Genetic Fuzzy Systems Applied to Ports and Coasts Engineering

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INTRODUCTION

Fuzzy Logic (FL) and fuzzy sets in a wide interpretation of FL (in terms in which fuzzy logic is coextensive with the theory of fuzzy sets, that is, classes of objects in which the transition from membership to non membership is gradual rather than abrupt) have placed modelling into a new and broader perspective by providing innovative tools to cope with complex and ill-defined systems. The area of fuzzy sets has emerged following some pioneering works of Zadeh (Zadeh, 1965 and 1973) where the first fundamentals of fuzzy systems were established.

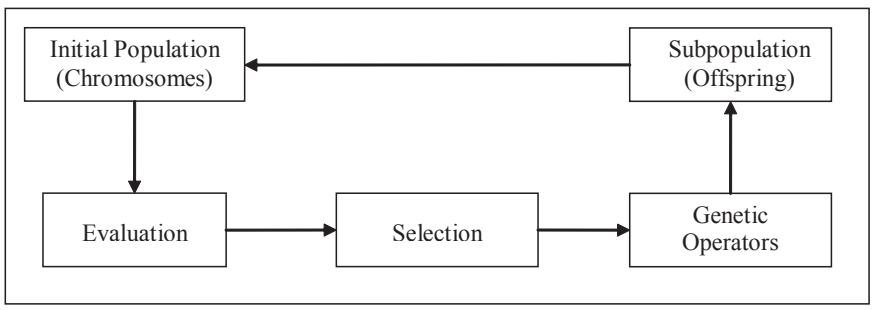
Rule based systems have been successfully used to model human problem-solving activity and adaptive behaviour. The conventional approaches to knowledge representation are based on bivalent logic. A serious shortcoming of such approaches is their inability to come to grips with the issue of uncertainty and imprecision. As a consequence, the conventional approaches do not provide an adequate model for modes of reasoning. Unfortunately, all commonsense reasoning falls into this category.

The application of FL to rule based systems leads us to fuzzy systems. The main role of fuzzy sets is representing Knowledge about the problem or to model the interactions and relationships among the system variables. There are two essential advantages for the design of rule-based systems with fuzzy sets and logic:

- The key features of knowledge captured by fuzzy sets involve handling uncertainty.
- Inference methods become more robust and flexible with approximate reasoning methods of fuzzy logic.

Genetic Algorithms (GAS) are a stochastic optimization technique that mimics natural selection (Holland, 1975). GAs are intrinsically robust and capable of determining a near global optimal solution. The use of GAS is usually recommended for optimization in high-dimensional, multimodal complex search spaces where deterministic methods normally fail. GAs explore a population of solutions in parallel. The GA is a searching process based on the laws of natural selections and

Figure 1. A typical GA cycle



genetics. Generally, a simple GA contains three basic operations: selection, genetic operations and replacement. A typical GA cycle is shown in Fig. 1.

In this paper it is shown how a genetic algorithm can be used in order to optimize a fuzzy system which is used in wave reflection analysis at submerged breakwaters.

BACKGROUND

Many works have been done in the area of artificial intelligence applied to Coastal Engineering. It can be said that Artificial Intelligence methods have a wide acceptance among Coastal & Ports Engineers. Artificial Neural Network has been applied for years with very good results. The big drawback is their inability to explain their results, how have reached them, because they work as a black box and it can not be known what happen inside them. Over the last few years, a lot of works about fuzzy systems with engineering applications have been developed (Mercan, Yagci & Kabdasli, 2003; Dingerson, 2005; Gezer, 2004; Ross, 2004; Oliveira, Souza & Mandorino, 2006; Ergin, Williams & Micallef, 2006; Yagci, Mercan, Cigizoglu & Kabdasli, 2005). These systems have the advantage of being easy to understand (their solutions) and the capacity to handle uncertainty. However, most of these found a problem with knowledge extraction; when they try to define their RB and DB, in many cases for the difficulty of the problem and more often for the difficulty of represent all the expert knowledge in some rules and membership function.

To overcome these problems Genetic Fuzzy Systems (GFS) emerged, in which expert advice it is not as important as in Fuzzy System (FS) since it could be only needed to define the variables involved and its work domain. GFS (Cordón, et al., 2001) allow us to be less dependent on expert knowledge and in addition it is easier to reach better accuracy with these systems since they can realize a tuning process for membership functions and refine the rule set in order to optimize it. Following a specific application of GFS for wave reflection analysis at submerged breakwaters is presented.

While other kinds of techniques have been applied to that problem (Taveira, 2005; Kobayasi & Wurjanto, 1989; Abul-Azm, 1993; Losada, Silva & Losada, 1999), it is a novel approach to estimate reflection coefficient, since a GA will determine the membership functions for each variable involved in the fuzzy system.

ANALYSIS OF WAVE REFLECTION AT SUBMERGED BREAKWATERS WITH A GENETIC FUZZY SYSTEM

Fuzzy rule-based systems can be used as a tool for modelling non-linear systems especially complex physical systems. It is well known fact that the breakwater damage ratio estimation process is dynamic and non-linear, so classical methods cannot be able to capture this behaviour resulting in unsatisfactory solutions.

The Knowledge Base (KB) is the FS component comprising the expert knowledge knows about the problem. So is the only component of the FS depending on the concrete application and it makes the accuracy of the FS depends directly on its composition. The KB is comprised of two components, a Data Base (DB), containing the definitions of fuzzy rules linguistic labels, that is, the membership functions of the fuzzy sets, and a Rule Base (RB), constituted by the collection of fuzzy rules representing the expert knowledge.

There are many tasks that have to be performed in order to design a concrete FS. As it has been shown previously, the derivation of the KB is the only one directly depending on the problem to solve. It is known that the more used method in order to perform this task is based directly on extracting the expert experience from the human process operator. The problem arises when there are not able to express their knowledge in terms of fuzzy rules. In order to avoid this drawback, researches have been investigating automatic learning methods for designing FSs by deriving automatically an appropriate KB for the FS without necessary of its human expert.

The Genetic algorithms (GA) have demonstrated to be a powerful tool for automating the definition of the KB since adaptativa control, learning and self-organization can be considered in a lot of cases as optimization or search process. The fuzzy systems making use of GA in their design process are called generically GFSs.

These advantages have extended the use of GAs in the development of a wide range of approaches for designing FSs in the last years. It is possible to