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Research Article

Theory of Variable Fuzzy Sets for Artificial Emotions Prediction

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Emotions have a very important impact on human's beliefs, motivations, actions, and physical states. Emotions predicting and its application in intelligent system can improve the interaction between humans and machines. Current research in artificial emotion focuses on how to measure, calculate, or compute it. However, the transfer of emotion is often too complicated to present full emotion states and changes. This paper combines with emotional dimension and theory of variable fuzzy sets to present a predicting artificial emotion model and shows illustrated example of it. This study shows that any raw data from input can be computed with variable fuzzy set. It provides a mathematical method for representing emotion quantitative, gradual qualitative, and mutated qualitative change. This framework improves calculation methods and mechanisms, closer to real emotional changes.

1. Introduction

Kansei Engineering focused on the development or improvement of products and services by translating the customer's psychological feelings. It paid attention to artificial emotion or affective computing.

Due to the fact that self-adaptive systems may be able to run without any external operations, people can do more high level goals [1], such as nonplayer character (NPC) in games.

Current study of affective computing process often used relatively simple model of the probability of showing emotional changes. This mode of operation is helpful for quantitative emotional changes. However, it is difficult to consider or present qualitative emotional situations.

This study combines with emotional dimension [2] and the theory of variable fuzzy sets [3] and presents a forecasting artificial emotion framework. It provides an innovative approach to predict artificial emotions and feelings decision system designs. In addition to retaining the original feeling of quantitative character, it also shows true feelings of gradual qualitative change and mutated qualitative.

2. Theoretical Background

2.1. Artificial Emotion and Affective Computing. The artificial emotion or affective computing is a new research direction of increasing concern in the artificial intelligence field, and its main research themes are mostly concentrated in the simulation and identification of human emotional process, so the computer can generate human-like emotions. Different domains such as psychology, cognitive science, and information science from different angles try to simulate and measure emotion generation.

It is generally believed that professor Picard at the Massachusetts Institute of Technology is the beginner of affective computing. In Japan, Kansei engineering from the 1990s combines emotional and engineering. It adds emotional feelings to the product design and manufacturing and changes the mode of intuitive experience to guide the design. For example, in the automotive appearance design, use SVR (support vector regression) for evaluation to predict consumers' affective responses for green technology vehicles [4]. In addition, they are also based on affective computing model in e-learning system [5].

There are two kinds of ways to research the mental model: the basic emotions theory and dimension theory [6].

2.2. Emotion Modelling. In the field of artificial emotion, many studies have focused on intelligent computing systems to create a perception, recognition, and understanding of human emotions. The machine that has the emotion is very

