Hausdorff space, assume adjacent objects, where any internal or external forces, keep topological relation, just would replace the exact position of object vertex. Therefore we could be assured of the existence of points for a time division. This lets to lay some predefined points without any attribute assigned, in space which are occupied by object bodies. Thus two adjacent objects with the same split borders would have common points snapped.

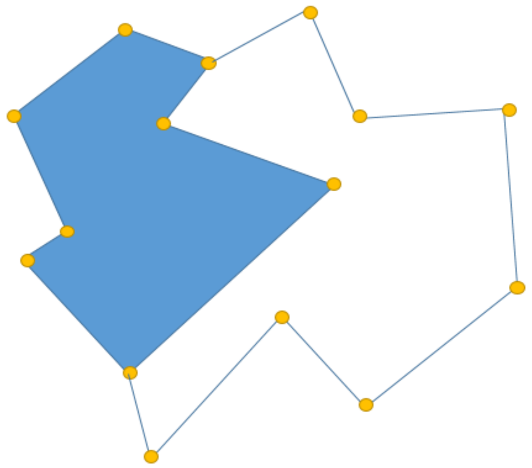


Figure 5. Topological based model for land use cover

As the simulator algorithm moves the point in space, consequently object bodies will change their geometry status whereas they have tied themselves to mobile points.

Spatio-Temporal Storage segment

The other challenge is to do semantic structure for the operational maintenance of constraints. However logical structure should support simple access of computational modules to constraints. The main concept is to design which behaves smartly. Whereas there are considerable changes in point's locations during the time, so a daily bulky update routine to the database (where keeps feature foot print's locations) would be inevitable. Such obesity in database log size directly causes speed depletion in database operation and in addition, it decreases modules performance which accesses data in the database due to huge data that should be processed.

Such logical structure can decrease database log size via smart database maintenance mission. This would be done due to automatic database log reduction in which keeps primary data value. A cognitive algorithm before simulator modules defines data importance and priority so that data maintains its primary capabilities to simulate behavior.

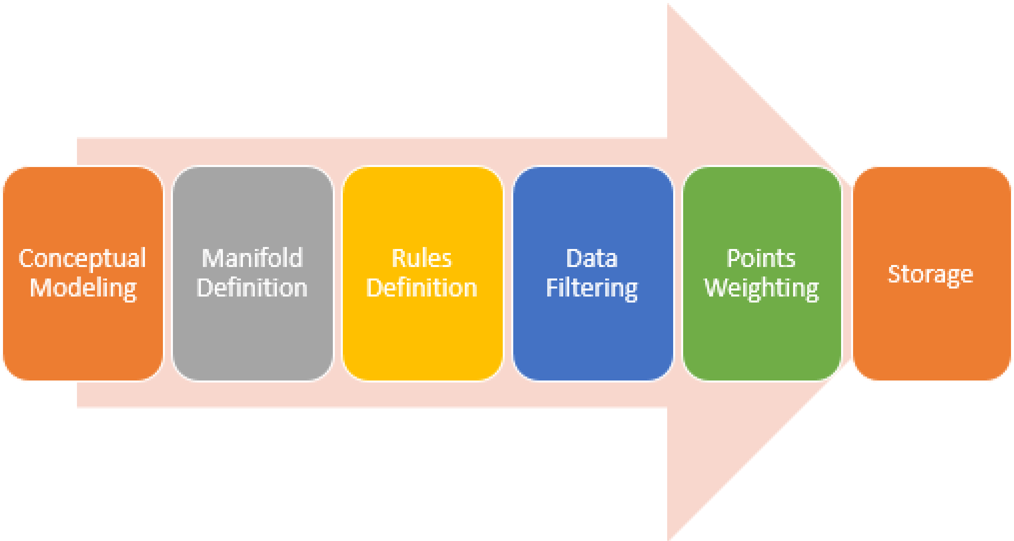


Figure 6. Block diagram of the data storage division

Besides data priority and importance issues, a filtering mechanism is mandatory to remove data blunders and mistakes. Different techniques would be used in data mining but the prosperity of each method strongly depends on the intrinsic of data itself.

Whereas input data reflects the natural phenomena description, a proper method should be defined well-matched with the nature of phenomena behaviors. To do it a manifold is defined which represents environment status, and each arbitrary single vector, that is a single environmental observation, is compared against the manifold.

The comparison process deploys a combination of network, rules, and structural aspects of neighborhood methods.

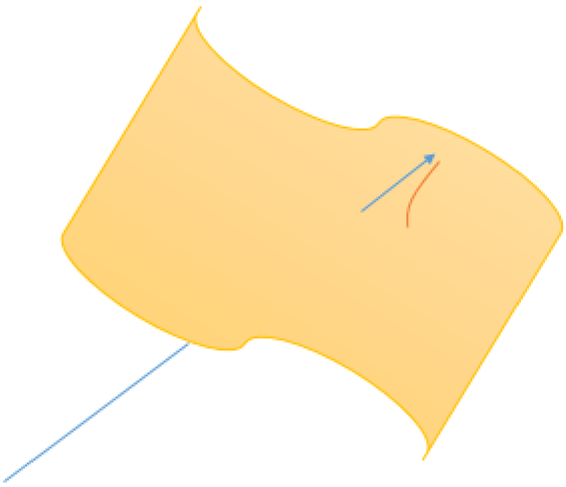


Figure 7. Local curvature of any arbitrary points

E.g. local curvature of a given single vector in its small neighborhood area, in respect to the manifold, is assumed as a criterion. It would be checked piece wisely to the predefined rules on a different part of manifold to evaluate validation of local rules. So if any vector passes this check, will be accepted as the correct observation.

Data providing Network

The third block is devoted to the data acquisition division which mainly fosters the whole structure. In the real world, there are so many problems associated with spatial data capturing issue which significantly restricts the success of a simulator system. To solve it, a subsystem is required to be responsible for spatial data providing. The subsystem provides data based on a distributed network of sedimentary, potable, or mobile sensors equipped with different environmental sensors.

