USING FUZZY INFERENCE SYSTEMS FOR AREA SELECTION

F I S : Re-survey Decision System

Navigational safety and political-economic considerations make it essential for port administrations and hydrographic services to have a prioritised survey programme. Finding criteria that reflect the importance of re-survey over a given area is fundamental here. A better way must be found than traditional thematic classification. Fuzzy Inference Systems (FIS) have been used successfully to deal with such problems. This article presents its use for hydrographic re-survey selection. Establishing a re-survey priority programme is no ordinary task. Specialists must analyse many kinds of information that, due to their complexity, must be combined in criteria: first to find where re-survey is necessary and then to support the decision as to where should be done first.

Data Preparation

The first step is to prepare and organise the necessary information into a database linked to the area represented. Information from previous surveys, mainly represented by its metadata, is the most important and more visible component of such required information. To prevent unnecessary work, and before putting metadata into the database, it is important to study and establish which kind of survey, according to standards and age limits, should be used to determine the need for re-survey. Establishing what should be the minimum or ideal technical standards applied to each part of the area is another preliminary requisite. It is true that the IHO via S-44 determines minimum standards for each survey order but it is indispensable that the geographic limits to be applied to each are pointed out. As clarified in S-44, the competent authorities should also study the necessity for creating areas where, due to their strategic or economic relevance, specific and more rigid criteria should be used. An example of the borders of previous surveys, combined with technical standards areas, can be seen in Figure 1.

Other Information

Gathering other relevant information and fixing geographic limits to which they are applied is also important. Data such as rate of seabed variâ€“ation, volume of maritime traffic and area classification according to navigation-safety relevance parameters are important for the future criteria. First, however, we have to know exactly what additional information will be used in the re-survey decision and only then insert it into the database, otherwise gathering such data may prove a waste of time. We must also consider the difficulty of fixing geographical-limit borders in the data. Finally, from the information (previous survey metadata, necessary technical standards and other relevant information), once digitised, it will be possible to determine the most important indicators to be used. They may then be combined to form criteria.

Age Indicator

The age of a survey is the most important and clearly identifiable indicator. When we classify a survey by its age we are inserting notions of modification in many factors concerning the physics and economics of the area. This classification can also express technical evolution of the equipment used to survey the area. Consequently, â€˜ageâ€™ is the great substitute for all parameters that we cannot use as indicators and it is thus important that we do not overstate or diminish its importance, establishing its weight in accordance with other indicators in the criteria.

Spatial Modification

Spatial modification indicators are also important. The main reason for re-survey of an area is that change has occurred. Although the land is important, the express modification motivating re-survey is seabed variation. Establishment of a rate determining this change is also a difficult job. There are several ways to measure it, from comparing the bathymetric data to methods of sediment profiling. Considerable effort must be made to establish and periodically update such data if we truly want to discover the necessity for re-survey of a given area.

Technical Indicators

Technical indicators can be obtained by comparing the existing technical information of survey metadata with the ideal or minimum standards previously established. The factors used for comparison are those expressed in S-44: positioning/depth precision, line spacing and bottom coverage. The easiest way to combine metadata with standards is to determine a ratio between them. Fixing this information for line spacing and bottom coverage will probably pose no problem. But sometimes finding this number for the other ratios (depth and positioning measurement) is not an easy task; particularly if we consider old surveys for which some such metadata is not available. In these cases careful consideration should be given to inserting this kind of information in the age indicator.

Prioritising

After determining whether or not areas are actualised it is also importâ€“ant to classify them, identifying the most important areas for re-survey. Several relevance indicators can be used to construct such criterion. Probably the most visible and importâ€“ant are economic and navigation-safety relevance rates. The competent authorities must choose these, giving due consideration to defining disposable data and difficulties in combining their degree of importance into a rate.

Thematic Classification

But how should this information be used to establish the necessity and priority of re-survey One way to achieve this would be thematic classification of the indicators, establishing sets for each according to necessity. The sets could then be combined using logic and mathematical rules in order to reach criteria for re-survey. However, this methodology may be not as simple as it appears. Most indicator data, such as the age of survey, is expressed in continuous scales without a clear border of change between one class and another. Further, the number of rules of logic necessary for combination of the indicators and their sets will be too many. Fuzzy Logic emerges as a good solution to these problems.

