A Fuzzy Approach to Enhance Post Flood Damage Assessment for Quality Risk Analysis

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Abstract

Floods have put people; infrastructure, building and other things at risk where it can be destructive thus bring serious losses to the affected victim. Post flood damage assessment requires crucial information for decision support, where it has gained more importance with the evolving context for flood risk management. However due to various uncertainties that originate from data collection, damage figure and damage function it is still insufficient to obtain accurate flood damage estimation with the required time lead. The objective of this research is to model post flood damage assessment model using artificial intelligent approach called fuzzy system. Uncertain parameters that include water depth, water velocity, and type of debris and duration of inundated are identified and constructed as main determinants for damage assessment result. Fuzzy approach is used in the damage assessment model due to the characteristics of the parameters, which are identified as uncertain. This would improve the current assessment model that gives a better result.

Keywords: Flood damage assessment, artificial intelligent, uncertain parameters, fuzzy system

1. Introduction

Flood becomes destructive when the rate of rainfalls is heavy and the water overflows from the river, lake or sea to the dry land. It puts people, infrastructure, building and other things at risk that can bring serious losses to the affected victim. Assessment of damage due to flood is a challenge for the flood victim when it is possible to assess it after the water has subsided and they return to their belongings. Information is crucial to assess damage at post flood. Required information is to be collected from the flood victim and reported back to the flood relief center through the channels establish by the center. This method is prone to error when data is collected and recorded manually by center. This would affect the damage estimation and assessment and the amount of aid to be given to the victim.

There are many research efforts that contributes to mitigating and managing flood such as in flood early warning system (Melnikova, Jordan, and Krzhizhanovskaya 2015; Pyayt et al. 2015; Sättele, Bründl, and Straub 2015), flood forecasting (Fuchs et al. 2013; Gaudiani et al. 2014; Wang et al. 2013; Zhou and Chen 2013), flood monitoring (Ancona et al. 2014; Bayraktar and Bayram 2009; Long et al. 2014; Memon et al. 2015) and flood prevention (Kalyuzhnaya and Boukhanovsky 2015). However very little effort is found for managing post flood (Parsons et al. 2015).

Study has divided flood damage into four types: direct tangible, direct intangible, indirect tangible and indirect intangible. Direct flood damage measures the severity of damage due item contact with flood water. Indirect flood damage measures the effect from direct damage on tangible and intangible item (Dutta, Herath, and Musiake 2001). This paper measures the estimation of direct flood damage on house and its content at post flood. Estimation of flood damage is a complex process that uses huge volume of hydrologic with consideration of socioeconomic factor (Jongman et al. 2012). Other model complemented damage assessment model with supporting factors likes water velocity, flooding duration, water contamination, precaution and warning time.

This paper uses fuzzy as solution to post flood damage assessment. It models flood damage assessment and fuzzy-based decision techniques incorporate inherent imprecision, uncertainties and subjectivity of available data. These attributes are propagated throughout the model for more realistic results. Fuzzy approach modeling techniques can also be used in post flood damage assessment to assess the severity of damage in cases where the experts do not have enough reliable data to apply statistical approach.

2. Framework for Post Flood Damage Assessment

The governance of flood management in Malaysia is divided into two areas that are flood risk management, which is concern in decision-making process and flood management, that is related with life cycle of managing flood (Maidin et al. 2014). Recovery and development are phases at post flood, the issue addressed in this paper. The goal of post flood is to restore the life of flood victim to normal. This paper has designed a framework to assess damage at post flood using uncertain parameters that is the flood data and socio economic data retrieved from its repositories as shown in **Error! Reference source not found.**.

The rule-based repositories stores damage assessment rule defined for socio economic data. The rules and data are retrieved into inference and query engine to produce intermediate assessment variable. The architecture of the inference engine is shown in Figure 2 and the detail it is discussed in the next section. Fuzzy damage assessment engine uses the value computed from inference engine to find monetary losses. The value will be display in a form that can be understood by the user assisting them in further step of decision making.

The paper uses house and household item data published by Household Income and Basic Amenities Survey Report 2012 as socio economic data. The data is selected due to the major damage from direct water contact to the house and its content compared to others damages (Gasim et al. 2014).

3. Fuzzy Rule-Based System for Post Flood Damage Assessment

The fuzzy logic model is designed with several inputs and one output. The number of output corresponds to the linguistic variables (indicators), which described the flood (Zlateva, Pashova, and Stoyanov 2011). The output represents a complex post flood damage assessment. Post flood inference engine consist of three models as shown in Figure 2.