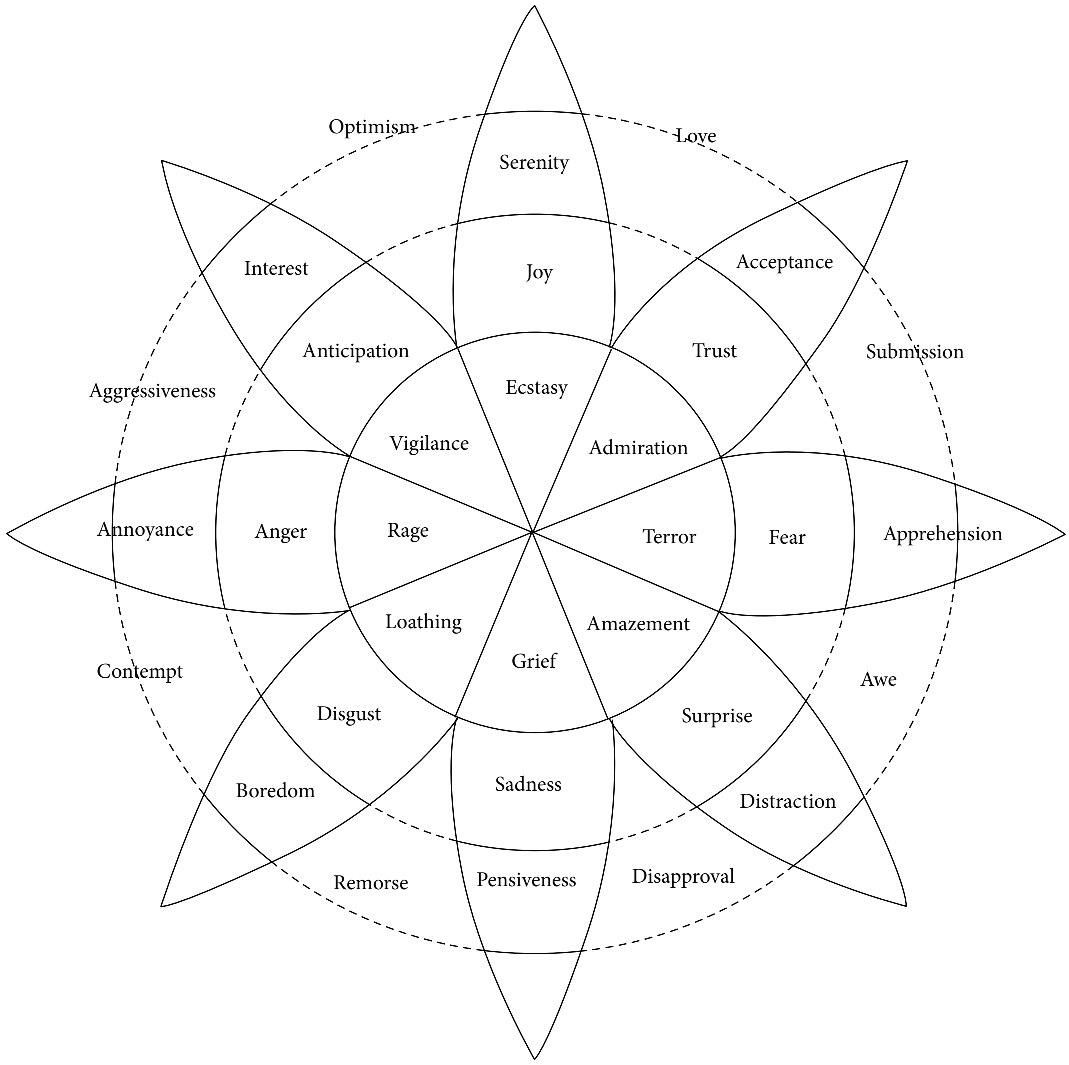

FIGURE 1: Plutchik emotional wheel.

difficult to study, because the emotion is a random process of change, affected by many factors. To achieve emotional intelligence system, we must first establish an appropriate computational model to describe the emotion.

Emotional model should consider the dynamic interaction of various emotions but mostly be simplified for research convenience. In this study, we use Plutchik's three-dimensional model to describe the relations among emotion concepts, which are analogous to the sections on a wheel [2]. The cone's vertical dimension represents intensity, and the circle represents degrees of similarity among the emotions. The eight sectors are designed to indicate that there are eight primary emotion dimensions defined by the theory arranged as four pairs of opposites. In the exploded model the emotions in the blank spaces are the primary dyads—emotions that are mixtures of two of the primary emotions, as shown in Figure 1.

3. Variable Fuzzy Sets

3.1. Opposition Fuzzy Sets. Variable fuzzy sets define the relative membership function based on fuzzy set definition. It gives the iteration variable fuzzy clustering model, variable fuzzy pattern recognition model, and variable fuzzy recognition model confrontation. The base model with the core content of variable fuzzy set is fuzzy clustering, recognition; theoretical models set the best decisions.

Variable fuzzy sets constructed from the principle of contradiction movement and the concept of dynamic describe things as follows.

Located on the opposition on the domain U vague concept (of things, phenomena) to A and A^c indicates that the nature of attraction and repulsion, for U any element u, $u \in U$, in reference to the continuous left pole $[1, 0]$ and any right pole $[0, 1]$ point, and attraction and repulsion relative membership degree were $\mu_A(u)$, $\mu_{A^c}(u)$, and $\mu_A(u)+\mu_{A^c}(u) = 1$. Let

$$\underset{\approx}{A} = \{(u, \mu_A(u), \mu_{A^c}(u)) \mid u \in U\} \tag{1}$$

when

$$\mu_A(u) + \mu_{A^c}(u) = 1, \quad 0 \le \mu_A(u) \le 1, \; 0 \le \mu_{A^c}(u) \le 1. \tag{2}$$

$\underset{\approx}{A}$ is called opposition U of fuzzy sets. Left pole P_l : $\mu_A(u) = 1$, $\mu_{A^c}(u) = 0$; right pole P_r : $\mu_A(u) = 0$, $\mu_{A^c}(u) = 1$. P_m reference continuum left pole $[1, 0]$ and right poles of gradual qualitative point $[0, 1]$; that is, $\mu_A(u) = \mu_{A^c}(u) = 0.5$.