Fuzzy Sets

Fuzzy Logic concepts are based on the â€˜Fuzzy Sets Theoryâ€™ conceived by Lofti Zadeh. The main objective of fuzzy sets is to generalise the idea represented by the conventional-sets theory, making it approach the imprecision of human reasoning. Unlike conventional sets, where an element belongs to a set or not to a set, in fuzzy sets a given element is associated with a set by a degree of membership (Âµ) that varies from zero to one. This treatment makes it possible that transition between conditions of belonging or not belonging do not occur in a crisp, abrupt way but instead progressively. The Fuzzy concept thus better expresses membership of continuous scale numbers such as temporal, geo-biophysics and socio-economics data characterised by gradual transition.

Fuzzy Logic

When we use thematic classification in logical inference an intersection may be viewed as the logic operation â€˜andâ€™, the union as â€˜orâ€™ and the complement as â€˜notâ€™. As in conventional sets, there are specific, defined operations for union, intersection and complement in fuzzy sets. Therefore we can apply rules of logic for fuzzy sets as we do for ordinary sets. This is what we call Fuzzy Logic. Fuzzy Logic can classify the same phenomenon in a lesser number of sets than can conventional logic. Its use thus becomes advantageous when combining a large number of antecedents to form a predicate; it avoids creation of many unnecessary sets that would raise the number of rules and consequently the complexity of the logic inference system.

FIS in Practice

Fuzzy Inference System (FIS) is a technique based on a simple input, process, output flow concept that uses Fuzzy Logic for Decision Support Systems. In FIS input is associated with a fuzzy set by a degree of membership in a proâ€“cess called â€˜fuzzificationâ€™. The sets are then combined in the inference unit through rules of logic so as to generate results associated with output sets. These results are then combined in a process called â€˜defuzzificationâ€™ to obtain a single crisp value output. There are several types of FIS model with different functions for the processes of inference and defuzzification. The choice of the best type to use depends on which kind of information is used in the system. We suggest, initially, for its simplicity and widespread implementation in existent software, use of the Mandani FIS model.

Methodology

All previously surveyed areas and their metadata must first be clearly specified. It is also fundamental to establish areas of other information that will generate indicators, such as ideal technical standards and rate of seabed variation. All this information should be kept in a database following, as far as possible, S-57 standards to simplify its use and analysis. In a GIS, the survey areas must be sequentially intersected with other information areas. It is very important, as there is overlapping of many of the survey areas, to make this combination individually for each survey so as to avoid errors in mixing the various metadata records. As result, each new area will correspond to a specific record in a database, with all the individual information needed to establish the necessity of re-survey.

Actualisation

Now it is necessary to use a FIS to select areas requiring survey acâ€“tualisation by combining age indicator with special-modification and technical indicators. To accompany realisation of main metadata and available information we suggest the seabed variation rate as spatial modification indicator. As technical indicators we suggest ratio of line-spacing and bottom-coverage obtained by comparing survey metadata with established ideal standards. Also recommended is an age indicator; establishment of fuzzy sets must also consider other spatial modification and technical parameters such as evolution in measurement techniques in position and bathymetric data.

Sets and Rules

All the sets and rules used in the FIS must be established carefully during meetings of specialists. It must be borne in mind that the construction of sets will affect rules and vice versa. Also significant is the individual reality of areas when specifying these parameters. For instance, a country that began to use side-scan sonar equipment in 1982 should not have the same sets and rules as another that began such use only in 1987. The sets and rules must be revised periodically to accommodate modifications both in priority and in area reality.

FIS Prioritising

After reaching a number that expresses the actual need for each record, this information will be used together with the prioritising indicators in a new FIS to establish the priority status of the area. It is important that sets and indicator numbers are not too big, otherwise the number of rules will be excessive, complicating their establishment and modification. We suggest using as prioritising indicators the economic and navigation-safety relevance rates established according to disposable information and reality as per the study.

Visualising Results

After applying the methodology it will be necessary to use the GIS again in order to remove superimposition of information and show truly the need for area actualisation and prioritising. To make this possible priority must be established for plotting resultant areas, overlaying those of higher-grade actualisation and priority with those of smaller-grade. For instance, if we have two surveys that intersect in a specific area and one does not need actualising while the other does, the intersection will accompany the more actualised and will not require actualisation. It is important, therefore, to determine by spatial analysis the coordinates of these new areas and what is going to be their actualisation and prioritising grade. Figure 6 shows an example of what should be the typical map resulting from this methodology.

Concluding Remarks

The use of FIS together with GIS is a viable way to establish the necessary criteria for selection and prioritising areas for hydrographic re-survey. Fundamental here is knowledge of metadata from previous surveys. It is also important to carry out preliminary studies and collect and make spatial other necessary data to establish indicators. Indicators, sets and rules should be established carefully. Each must consider specific reality and be revised periodically. Only with such constant effort will it be possible to find an acceptable way to help solve the problem of making re-survey decisions.