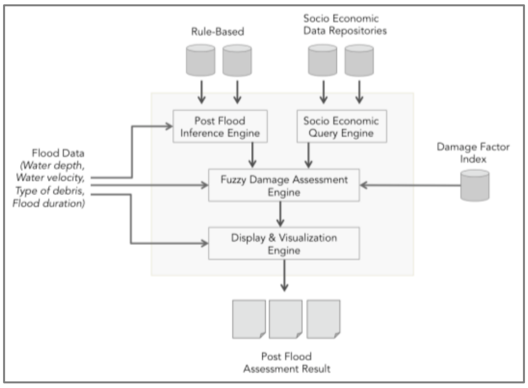

Figure 1: Framework for Fuzzy Rule-Based System for Uncertain Post Flood Damage Assessment

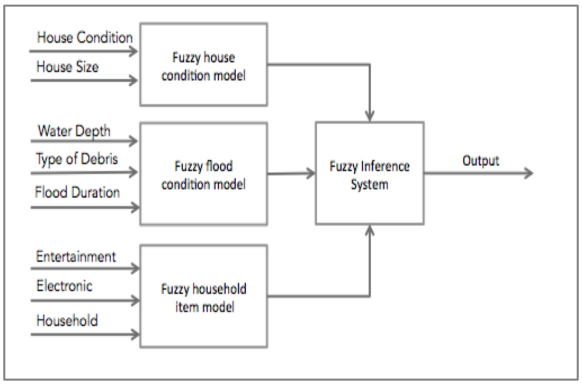

Figure 2: Fuzzy models for Post Flood Damage Assessment

Each model receives many inputs from input indicators. The input indicators are input parameters of the designed fuzzy system. These parameters corresponds to flood and damage affected on house and household items in the house.

The proposed fuzzy logic model is designed with previously defined input parameters. Every subsystem gives an intermediate output variable. The output from each subsystem is defined as Intermediate Variable 1 “House Damage Factor”, Intermediate Variable 2 “Flood Damage Factor” and Intermediate Variable 3 “Appliances Damage Factor”. These intermediate output variables will be processed by Fuzzy Inference System (in Figure 2), which will produce the complex post flood damage assessment value. The value is a criterion for final decision-making about the degree of damage for a particular area. The higher value corresponds to the more severe post flood damage.

4. Design of Fuzzy Logic Model

Linguistic variables are quantitative value that corresponds to qualitative feature (Zlateva, Pashova, and Stoyanov 2011). These variables are information and decision that are closely linked make a decision from imperfect information using different method. Possible types of cases and damage assessment on living property are defined by the expert that depends on quality and uncertainty of the available information from various sources.

In fuzzy logic house condition subsystem the input linguistic variables for Input 1 and Input 2 are represented membership functions, that are, {“Very Small”, “Small”, “Medium”, “Big”, “Very Big”} and {“Bad”, “Medium”, “Good”}. The input variables are assessed in the interval [0,1] and [0 – 100]. The fuzzy logic system output (house damage factor) is describes as {“Good”, “Fair”, “Risky”, “Very Risky”}. The post flood damage assessment is assessed in the interval [0,100] using triangular membership functions. The input and the output membership functions are shown in Figure 3 and Figure 4.

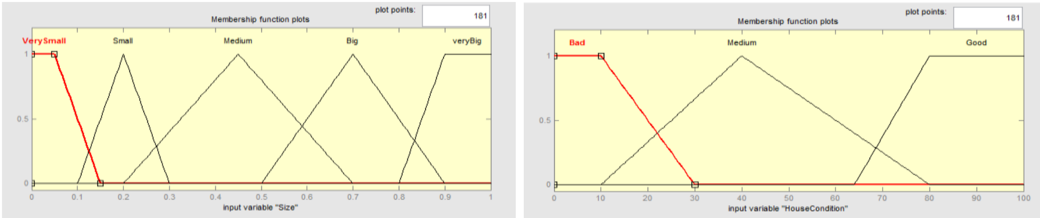

Figure 3: Membership functions of the input indicators for Fuzzy Logic House Condition Subsystem