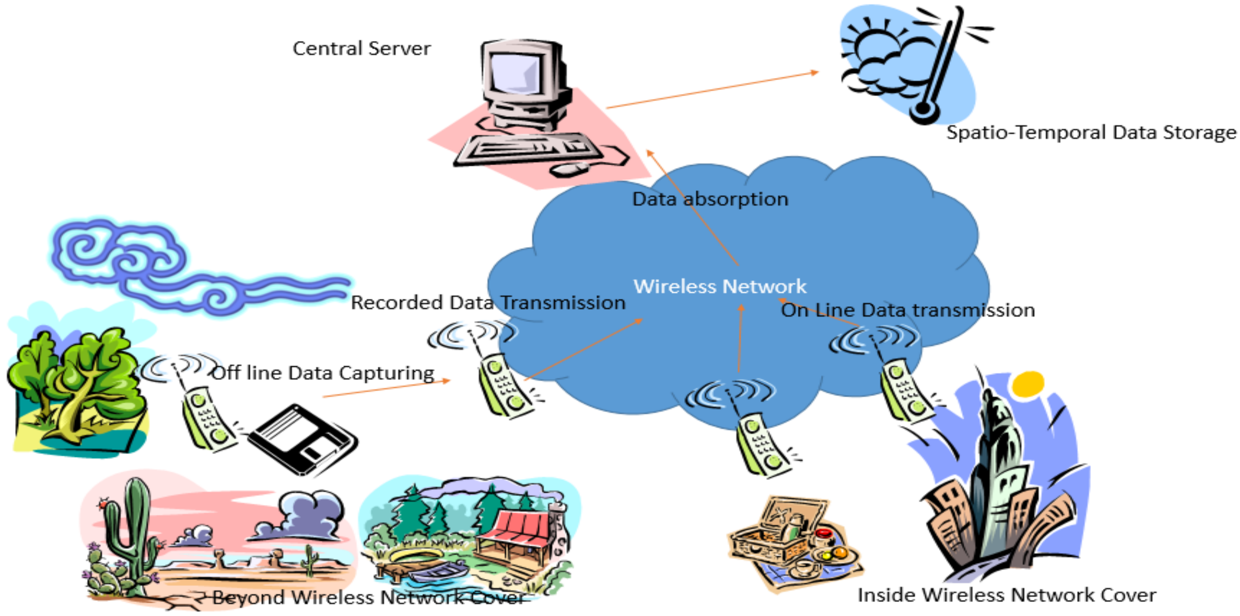
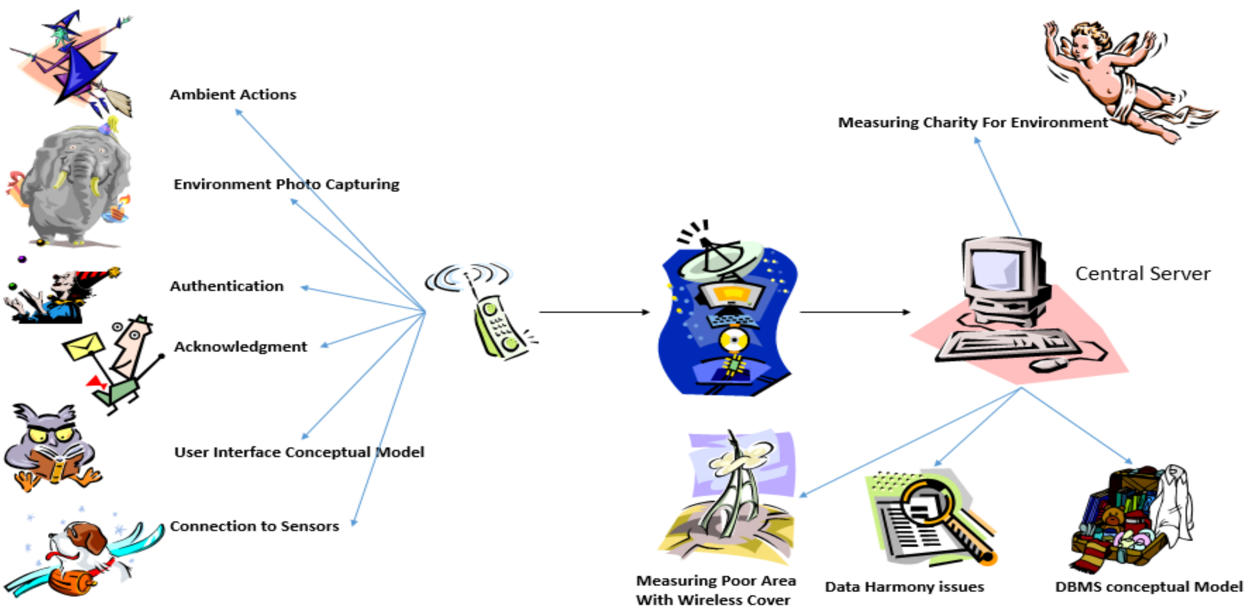


Figure 8. Diagram of Data Providing Network Block

In so many countries, there are not any governmental investment resources for adequate environmental sensing infrastructure. To make up for insufficient infrastructure equipment, a complex distributed network is proposed, composed of some inter-related physical objects in 3 main categories.

The first category includes sedimentary cheap sensors which transfer environmental parameters via GSM modules to a central database server. The second group is dedicated to those data which is captured due to people's cell phones unintentionally. The third category implies specified applications that have been designed intentionally by force groups to monitor the environmental status, especially for critical situations. The ability of offline-online functioning ensures the whole environment is covered even for those parts of the country with poor or insufficient wireless network infrastructure.

An important notion about all three mentioned categories is the capturing software. Whereas many of the methods are entrance gates indeed, therefore it would be a suitable location to limit data input system to decrease further system post process.



The above picture illustrates key points and potential capabilities related to software division which should be installed on both sides, client and server. In the proceeding part, the geometric simulator will be discussed in more detail.