3.2. The Relative Proportions of the Function. Consider

$$E(u) = \frac{\mu_{A^c}(u)}{\mu_A(u)} \tag{3}$$

when

$$\begin{aligned} \mu_A(u) &> \mu_{A^c}(u), \quad 1 > E(u) \geq 0, \\ \mu_A(u) &= \mu_{A^c}(u), \quad E(u) = 1, \\ \mu_A(u) &< \mu_{A^c}(u), \quad \infty > E(u) > 1. \end{aligned} \tag{4}$$

$E(u)$ call u for $\underset{\approx}{A}$ the relative proportions of degree. Mapping is

$$E : U \longrightarrow [0, \infty) \qquad u| \longrightarrow E(u) \in [0, \infty]. \tag{5}$$

It is called u for $\underset{\approx}{A}$ the relative proportions of the function.

The relative proportions of function represent a reference continuum at any points $\mu_{A^c}(u)$ and $\mu_A(u)$ of the relative ratio of the number of axes that opposing parties or the nature of the degree of attraction and repulsion ratio. $E(u) = 1$ point P_m describes the nature of attraction and repulsion dynamic equilibrium of the gradient type qualitative community. $1 > E(u) \geq 0$ can be changed by, $E(u) = 1$ qualitative point by gradient type $\infty > E(u) > 1$, you can change in the opposite direction. $E(u) = \infty$. P_l shows that the attraction and repulsion point reached abrupt qualitative change in the nature of community. Therefore, the relative proportions of the two functions a give complete description of the natural dialectic about a qualitative change in formation: gradient (nonexplosive qualitative) and mutant (explosive qualitative).

Let

$$\begin{gathered} V = \left\{ (u, U) \mid u \in U, E(u) = \frac{\mu_{A^c}(u)}{\mu_A(u)}, E \in [0, \infty] \right\}, \\ A_+ = \{u \mid u \in U, 0 < E(u) < 1\}, \\ A_- = \{u \mid u \in U, 1 < E(u) < \infty\}, \\ A_0 = \{u \mid u \in U, E(u) = 1\}, \\ A_* = \{u \mid u \in U, E(u) = \infty\}. \end{gathered} \tag{6}$$

V is called variable fuzzy sets. A_+, A_-, A_0, A_* are called fuzzy variable set V attraction (main) domain, exclusion (main) field, and gradient-type and mutant type qualitative community sector.

Let C be a variable factor V

$$\text{set}: C = \{C_A, C_B, C_C\}. \tag{7}$$

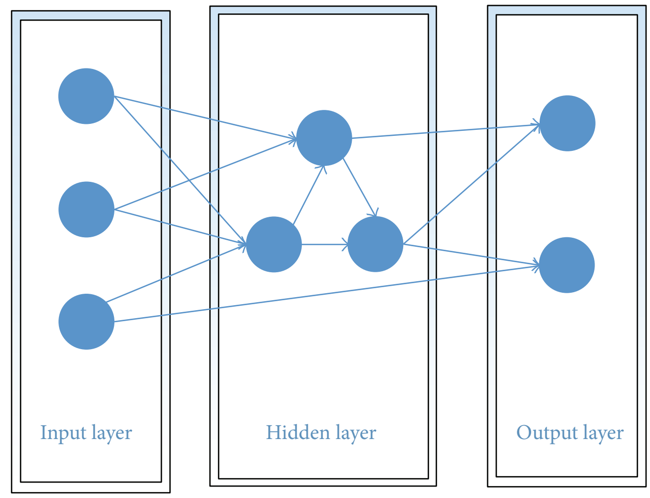

Figure 2: Tree-layer architecture.

C_A is variable model set, C_B variable model parameter set, and C_C other variables except for model and parameter set outside, so

$$\begin{aligned} A^- &= C(A_+) \\ &= \{u \mid u \in U, 0 < E(u) < 1, 1 < E(C(u)) < \infty\}, \\ A^+ &= C(A_-) \\ &= \{u \mid u \in U, \infty > E(u) > 1, 1 > E(C(u)) > 0\}. \end{aligned} \tag{8}$$

Unified called variable fuzzy sets V on variable factors set C gradient type variable domains, where $E(C(u))$ represents a function of the relative proportion of $C(u)$ as transformed.