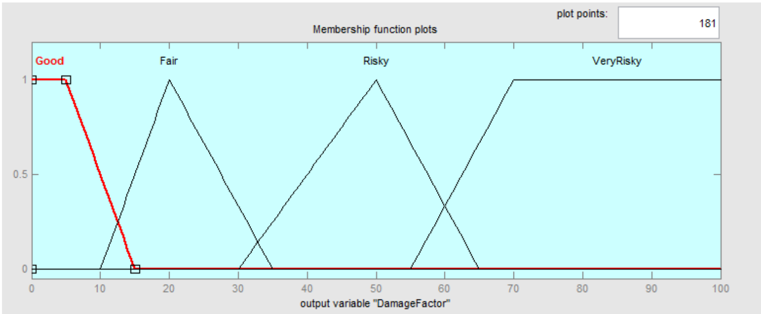

Figure 4: Membership functions of the output indicators for Fuzzy Logic House Condition Subsystem

The membership functions for fuzzy logic flood condition subsystem are {"Low", "Medium", "High", "Very High"}, {"Short", "Medium", "Long"} and {"Low", "Medium", "High"} for Input 3, Input 4 and Input 4. These input are assesses at the interval of [0,5], [0,10] and [0-100] using trapezoid membership functions. The fuzzy logic system output (flood damage factor) is describes as {"Good", "Fair", "Risky", "Very Risky"}. The post flood damage assessment is assessed in the interval [0,100] using triangular membership functions. The inference surfaces in 3D for the three fuzzy logic subsystems are given in Figure 5.

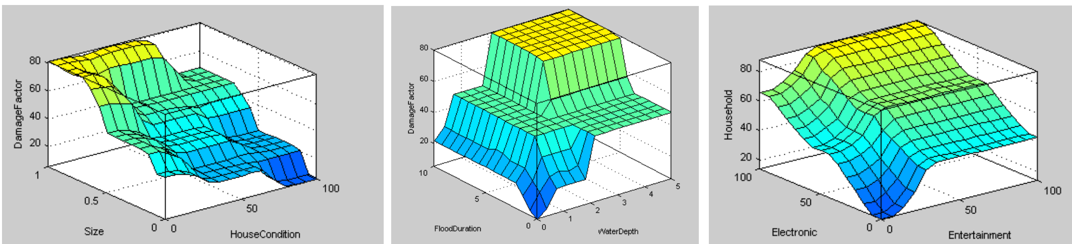

Figure 5: Surfaces if the fuzzy logic subsystems

5. Fuzzy Rule Based Model Application

Table 1, Table 2 and Table 3 summarize the result of data set assessment using the proposed fuzzy logic model and the characteristics of the input. In Table 1, it can be deduced that that house condition "Bad" and "Medium" contributes the most to the house damage factor. However, the damage factor for house condition "Good" is reasonable

Table 1: Fuzzy inference result for House Condition Subsystem

House Condition	Bad				Medium				Good			
Size (%)	10	30	60	90	10	30	60	90	10	30	60	90
Damage factor	35	48	69	81.3	21.9	35	43.2	80.4	6.08	22	38.3	48.3

The minimum and the maximum water depth's value in Table 2 indicates that most houses will stay dry and it is possible to walk through the water, and both first floor and rood will be covered by the water as suggested by Japanese Flood Fighting Act 2001 for Water Depth Classification Suggestion. It is shown that type of debris gives major contribution to the damage condition from "Fair" to "Very Risky.

Table 2: Fuzzy inference result for Flood Condition Subsystem

Water Depth (meters)	3	3	3	0.5	0.5	0.5
Flood Duration (days)	3	3	3	1	1	1
Type of Debris (%)	10	50	80	10	50	80
Damage condition	Fair	Risky	Very Risky	Good	Good	Fair
Damage Factor (%)	21.7	48.2	81.3	13.2	13.8	27.7

Table 3 summarizes severity of damage on household item for entertainment and electronic. The inputs are classified as low and high percentage for entertainment indicates the general number of entertainment appliances in the house. Result shows that the damage factor goes higher with higher percentage of entertainment and electronic appliance.

Table 3: Fuzzy inference result for Household Item Subsystem

Entertainment (%)	10 (Low)				60 (High)			
Electronic (%)	10	30	60	90	10	30	60	90
Damage Factor	14.8	34.0	43.3	65.9	43.3	56.1	65.9	87.8

6. Conclusion

A fuzzy logic model for post flood damage assessment is proposed. The study covers house, flood condition and house hold items. It can be concluded that the developed fuzzy logic system can successfully evaluate post flood damaged from analyzing the obtained result. The advantage of fuzzy logic system impacts criteria in all parts of the system. This model is adjustable and databases made from various elements are required. It is easy to incorporate the knowledge dealing with post flood. The designed fuzzy system is part of the post flood integrated information system, which will be developed.

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