Fuzzy Cognitive Maps in Modelling

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Fuzzy Cognitive Maps (FCM) is a tool merging the properties of Artificial Neural Networks (NN) and fuzzy systems. FCMs are bipolar directed fuzzy graphs consisting of Concepts (nodes) assigned fuzzy membership degrees expressing the intensity or level of the property associated with the given concept; and of directed influence values (edges) which have a sign (expressing whether the influence is positive or negative) and a fuzzy membership degree of the intensity of the influence. E.g., if C_1 and C_2 are two concepts, μ_1 is the degree of C_1 and μ_2 of C_2, the directed edges e_{12} and e_{21} have $\pm \mu_{12}$ and $\pm$ μ_{21}, respectively, denoting that C_1 influences C_2 either in the positive sense (increasing its level) with + μ_{12}, or in the negative sense (decreasing C_2) with - μ_{12}. FCMs are suitable to model multicomponent systems with multiple mutual influences, such as, e.g. a management system. Because of the NN-type behaviour of FCMs, they may be used for simulating a system that changes in time, and possibly converges to a steady state (called fixed point attractor). It is interesting to fit the FCM to a series of historical data and calculate the expected development of the system in the future – a way for time series prediction. Such fitting may happen by various machine learnning techniques, such as evolutionary and memetic algorithms, among others. In this case the FCM model will be determined by theis fitting, including all membership degrees at the concepts and at the edges. On the other hand, often experts determine these values (approximately) in advance, and thus the FCM model is ready for prediction - starting from a known initial state.

In our past reserch we found real life applications (such as waste management, bank management, etc.) where one or both of the starting data were available. Especially interesting is the case when experts determine the membership degrees and then the FCM is matched to the historical data. In some case we found contradiction in the contents and this fact started a deeper methodological research about how to fit the proper FCM to a given problem, and how to transform the size and complexity of such models, so that theyt reemain intuitive, and tyransparent, while the fineness and precision of the model is satisfactory from the point of view of the application field.

This talk will give some formal definitions in connection with FCMs, and then show the iterative (NN-like) behaviour. The next question to be discussed will be the existence and number of fixed point attractors (sustainable state of the system to be modelled), a topic that has not yet been satisfactorily clarified in the literature. In this respect we have presented some entirely new results in the form of mathematical statements.

In the next a novel extension, the Fuzzy Grey Cognitive Map will be introduced, and it will be shown that they are more adequate in modelling real life systems, as human experts often hesitate in giving concrete degrees, and subjectivity and uncertainty of the experts prevent any clear and deterministic membership values at the concepts and edges. The next real application motivated extension is the application of fuzzy numbers for determining the memberships. Some results about the existense and uniqueness of a fixed point attractor are also stated here.

The other main stream of the research reported here focuses on the transformation of FCMs (as far in the classic sense), especially by reducing the size of the model, namely, the number of concepts, which of course also results in the drastic reduction of the number of edges in the new model. A novel reduction technique, based on a very special FCM compatible metrics (a distance measure between two concepts where all the influence degrees to other concepts and the way around are known and compared) is proposed, illustrated by a real life problem, where the obvious contradiction between the expert assessment and the historical data points towrds the necessity of the refinement of the mmodel, and then, towards a transformation that leads to the emerging of new concepts that have to be interpreted in the context of the application problem. An extensive simulation, applying a large number of real life and randomly generated examples for large size FCMs and respective reductions allows the discussion of to what extent such a transformation preserves the properties of the original FCM, with a special stress on the existence, number and parameters of the fixed points.

The last topic of the talk is about the sensitivity of the FCMs, where it may be assumed that expert assessments are subjective and uncertain, and the uncertainty or error in the membership values may cause instability, even, a total change of behaviour of the FCM. One more real life example will be presented and evaluated.