Quality Aspects of Monitoring Environmental Variations Using Combined GIS & Remote Sensing Techniques with Emphases on Data Modeling

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SUMMARY

The importance of quality assessment of monitoring and mapping environmental variations forces itself and cannot be neglected, as the number of experiments and projects of environmental remote sensing applications increase, and the lunch of new satellites and sensors dedicated to environmental monitoring is more and more year by year, due to the international communities realizing the affect of ecological aspects; increasing pollution of the water; land and air; damage of wild life, hazardous catastrophes, land degradation, and many more aspects where the combined technology of remote sensing and GIS proved its aid to recovery and successful decisions.

Although, technical knowledge of the subject is becoming clearly tending to draw the lines for what can be monitored and detected using what type of sensor, which and on what conditions spectral range are the features sensitive to; aspects of the effects for quality assessment of the result and its GIS storage methodology containing the relationships and topology among other modeling issues on decision making and planning is some how partially neglected.

The final products gained from executing remote sensing projects, are in one form or another, maps and reports (Digital Thematic Maps with Meta Data), these products when encountered in a GIS complete system shall benefit the users, planners, environmental conservers, and decision makers in a great manner. Therefore, the understanding of how good, accurate, and reliable this information is, shall definitely take a major part in the formation of the correct decisions, and consequences due to taking certain actions, or due to the neglect of those actions shall be known and errors shall be limited.

Other than the assessment of quality issues and their effects, the methods of representing quality aspects within the GIS environment, is also an issue of this paper. The user of the GIS for such environmental remotely sensed information should be able to monitor the limitations of the information in hand, the matter which will prevent or reduce the probability of false decisions from occurrence.

Some examples are to be shown such as some issues of soil erosion, and the quality aspects of the different factors among which slope and slope aspect are of particular importance, and

due to the 3D type of such information some surface modeling aspects related to the issue are investigated within the domain of the research work.

Finally relationships among other aspects of data models for such issues of environmental monitoring and planning are discussed, and implementation issues for Geodatabase are shown.

The results obtained from this investigation proved the importance of considering quality issues in environmental remotely sensed GIS data, as much as it showed the advantages of implementing the new storing technical issues using data models, relation ships, topology, subtypes, ranges, .etc.

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1. ACTUAL VERSUS REQUIRED

The correct decision relies on many factors such as time and money besides the reliability of the data, which are sub factors of total quality. This means cost effective decisions are to be taken using GIS analysis.

The probability of taking the correct decision is affected by time, and cost besides the quality.

D = f (Q * C/T)

The optimum accepted quality (Q) of an environmental mapped issue, as much as the accepted cost over time, depend on the type of problem in hand and its related factors. These optimum or acknowledged factors should be clearly set in standards, and should be built into GIS environmental web based monitoring and analysis systems. Moreover, they should be built in an object oriented manner so as to provide inheritance for further refinements of the rules, as much as allowing some facts to use the ancestor while others use the successor depending on the specific requirements of the topic in hand and its related issues.

As a result of building such a system and using it for analyses, a correct decision shall be leaded and proposed for further manual human interactive analysis and checks to take part. Of course the environmental spatial information system should have many automated interpretation and classification algorithms built in, or at least if this is not possible for a certain theme due to its reliance on human or manual visual interpretation, then a clear process guidelines should be provided through the system's help or wizard derived analysis.
The system should also use the object oriented quality information to indicate the optimum display of the information and its accuracy and validity among other measures, as much as providing the users with hints when preparing templates for plotting and/or while over zooming the special information.

Total Quality (TQ) issues for GIS are important operations, because the probability of taking the correct decision is directly proportional to the factor values of total quality, such as the validity (V), reliability (R), accuracy (A), permissibility (P), and other (O) factors which are specific to the environmental topic in hand.

Strength = Actual accuracy – Optimum accuracy or hypothetical Real value
Condition of Acceptance is that the Range – Strength Should be equal to or grater than 0

(e.g. the average accuracy of point data deviates from the average real value with +/- 2 cm, and the permissible or aloud value is +/- 3cm)

The strength is the closeness of the value to the hypothetical real value, while it should fulfill the condition of acceptance.

$$Q = f (A + P + O+V)$$

The weight of data accuracy, validity, cost, and operational time is a function of the type, nature, properties and usage of the data.
Usage covers many aspects among which are market issues, government and national needs, etc.