4. Geometric simulation

4.1 EM Modeling

Curve predictor has long been considered by many. E.g. to simulate growth curve, generalized algorithms such as EM has been deployed. (Potthoff R.N., Roy S.N., 1964) However, for some years, such technique was the target to optimization scopes (Rao C.R., 1987)

Table 1. EM algorithm based concept

Individuals	Time points				
	t_1	t_2	$\cdots$	t_{q-1}	t_q
Past					
1	y_{11}	y_{22}	$\cdots$	$y_{1,q-1}$	y_{1q}
2	y_{21}	y_{22}	$\cdots$	$y_{2,q-1}$	y_{21}
$\vdots$	$\vdots$	$\vdots$		$\vdots$	$\vdots$
$n-1$	$y_{n-1,1}$	$y_{n-1,2}$	$\cdots$	$y_{n-1,q-1}$	$y_{n-1,q}$
Current					
n	y_{n1}	y_{n2}	$\cdots$	$y_{n,q-1}$	?

Such problems simply assume a normal distribution of measurements on time. However, EM algorithms were discovered as a simple technique that could be applied to any arbitrary application. (Liski E.P., 1985)

This technique has been used to predict missing data in datasets. (Hartley H.O., Hocking R.R., 1971), (Orchard T., Woodbury M.A., 1972), (Dempster A.P., Laird N.M., and Rubin D.B., 1977)

4.2 Potthoff and Ray Model

In an early model

$$E(Y_{n\times q}) = X_{n\times m}\, B_{m\times p}\, T'_{p\times q}$$

In the above equation, Y is normally distributed observation matrix, X is the design matrix and T is the regression matrix. Matrix B includes unknown parameters. (Potthoff R.N., Roy S.N., 1964)

The expectation and Maximization algorithm which is known as EM has been referred to by so many since 1970 (Beale E.M.L., Little R.J.A, 1975). Although it is primarily has been used to find missing data, it has significant potential in data prediction too.

(1)

$$L\left(B,\sum Y\right) = -\frac{1}{2}tr(Y-XBT')'(Y-XBT')'^{\Sigma Y^{-1}} - \frac{n}{2}log\sum Y$$

This technique is an expectation approach that is iterative and is done in two steps, expectation and maximization. Although this strategy has been recognized for the prediction of measurements, (Erkki P. Liski, Tapio Nummi, 1990), the normal distribution of data, limits the possible extent of its applications besides the other main problem; it means process load.

4.3 Auto Regressive Model

A logical process prefers to filter data input to remove any noise. (M. A. Farahat, M. I. Abdalla, Z. H. Ashour, 2000), thus a linear filter extracts y(t) from a(t), as cleaned and filter time series data. In the following equation

(2)

$\emptyset(\beta)y(t)=a(t)$ where, $\emptyset(\beta)=1-\emptyset1\beta-\emptyset2\beta2 \cdots-\emptyset p\beta p$

(3)

$y(t-1)=\beta y(t)$

β is a back shifting operator to derive the next observation from the previous one.

The model has indicated acceptable speed in the process but its accuracy critically falls as time spans decrease for future forecasting.

4.4 Moving Average Model

In this model, the current value of the time series y(t) is expressed linearly in terms of current and previous values of a white noise series {a(t), a(t−1),⋯}. This noise series is constructed from the forecast errors or residuals when load observations become available. The order of this procedure depends on the oldest noise value on which y(t) is regressed. A moving average of order q, MA(q), can be written as:

(4)

$$y(t)=a(t)-\theta_1 a(t-1)-\theta_2 a(t-2)\cdots-\theta_q a(t-q)$$

A similar application of the backshift operator on the white series will allow equation (3) to be expressed as:

(5)

$y(t)=\theta(\beta)a(t)$ (4) where, $\theta(\beta)=1-\theta_1\beta-\theta_2\beta^2 \cdots-\theta_q\beta^q$

4.5 Curve Prediction

STLF algorithm has been recently proposed as a simple, fast, and accurate technique (Farahat M.A., Talat M., 2012). The proposed Technique uses the Curve Prediction CP algorithm as the base and deploys Genetic Algorithms to estimate the curve Gaussian parameters.

In recent years some classical methods all based on a mathematical and statistical analysis of time series data have been presented. Classical STLF approaches use regression exponential smoothing, Box-Jenkins, autoregressive integrated moving average (ARIMA) models, and Kalman filters.

In addition, artificial neural networks and fuzzy neural networks as nature-inspired methods have been pursued. (Bansal R.C., 2003) However such back-propagating methods are poor proper in matching realistic situations and also critically low in speed. In addition, they sometimes have serious problems in sub-optimization algorithms too. (H. Mao, X. Zeng, G. Leng, Y. Zhai, and J. A. Keane, 2009)

5. *IMPLEMENTATION*

Case Study, Mighan Lake

To test the proposed solution, Mighan Lake, located in the center of Markazi province along with its surrounding fields selected. This area has a great potential to dispose of proper data that matches our requirements.

During the recent desiccation, there has been a steady downward trend in the lake's depth and its area. Therefore among the natural phenomena, it has dedicated a great potential to demonstrate natural geometrical changes.

Based on primary research and studies, a plan was designed to conduct the research activities.