The above definitions are an important part of the variable fuzzy sets, whereby you can get variable fuzzy sets; quantitative and qualitative change (gradient type, mutant type) judgment criteria are as follows:

(1) before and after the changes in the relative proportion of the function $E(u)$, $E(C(u))$ are greater than 1 or less than 1 for the amount;

(2) before and after the changes in the relative proportion of the function $E(u)$, $E(C(u))$ are from less than 1 to greater than 1 or greater than 1 to less than 1 by the formula for the gradient qualitative change;

(3) after the change of the relative proportions of the function $E(C(u)) = \infty$ for the abrupt qualitative.

4. Emotions Predicting System Based on Variable Fuzzy Set

4.1. 3-Layer Architature. The architecture reference to the relevant research for emotion forecasting system is composed of three layers [7]. The input layer collects data from environment like sensors (Figure 2), other systems, and so on. The input data are dependent on the domain. It would include all the external data with potential influence over the human's

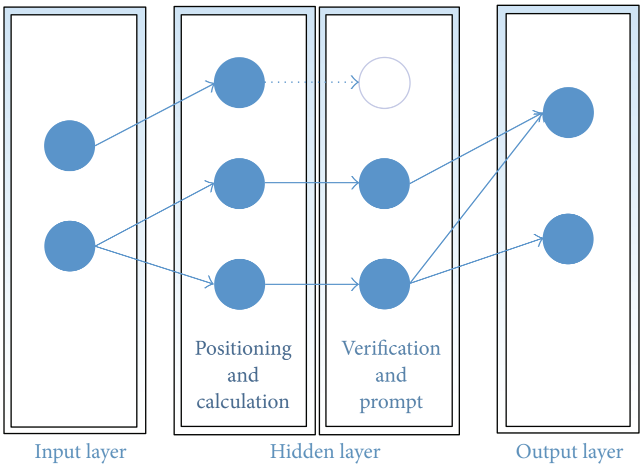

Figure 3: Four-layer architecture.

emotional states. It is possible to connect nodes in the input layer with the nodes in the output one. The hidden layer process the calculations between input and output layers.

The output layer is composed by a couple of nodes (arousal and valence). According to Plutchik's model; these are the needed concepts for determining the emotions.

4.2. 4-Layer Architature. Although the three-tier architecture can present the emotion change, the complexity of human emotions is not always random. This study determines the domain and range to reflect on the true emotions by variable fuzzy sets. Therefore, this study based on previous research and divided hidden layer into two a layer as Figure 3.

Due to computational reasons, an emotion is represented in the emotional space. Emotion's intensity is calculated as follows:

$$\phi = E(c(u)),$$
$$\psi_{\text{rad}} = \begin{cases} \arctan \dfrac{\sum u}{n}, & \text{if } 1 > E(C(u)) > 0, \\ \dfrac{\pi}{2}, & \text{if } E(C(u)) = 1, \\ \arctan \dfrac{\sum u}{n} + \pi, & \text{if } \infty > E(C(u)) > 1, \end{cases}$$
$$\psi = \psi_{\text{rad}} \cdot \frac{180}{\pi}, \tag{9}$$
$$\psi = \begin{cases} \dfrac{180}{\pi} \cdot \arctan \dfrac{\sum u}{n}, & \text{if } 1 > E(C(u)) > 0, \\ 90^{\circ}, & \text{if } E(C(u)) = 1, \\ \dfrac{180}{\pi} \cdot \arctan \dfrac{\sum u}{n} + \pi, & \text{if } \infty > E(C(u)) > 1. \end{cases}$$

For example, after a previous study of arithmetic, emotional changes from joy into sadness, but according to human knowledge, such a change is too much, by the definition of variable fuzzy sets, which may be mutated (explosive qualitative). With this approach and classification, you can filter certain mood change which is not realistic and provide a reference for the output layer on the system.

This paper presents variable fuzzy set as a technique for emotion predicting. It provides an operational blueprint so that researcher can consult it for predicting emotions in the future, especially in game development.

5. Conclusion

Emotions have a very important impact on human's beliefs, motivations, actions, and physical states. Emotions prediction in intelligent system can improve the interaction between humans and machines.