The confidence of the Decision is a function of the waited quality, time, and cost.
While the quality itself as shown by the equation above, is a function accuracy, permissibility and validity among others.

$$D = f (Q * W + T * W + C * W)$$

Another factor which is of high importance to decision making is the national importance of preserving an environmental issue, meaning that:

$$D = f ((Q * W + T * W + C * W) / E * W)$$

So for building decisions on the results of GIS operations utilized on digital dynamic thematic maps, has to conceder the total quality of the data and operations and consequently the information, which can be reached by the assessment and implementation of the following facts and operations:
- The quality of the information
- The structure of the information

For the assessment of GIS data quality in general and the environmental data quality in specific the following should be considered:
- Quality requirements and standards that enables taking correct decisions.
- Quality status of the available information.
- The discrepancy between the quality requirements and status.

Error1 (DR1) = Standard - status

Such as if we need to plot a map of existing coral reefs in an area of interest, say on the scale of 1: 500 000 (Provided that this scale is reliable for assessing the environmental issue in hand, and that it complies with the standard), and if supposing taking one measurements each one kilometer to determine the extents of corals would be sufficient for taking environmental decisions related to coral reefs, and the existing map was based on taking one measurement for every 2 km, then the reliability of the existing data falls dawn with an error factor which may lead to a deviation of the decision.

However, the method of creating such a coral status map for example may be done using an alternative method, which encounters an alternative technology or combination of technologies such as using remote sensing combined with the necessary in situ measurements. This alternative method can be of favorable for saving money and time, more valid (not so old), easier to obtain, and of suitable format, but still has to comply with the original rule of reliability, meaning that its accuracy should comply with the standards set for using this type of data for this specific type of analyses, which will lead to taking a correct decision as long as it is related to the results of the maps or digital GIS dynamic maps in our alternative method.

2. GIS ENVIRONMENTAL DATA QUALITY REQUIREMENTS

The quality requirement has to be taken from available rules and tabulated standards defined by specialists and responsible government organizations or research institutions, but they have to be raised and perhaps integrated in one way or another into the structure model of the data implementing rules of relations such as “Geodatabase”.

An example for environmental data quality requirements is when discriminating between alluvial aquifers decision should be made to determine where the line shall be drawn between the different types of those aquifers.
So which is considered of *Poor probable alluvial aquifers,* and which is considered a *Good probable alluvial aquifers.*

Once this matter is decided and confirmed by specialists, it shall be considered as a quality requirement rule. Meaning that the methods of data acquisition selected for gathering such information together with interpretation and classification methods should not only be capable of determining the geographical position of the aquifers but also discriminating between its different classes for meeting the quality requirement, or otherwise a combination of methods shall be used together to fulfill the quality requirements such as using sample data collected from in-situ measurements of the aquifers.

Further, risky amounts of factors affecting the quality of water gained from those aquifers, upon which the water shall be decided to be potable or not, such as the physical and chemical parameters of the drinking water which classifies the effected aquifers by the toxic materials or other condemnation factors (total dissolved solids, fluoride, and nitrate), are ruled by standards forming the quality requirement.

These rules are knowledge, this knowledge can be translated to a set of relational formulas, these formulas in turn decide the success of the chosen data acquisition method or the combination of methods such as remote sensing using satellite imagery and assessments of in situ measured data, they can also rule the quality of the stored data within a geodatabase enforcing geo-processing functions such as validation of those chosen rules.

Example of knowledge rules for potable water from aquifers (Environmental data requirements) are:

- Water is not potable if concentration of the fluoride is more than 1.5 mg/l.

- Water is considered hazardous and not potable if the concentration of nitrate exceeds 45 mg/l.
- Water is considered hazardous and not potable if the total dissolved solids concentration is more than 2000 mg/l.

These rules fall under certain standard, if this standard is accepted by an organization or a country then it is considered as an Environmental GIS Quality Requirement, and the data acquisition combined methods selected together with the interpretation, processing and classification methods, should be somehow capable of determining these values within the data, and thus satisfying the "Environmental GIS Quality Requirements" stated in the accepted standards.

Implementing this would solve the issue of the value of thematic maps. Such as that created by two companies as they are producing soil maps for an organization, one o them is using 50 samples collected from boreholes, in addition to 2 Landsat images, the other is using 5 images in addition to 10 samples collected from boreholes as in-situ collected data for calibrating supervised classification method. Now both are producing nice color thematic maps!!

So which of them has chosen the correct solution which provides a reliable data complying with the elements of total quality?
Which of them has quoted for a fair price?