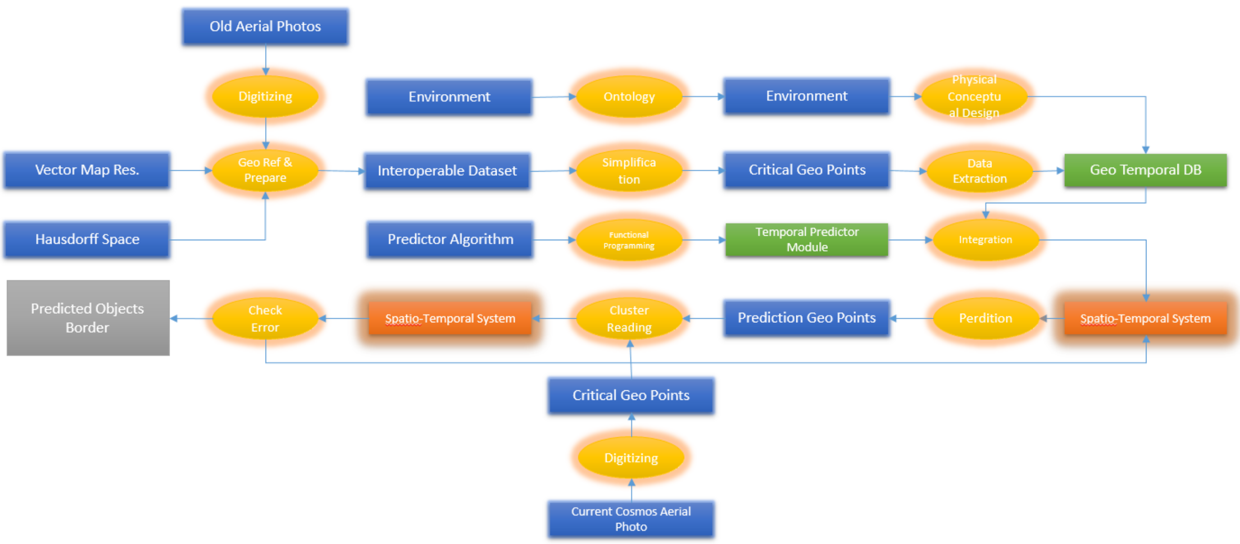


Figure 9. Plan Project diagram of different required elements of the project

Therefore 1:2000 aerial photo of the lake in 2007, beside 1:25000 NCC cover maps which has been produced in 1995 along with the Army Geographic Organization 1:5000 map produced in 1970, gives three-time closures that can be compared against its current situation in 2014. Likewise, the current geometric situation has been extracted from cosmos space photos.

Figure 10 depicts the land use for the year 1995.

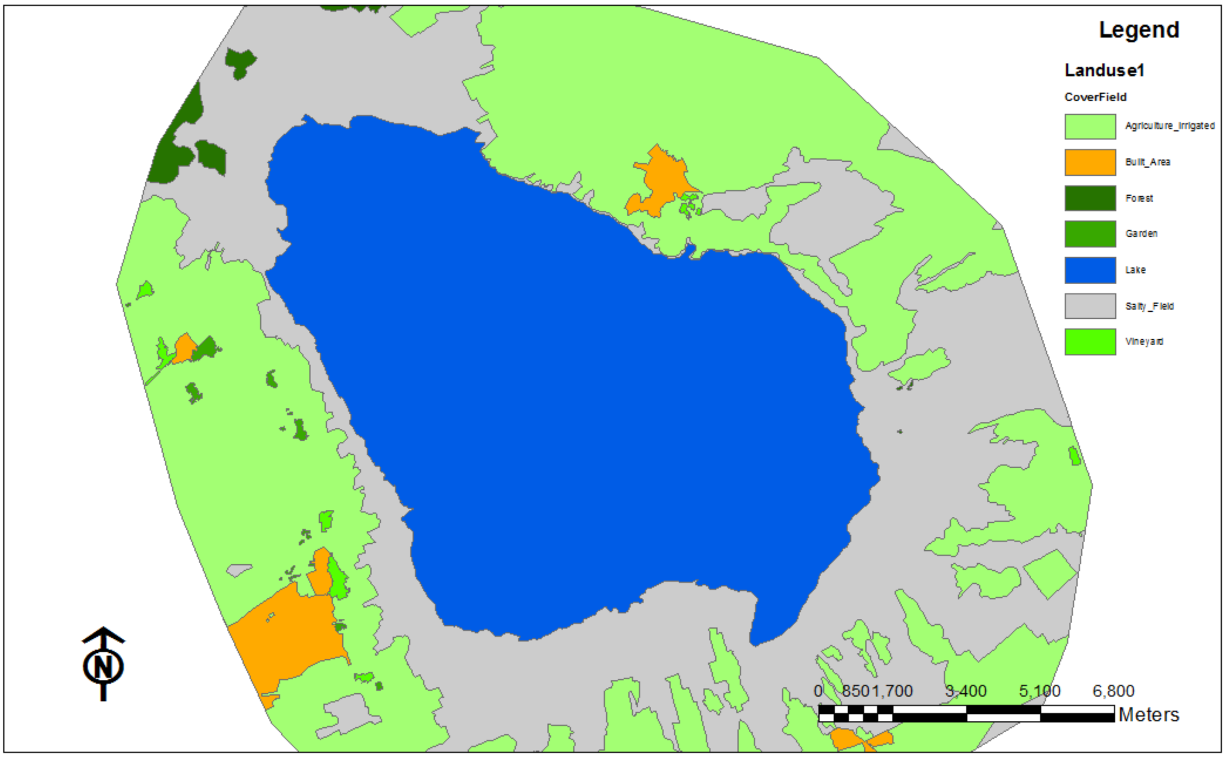


Figure 10. Based Land use map of Mighan Lake and its surrounded area

For the sake of simplicity, the geometric detailed structure of any time closure map was simplified by the point-remove algorithm. This mainly decreases the number of points that have to be processed due to lightening the processing burden and avoiding data intervention.

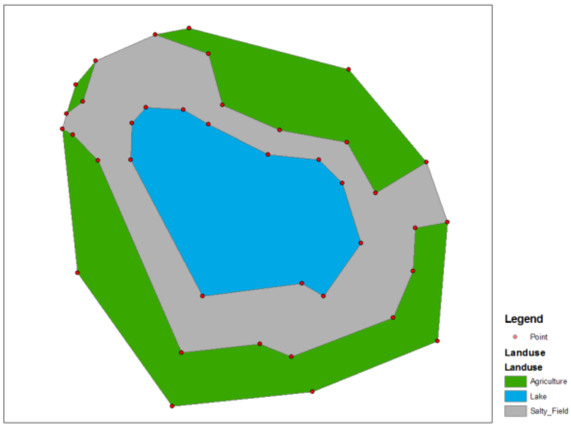


Figure 11. Simplified map

Figure 11 displays the whole lake with its suburb area, which has the same condition as Hausdorff space. Important points rather than extraneous points extracted to form-based computational space while each polygon is aware of points that have been constructed, due to the point's unique number.

39 critical points were selected to be tracked during 3 measured exposure times (in the last 50 years). Measurement of current point positions using last space photo of cosmos, enable us to judge the accuracy of proposed prediction software.