This paper combines with emotional dimension and the theory of variable fuzzy sets to present a predicting artificial emotion model and shows illustrated example of it. It shows that any raw data from sensor or input can be computed with variable fuzzy set. VFS is mathematic method for representing emotion quantitative, gradual qualitative, and mutated qualitative change.

This paper is not an empirical research. Future studies may investigate an evaluation system and verify models and real-world practice. This study does not seek to simulate human emotions rather to provide a framework to improve system for emotional computing. Therefore, it must consider the algorithms and applications (such as nonplayer characters in the game) to provide a flexible operation on emotional computing.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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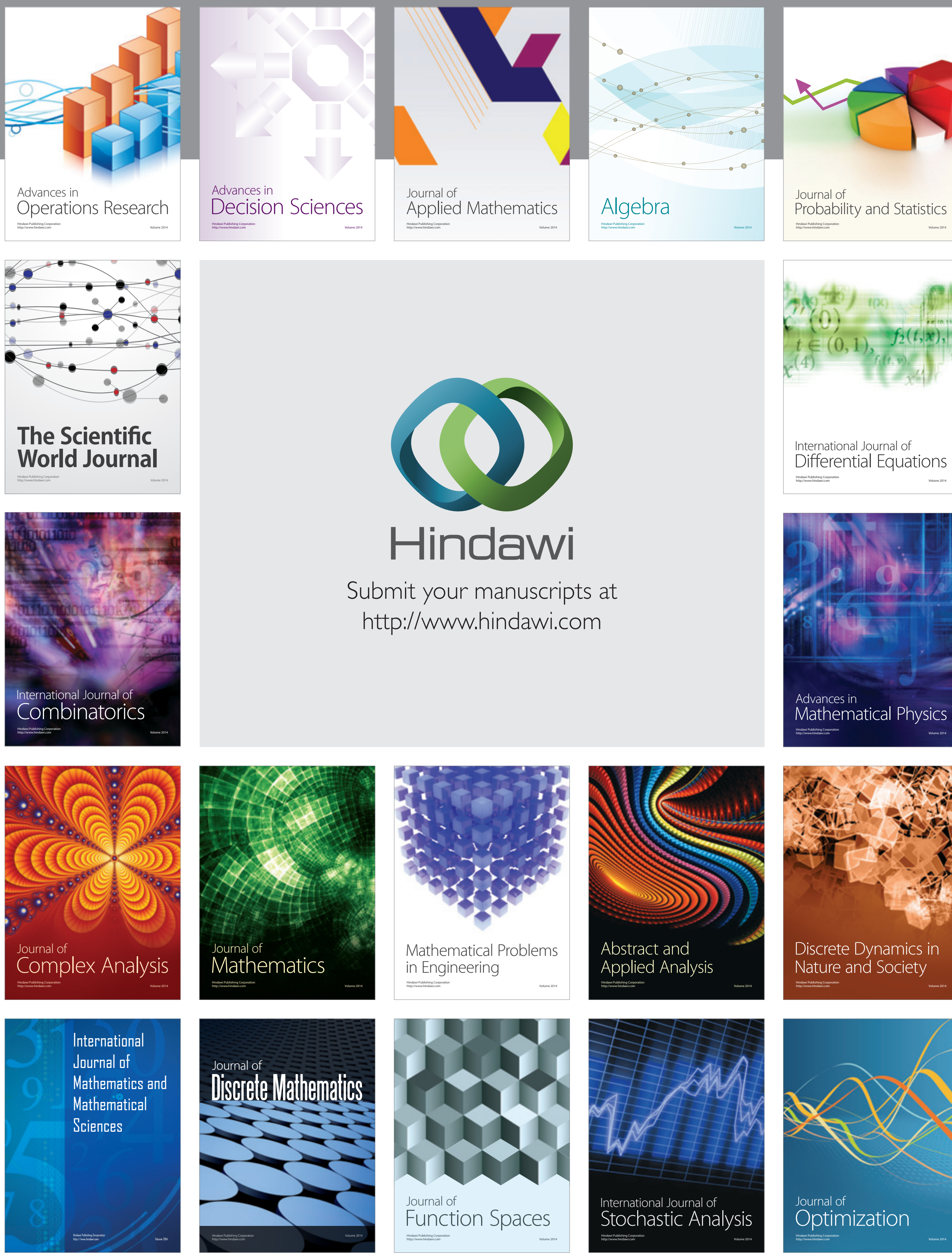
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