This should be solved by standards which are related to the elements of quality. The standards should show the limits of the least requirements of works related to the reliability of the results. These works should be a combination of methods comprising interpretation and field data collections for each particular theme related to the environment or natural resources. These methods may also contain only interpretation using images, or only field works, but sure should set the measures of quality of each theme.
Back to the example of soil classification, if say we say that producing a map of soil classes based on a standard scale of 1:10 000 would be over quality and meaning less, because the accuracy of the collected data dose not satisfy this standard scale, and there is no need actually for producing soil data that comply with this standard scale. Then what is standard scale, accuracy, validation and reliability for soil maps which will be as a reference for deciding the acceptance of combined methods (interpretation methods and field sample data collection) or not.
So it is clear that we are of vast need to standardize themes to required quality and put it into standards.

2.1 Quality of Environmental Data

For assessing the quality status of the GIS environmental data and information the following factors has to be assessed:

- Sources of data and interpretation accuracy
- Validity of the data
- The integration of the data in a modeled data structure

The completion of these steps and its comparison with the quality requirements of the data shall provide a measure for the environmental information reliability, for decision makers to depend on, as much as reducing the chance for making a false decision.

2.1.1 Sources of Data & Interpretation Accuracy

The quality of the data depends on sources the interpretation was executed on, the methods of interpretation, the use of field measurements for performing supervised classification and for cross checking, and on the algorithms used.

A major factor for interpretation accuracy if the interpretation method is relaying on visual or manual interpretation and not automated algorithms which is usually the case, is the experience of the interpreter himself for interpreting the theme in hand. So, the reliability of the result is effected by a factor gained from experience.

On the other hand, the solidness of the interpretation process will depend on the solidness of the different factor of interpretation, such as for example oil spill can be detected using synthetic aperture radar data, but there is a probability of false interpreted patches due to similarity of the resulted gray values and shapes, and here the experience factor plays a major roll.

Further, if the interpretation method is totally automated then a confidence value should be produced with the result indicating its reliability and quality.

2.1.2 Validity of the Data

The validity of the data on the other hand is a function of the time. The time period for certain type of information is a function of the changing speed of this data. If the data is too old for instance it may cause a deviation in the analysis and subsequently to the decision.
So, one of the factors that comprise the quality of the data is its validity, which is a function of the theme sensitivity. This validity must be built into the object oriented system and hence produce a factor of confidence for the analysis and its results.

2.1.3 The Integration of The Data in a Modeled Data Structure

The data is integrated in a data model structure such as geodatabase, so that the one part of the geodatabase will be TQ the total quality of the data. This is similar like topology and relationships, but it will comprise the factors of quality (accuracy, reliability, Validity, etc).

2.1.4 Assessment of the classified Information with the quality Requirements

The quality requirements for each environmental theme are set, and the total quality rules for it are organized in an object oriented manner, conditions are implemented.
The next step would be that the classified information should be validated against those rules and conditions designed for each theme.

The resulted classification may vary depending on the results of the validations and changes will be made to produce a final result which is reliable for guiding confident decisions

3. CONCLUSION

The investigation proved the importance of considering quality issues in environmental remotely sensed GIS data, as it affects the decision making.

Data modeling for GIS archived or stored environmental GIS data, show its positive effect on correctness of the analyzed information based on it.

Further investigations and testing should be done to implement the idea of building an object oriented quality management system within the analysis environments.

The resulted geodatabase shall contain a TQ total quality part which will provide the measures of quality of the other GIS data, as much as feeding the rules and conditions.
There is confusion when it comes to deciding the amounts of works that should be executed for a certain theme, the matter which causes unclearness of the cost, and this can only be solved by setting and implementing the standards that are related to environment GIS Quality Requirements that are accepted by the community.

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BIOGRAPHICAL NOTES

Achieved BSc (DTM experiments and change detection using GIS). and MSc. (Environmental Impact Assessment using Remote Sensing and GIS), from Budapest University of Technology & Economics. Started and completed 3 years of PhD studies in the department of Photogrammetry and GIS within the same university.
Assisted the management of mapping the 3rd district of Budapest in GIS, and programmed intermediate GIS software for assessment and analysis using, Delphi and C++ Builder. (other computer languages are Pascal Fortran and Basic)
Took par as a developer GIS engineer in the project for mapping fiber glass cable thrugh Hungary

Engineered and sub designed the photogrammetric project 2001 for Dubai. Designed the Photogrammetry of the Dubai Base Map project 2003. Designed the Lidar project for Dubai Municipality. Designed and currently engineering and technically managing an Environmental monitoring project for Dubai.
Former member of IEEE IGRAS and the author of more than ten papers dealing with the Total Quality of GIS and Remote Sensing topographic and environmental data.
Research and area of Interest other than the one mentioned above is Modeling 3D surface
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