The next graph depicts how temporal and historical point observations form the predicted geometry of a given object to current or any other arbitrary time.

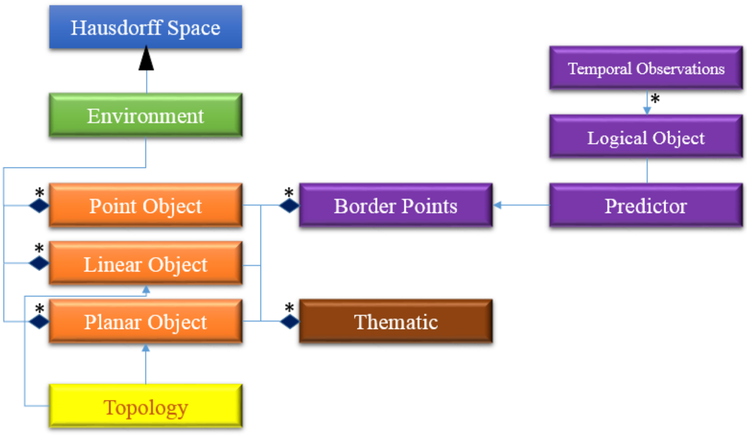


Figure 12. Temporal storage model diagram

As it is clear, any environment object is composed of point, polyline, or polygon features. Those structures also have been made from two important classes; thematic which stores feature attributes and border points which construct the outer hedge of objects. Meanwhile linear object class and polygon object class, both are created under the direct effect of topology class.

Border point class itself is created by an external predictor class behavior. The mentioned class has a relation to a logical object class which is defined by historical observation in temporal observation class.

Based on mentioned UML model, prediction software uses functional language to facilitate computation burden and develop processes, survey any kind of historical data, as much as possible. But actually, there are no serious limitations or restrictions to observations. Observations are stacked in temporal observation class that straightforward forms the logical class.

The software then will be able to construct border point class based on arbitrary algorithms which then reconstruct point, polyline, or polygon features in the environment space.

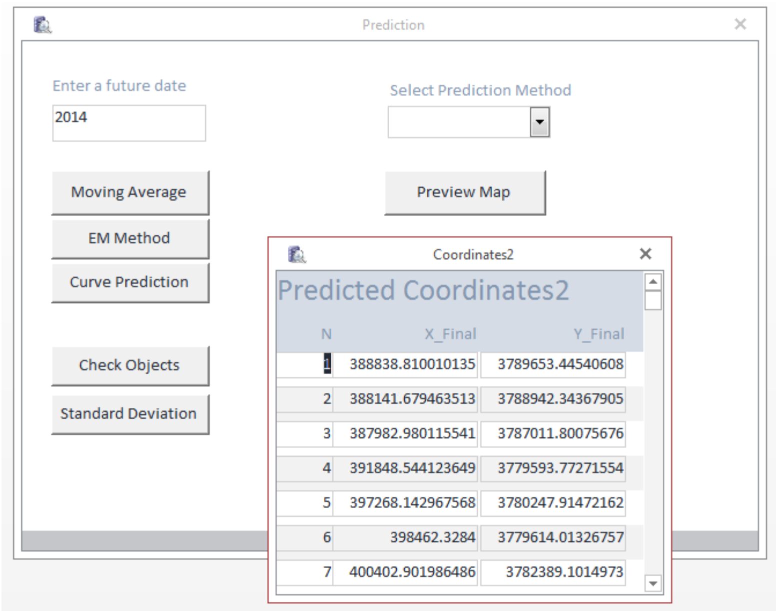


Figure 13. Developed predictor and geometry simulator software

As predicted coordinates are created, border points are updated due to their coordinates and according to topology class, form new object geometries.

Three main methods have been deployed to construct new predicted objects. EM, Curve Prediction, and moving average. The next graph depicts predicted coordinates according to the three mentioned models just beside they affect the geometry of features.

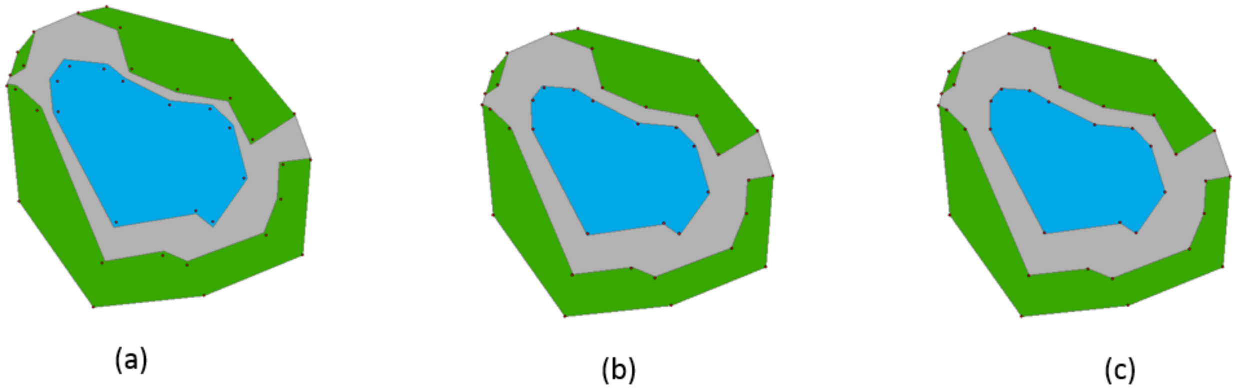


Figure 14.Three different prediction models, a: EM, b: Moving average as diff, c: Curve Prediction

As it is even visually clear in figure 14, curve prediction or short proposed model has highly affected primary points. Further consideration on feature geometries is possible as predicted coordinates affect the geometry and construct new features based on predefined methods on regular time. For example area of the lake has been lost more by using the EM method. Consequently, more fields have been added to agricultural land use again by EM Algorithm.

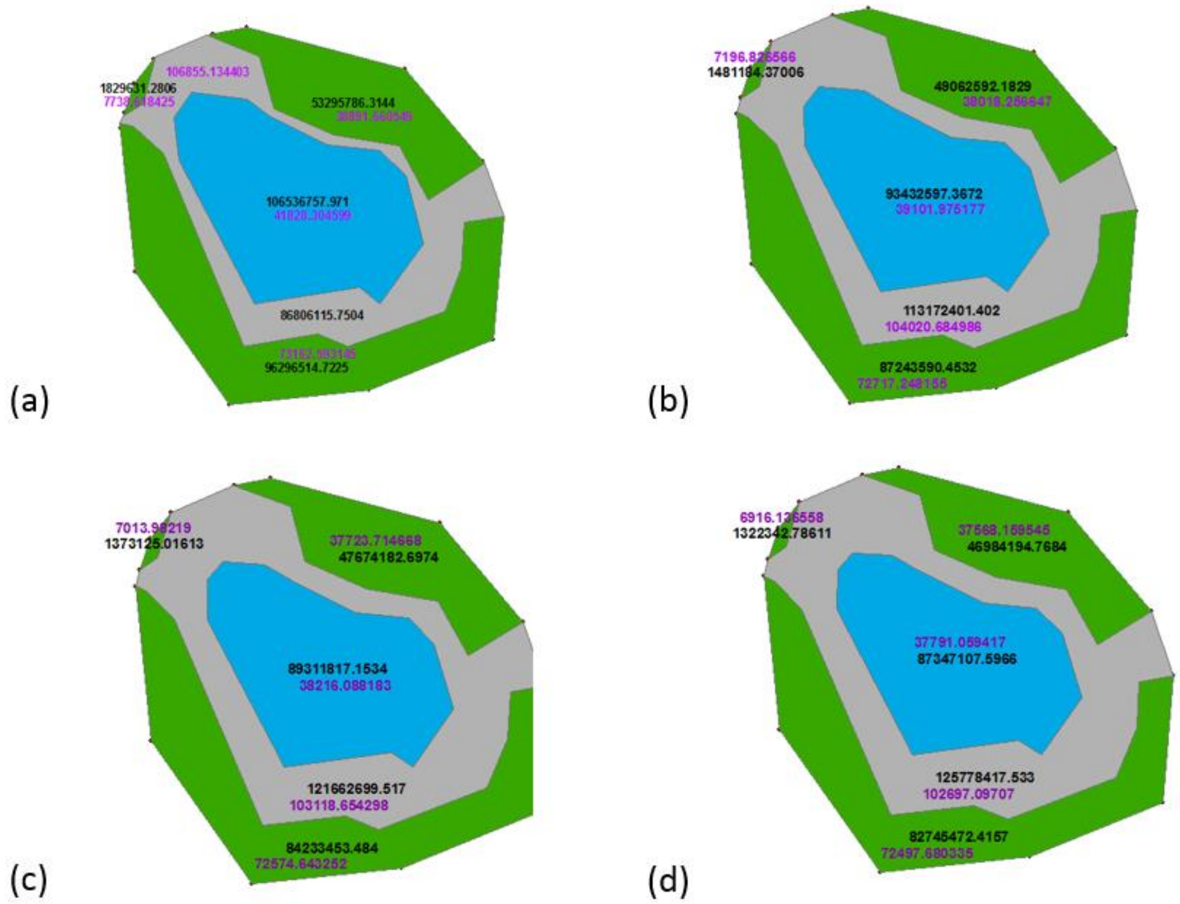


Figure 15. Comparison among predicted features' area and perimeter by different methods; a: Primary state, b: Curve, c: diff method, d: EM

However final evaluation of deployed methods is possible due to feature comparison against the real observed points based on newly captured cosmos space photo. As it was mentioned earlier, the comparison was done just based on 39 selected points. First new points were introduced to software and then they are compared against three methods predicted points automatically.

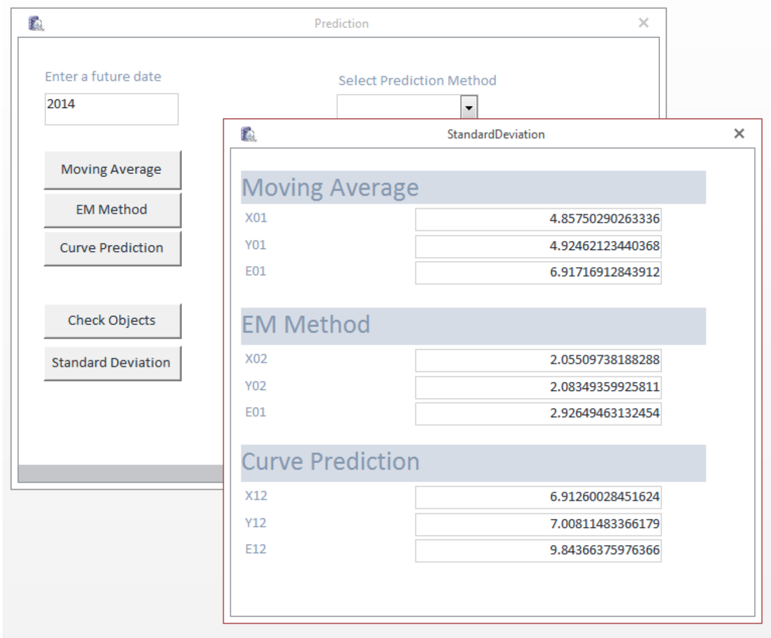


Figure 16. Standard Deviation regarding three different methods, standard deviation has been computed for x, y and both as overall "E"

As has been depicted in figure 16, the results of the overall standard deviation demonstrate the minimum error belongs to the EM algorithm. Field survey ashore of the lake, prove the same result as well. During recent years intensive desiccation has pushed back the lake borders. At the same time, people who settled around the lake have started illegal land tenure around their villages toward ashore.

CONCLUSION

Almost in every related GIS field, objects should be considered in the context of time. Despite the general interest in time, specifically in environment resource fields as in land use planning, all phenomena should be considered temporally. Furthermore for the scope of spatial data analysis and data fusion, regarding the long project lifecycle, data should be set time interoperable. Therefore there is a tremendous need for a Spatio-temporal modeling structure that best suit the environmental objectives.

Many have proposed their point of interest on the Spatio-temporal model especially those who are engaged in the mobile computing field. But their proposals mainly focus on moving objects or their activities and their concepts mainly cover data storage issues. Although there are so many ontologies that have been stated but rarely have notable concepts to be generalized for containing other glossaries.

On the other side even GIS experts in environmental fields which assume the time as an extra dimension and emphasize it in their analysis, often regard it as a thematic description of objects, add it as an extra physical or logical layer in their analysis while geometry remains intact.

Nevertheless, according to most environment processes, an object's geometry should be variant as other properties. It coincides to point, lines, polygons, or even 3D objects. Furthermore, it was dedicated that the Spatio-temporal model would be defined over a simple conceptual model. It would contain three main block diagrams; data providing network, Spatio-temporal storage, and geometric simulator. This paper has been dedicated to discussing geometric simulator elements in detail.

Firstly environment system properties were compared against Hausdorff space and it was mentioned that how topology would be deployed to describe the environment system. Then based on this advantage and according to a practical ontology, a conceptual model was designed to form the environment space.

In continuing with a suitable platform for geometry, predictor algorithms regarding their natures and similarity to objectives were selected as the core of the simulator. These algorithms had to predict the future geometry status of objects at any arbitrary time or synchronize the object geometries to the analysis time.

Meanwhile, another temporal model was proposed to acquire a data feeder and prepare it to enter the predictor algorithm. The intrinsic structure of the model also lets the bulky and fast data computing to algorithms. Therefore proposed model had reciprocal functions.

In addition, regarding conceptual model structure, functional language was used to implement predictor algorithms. This mainly simplifies implementation divisions and decreases the processing burden.

At the next step, different datasets had to be surveyed, collected, and prepared to enter simulator software. As it needed several data entries regarding different software requirements, an almost bulky data preparation line was designed, and then accordingly data was prepared.

Finally developed simulator software was tested against data. Although results depicted that the EM algorithm made objects' geometry more like real ones, but final software was finalized also with other algorithms.

The main reason refers to the natural diversity of different objects in the ecosystem and environment's object. As it is clear, there are so many different objects associated with different geometrical behaviors. Eventually, each object regarding its intrinsic nature in temporal geometry would need a different algorithm. Although different objects were not studied in the software, it would be a proper challenge to study the fitness of different algorithms against real objects.

References

Adnan M and Watling D. (2011). A model of joint choice of activity time, duration, sequence, and route for daily. Ninetieth Annual Meeting of the Transportation Research Board. Washington, D.C. Retrieved from http://am.online.trb.org

Aref W G and Samet H. (1991). Extending a DBMS with spatial operations. Berlin: Springer Verrlag.

Armstrong M P. (1988). Temporality in spatial databases. GIS/LIS'88: Accessing the World, (pp. 880–89). Texas.

Ashiru O, Polak J, and Noland. (2004). Utility of schedules: Theoretical model of departure-time choice and. Transportation Research Record 1894, 84-98.

Babbage Institute. (1959). (CODASYL) Records. Conference on Data Systems Languages. Minneapolis, MN, University of Minnesota Libraries.

Bansal R.C. (2003). Bibliography on the Fuzzy Set Theory Ap-plications in Power Systems. Transactions of Power System, 18(4), 1291-1299.

Beale E.M.L., Little R.J.A. (1975). Missing values in multivariate analysis. Statist(37), 139-145.

Bennett D A and Tang W. (2006). Modeling adaptive, spatially aware, and mobile agents. International Journal of Geographical Information Science(20), 1039-1066.

Bothwell J and Yuan M. (2011). A kinematics-based GIS methodology to represent and analyze spatiotemporal. Nineteenth ACM SIGSPATIAL (pp. 152-61). Chicago: Illinois.

Brimicombe Allan. (2010). GIS, Environmental Modeling, and Engineering. CRC Press, Taylor $ Francis Group.

Chang S-K and Fu K-S. (1980). Pictorial information Systems. Springer-Verlag Lecture Notes in Computer, 80.

Claramunt C and Thériault M. (1996). Toward semantics for modeling Spatio-temporal processes within GIS. Seventh International Symposium on Spatial Data (pp. 47-66). London: Taylor and Francis.

Codd E F. (1970). A relational model of data for large shared data banks. Communications of the ACM, 377-87.

Del Mondo G, Rodríguez M A, Claramunt C, Bravo L, and Thibaud R. (2013). Modeling consistency of spatiotemporal graphs. Data and Knowledge Engineering(84), 59-80.

Dempster A.P., Laird N.M. and Rubin D.B. (1977). Maximum likelihood from incomplete data via the EM algorithm. Statist. Sot. (B39), 1-22.

Dodge S, Weibel R, and Lautenschutz A K. (2008). Towards a taxonomy of movement patterns. Information of Visualization, 7, 1-13.

Duce. (2009). Towards an ontology for reef islands. In Janowicz K, Raubal M, and Levashkin S. Berlin, Springer Lecture Notes in Computer Science, 5892, 157-185.

Erkki P. Liski ,Tapio Nummi . (1990). Prediction in growth curve models using the EM algorithm. Computational Statistics and Data Analysis, 99-108.

Fang Z, Tu W, Li Q, and Li Q. (2011). A multi-objective approach to scheduling joint participation with variables. Transport Geography(19), 623-634.

Farahat M.A., Talat M. (2012). Short-Term Load Forecasting Using Curve Fitting Prediction Optimized by Genetic Algorithms. International Journal of Energy Engineering(2(2)), 23-28.

Gangemi A, Borgo S, Catenacci C, and Lehmann J. (2004). Metokosis Deliverable D07: Task taxonomies for knowledge content. Retrieved from http://www.loa.istc.cnr.it/Papers/D07_v21a.pdf

Gantner F, Waldvogel B, Meile R, and Laube P. (2013). The basic formal ontology as a reference framework for modeling the evolution of administrative units. Transactions in GIS(17), 206-26.

Goodchild M F, Yuan M, and Cova T J. (2007). towards a general theory of geographic representation in GIS. International Journal of Geographical Information Science(21), 239-60.

H. Mao, X. Zeng, G. Leng, Y. Zhai, and J. A. Keane. (2009). Short-Term and Midterm Load Forecasting Using a Bilevel Optimization Model. IEEE Transactions on Power Systems, 24(2), 1080-1090.

Hartley H.O., Hocking R.R. (1971). The analysis of incomplete data. Biometrics(27), 183-808.

Heuvelink, G.B.M. (1998). Error-propagation in environmental modeling. London: Taylor & Francis.

http://www.ifomis.org/bfo/. (n.d.). Retrieved from BFO: www.ifomis.org

Hunter G J and Williamson I P. (1990). The development of a historical digital cadastral database. International Journal of Geographical Information Systems(4), 169–79.

Koncz N A and Adams T M. (2002). A data model for multi-dimensional transportation applications. International Journal of Geographical Information Science(16), 551-69.

Kwan M-P, Janelle D G, and Goodchild M F. (2003). Accessibility in space and time: A theme in spatially integrated. Journal of Geographical Systems, 5, 1-3.

Langran G. (1992). Time in Geographic Information Systems. London: Taylor and Francis.

Langran G and Chrisman N R. (1988). A framework for temporal geographic information. Cartographica(25), 1-14.

Liski E.P. (1985). Estimation from incomplete data in growth curves. Commun Statist - Simula computer(1), 13-27.

M, S. (1985). Interactive graphic data processing in cartography. Computers and Graphics(9), 57-66.

M. A. Farahat, M. I. Abdalla, Z. H. Ashour. (2000). A Neural Network-Based Technique for Modelling and Forecasting of Electric Hourly Load Using Weather Information. Seventh International Middle East Power Systems Conference MEPCON'2000 (pp. 636-641). Cairo, Egypt: Ain Shams University.

Maldonado Ibañez A and Vázquez Hoehne A. (2010). Diseño de primitivas geométricas espacio-temporales paradescribir fenómenos dinámicos. GeoFocus(10), 232-51.

Miller, H. (1999). Measuring space-time accessibility benefits within transportation networks: Basic theory and. Geographical Analysis(31), 187-212.

Neutens T, Versichele M, and Schwanen T. (2010). Arranging place and time: A GIS toolkit to assess person based. Applied Geography(30), 561-575.

Nixon V and Stewart Hornsby K. (2010). Using lifespans to model dynamic geographic domains. International Journal of Geographical Information Science(24), 1289-1308.

Orchard T., Woodbury M.A. (1972). A missing information principle: theory and applications. 6th Berkeley Symposium on Math. Statist., 1, pp. 697-715.

Peuquet D J and Duan N. (1995). An event-based spatiotemporal data model (EDM) for temporal analysis of geographical data. International Journal of Geographical Information Systems(9), 7-24.

Potthoff R.N., Roy S.N. (1964). A generalized multivariate analysis of the variance model is useful, especially for growth curve problems. Biometrika(51), 313-326.

Rao C.R. (1987). Prediction of future observations in growth curve models, StatisticaI Science(2), 434-71.

Royse, K.R., Rutter, H.K., and Entwisle, D.C. (2009). Property attribution of 3D geological models in the Thames Gateway, London: New ways of visualizing geoscientific Information. Bulletin of Engineering Geology and the Environment(68), 1-16.

Shaw S-L and Yu H. (2009). A GIS-based time-geographic approach of studying individual activities and interactions. Journal of Transport Geography, 17, 141-149.

Sinton, D.F. (1978). The inherent structure of information as a constraint to analysis: (H. U. Design, Ed.) Harvard papers on geographic information, 7, 1-17.

Stewart, K. (2013). Thinking about Space-Time Connections: Spatiotemporal. Transactions in GIS, 791-807.

Stonebraker M and Rowe L A. (1986). The design of POSTGRES (Vol. 15). ACM SIGMOD Record.

Time Biography. (n.d.). Retrieved from http://spaceandtime.wsiabato.info

Timmermans H and Zhang J. (2009). Modeling household activity-travel behavior: Examples of state-of-the-art. Transportation Research(part B), 187-190.

Tryfona N and Jensen C S. (1999). Conceptual data modeling for spatiotemporal applications. GeoInformatica(3), 245-68.

Worboys M F. (1994). A unified model for spatial and temporal information. Computer Journal(37), 26-34.

Worboys M F. (2005). Event-oriented approaches to geographic phenomena. International Journal of Geographical Information science(19), 1-28.

Xu J and Güting R H. (2013). A generic data model for moving objects. GeoInformatica(17), 125-172.

Yang L and Worboys M. (2011). A navigation ontology for outdoor-indoor space. Third International Workshop on Indoor Spatial Awareness (pp. 31-34). Chicago: Illinois.

Yin L, Shaw S-H, and Yu H. (2011). Potential effects of ICT on face-to-face meeting opportunities: A GIS-based. Journal of Transport Geography(19), 422-433.

Yu S and Spaccapietra S. (2010). Knowledge infrastructure for intelligent query answering in location-based services. GeoInformatica(14), 379-400.

Yuan M and Stewart Hornsby K (eds). (2007). Computation and Visualization for Understanding Dynamics in Geographic Domains: A Research Agenda. Boca Raton, FL, CRC Press.

Zheni D, Frihida A, Ghezala H B, and Claramunt C. (2009). A semantic approach for the modeling of trajectories in space and time. Advances in Conceptual Modeling: Challenging Perspectives (pp. Verlag: 347–56). Berlin: Springer.

Maroufan, K. A., Mirzaei, H., Matin, A. A., Javadi, A., & Amani-gadim, A. (2019). Environmental Monitoring of 17β-estradiol and Estrone in Ardabil's Drinking Water Source as Endocrine Disrupting Chemicals. Archives of Pharmacy Practice, 10(3), 98-106.

Kryukova, E. M., Khetagurova, V. S., Ilyin, V. A., Chizhikova, V. V., & Kosoplechev, A. V. (2021). Forming students' environmental culture: modern educational approaches and technologies. Journal of Advanced Pharmacy Education & Research, 11(2), 113-118.