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Research Article

An Emotional Agent Model Based on Granular Computing

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Affective computing has a very important significance for fulfilling intelligent information processing and harmonious communication between human being and computers. A new model for emotional agent is proposed in this paper to make agent have the ability of handling emotions, based on the granular computing theory and the traditional BDI agent model. Firstly, a new emotion knowledge base based on granular computing for emotion expression is presented in the model. Secondly, a new emotional reasoning algorithm based on granular computing is proposed. Thirdly, a new emotional agent model based on granular computing is presented. Finally, based on the model, an emotional agent for patient assistant in hospital is realized, experiment results show that it is efficient to handle simple emotions.

1. Introduction

Emotions are essential to intelligence and makes human having better creativity and flexibility in the aspects of solving problem [1]. Artificial emotion is a research field which uses the means of information and science technology to imitate, recognize and understand the process of human being's emotion, enabling the machine to create the emotion which is similar to human being and communicate with human being harmoniously. Emotions of human are very complex and widely spread; they influence how we think, adapt, learn, behave, and how humans communicate with others [2–4]. The importance of emotion has been identified in human-like intelligence recently. Some neurological evidence proves that emotions do in fact play an important and active role in the human decision-making process [5]. Therefore, the research on emotional agent helps to improve the characteristic of intelligence of agent [2]. On the view of agent, emotions are evaluations and reactions for current interior status and the relation status between agent's desire and plan by

agent in exterior environment. To transact emotions more effectively, based on the granular computing theory [6] and the traditional BDI-agent model, in this paper, the author initially puts forward an a new emotion knowledge base, then proposes a new emotional reasoning algorithm, and lastly presents an emotional agent model based on granular computing.

2. Related Work

Bates [2] is building a believable agent, which only describes basic emotions and innate reactions. However, it presents a good starting point for building computer simulations of emotion. The basic emotions that are simulated in the model are anger, fear, sadness, happiness, disgust, and surprise.

Ushida et al. [3] proposes an emotional model for life-like agents with emotions and motivations. The model consists of reactive and deliberative mechanisms. A basic idea of the model comes from a psychological theory, called the cognitive appraisal theory. In the model, cognitive and emotional processes interact with each other based on the theory. A multimodule architecture is employed in order to carry out the interactions.

Maria and Zitar [4] propose a modeling of artificial emotions through agents based on symbolic approach. The symbolic approach utilizes symbolic emotional rule-based systems (rule base that generated emotions) with continuous interactions with environment and an internal thinking machinery that comes as a result of series of inferences, evaluation, evolution processes, adaptation, learning, and emotions. Agent architectures are presented as a generic blueprint on which the design of agents can be based. Our focus is on the functional design, including flow of information and control. With this information provided, the generic blueprints of architectures should not be difficult to implement agents, thus putting these theoretical models into practice.

El-Nasr et al. [5] propose a fuzzy-logic-adaptive model of emotions, which is modeled to produce emotions and to simulate the emotional intelligence process. The model is built using fuzzy rules to explore the capability of fuzzy logic in modeling the emotional process. Fuzzy logic helps them in capturing the fuzzy and complex nature of emotions. They conclude that the use of fuzzy logic did improve the believability of the agent simulated.

Lin [6] firstly suggested the term granular computing. Granular computing is a new way to simulate human thinking to help solve complicated problems. It involves all the theories, methodologies, and techniques of granularity, providing a powerful tool for the solution of complex problems. Granular computing has begun to play important roles in bioinformatics, e-Business, security, machine learning, data mining, and wireless mobile computing in terms of efficiency, effectiveness, robustness, and uncertainty.

Chown et al. [7] present a cognitive architecture for an interactive decision-making agent with emotions. The premise of this model is that emotions serve as a kind of automatic assessment system that can guide or otherwise influence the more deliberative decision-making process. However it did not quantify the emotion representation so it is very difficult to apply it into the real system.

Paolo and Robert [8] describe that the encounter between emotion research and agent-based technology is multifaceted. On the one hand, results from emotion research start to serve as role model from nature, providing inspirations for technical design criteria for individual agents at the micro-level and agent groups and societies at the macro-level as well as the sophisticated linkages in between them. On the other hand, they are of immediate impact in important aspects of human-agent interaction and effective social cooperation

between humans and conversational interfaces. In the broad survey, they offer an interesting selection of results from different areas of emotion research.

Gratch [9] proposes a command and control modeling architecture, which begins to address how behavioral moderators influence the command decision-making process. This modeling architecture is extended to support wide variability in how a synthetic commander performs his activities based on the influence certain behavioral moderators. It differs from other computational models of emotion.

Poel et al. [10] introduces modular hybrid neural network architecture, called SHAME, for emotion learning. The system learns from annotated data how the emotional state is generated and changes due to internal and external stimuli. Part of the modular architecture is domain independent, and part must be adapted to the domain under consideration. The generation and learning of emotions is based on the event-appraisal model.

3. Emotional Knowledge Base Based on Granular Computing

According to the basic emotional theory, we can divide the human being's emotion into N basic types. In this paper, the author expresses the emotional space as a vector space E, $E = \langle e_i \mid i = 1, 2, \ldots, N \rangle$, N stands for the total amount of emotional types. Since the emotional intensity has fuzzy characteristic, it is not easy to show by continuous quantity, so we can use discrete quantity to show every type of emotional intensity and can divide it into M levels. To make it simple, we choose the category -five index system from fuzzy mathematics to express approximately a particular emotional strength value V_i, whose functions are defined as follows:

$$V_i = \begin{cases} 0, & \text{neither the main body nor the body has;} \\ 0.3, & \text{the emotion is weaker;} \\ 0.5, & \text{the emotion is common;} \\ 0.8, & \text{the emotion is stronger;} \\ 1, & \text{the emotion is very strong.} \end{cases} \tag{3.1}$$

Then the emotional model could be showed as follows:

$$\begin{pmatrix} E \\ V \end{pmatrix} = \begin{pmatrix} e_1 & e_2 & \cdots & e_n \\ v_1 & v_2 & \cdots & v_n \end{pmatrix}. \tag{3.2}$$

Since the emotion type is basically stable, so the emotion model could be simplified to the emotional vector space $E = \langle v_1, v_2, \ldots, v_n \rangle$.

Definition 3.1. The emotional knowledge base is a triple group $K = \langle T, S, B \rangle$, among which T describes the principle concept and definition on the emotional field, and forms the emotional field concept axiom; S is a causal constraint relation existing between the emotional field facts and formulas, and it is called emotional causal constraints axiom, which ensures the consistency and integrality of emotional knowledge base. B is the description for the facts and data under the current condition of emotional field, that is, a current emotional set, which is dynamic and changeable.

The basic form of the concept axiom is

$$\forall x(C(x) \longrightarrow D(x)). \tag{3.3}$$

Among them, C and D are the concepts. X is any individual subject. Normally, we omit the universal quantifier $\forall x$ to be simplified $C(x) \rightarrow D(x)$, which shows that the concept C is included in the concept D. As an independent unit, the concept axiom points out the containment relationship between basic concepts in the field of independent units.

The basic form of casual constraint axiom is

$$\forall x_1 \cdots \forall x_n (\alpha \longrightarrow \beta). \tag{3.4}$$

Among which, α and β are formulas with individual argument, and all individual argument are inside $x_1, \ldots, x_n$. The intuitive significance is, for any individual $x_1, \ldots, x_n$, $\alpha(x_1, \ldots, x_n)$ covers $\beta(x_1, \ldots, x_n)$. Normally, we would omit the universal quantifier $\forall x_1 \cdots \forall x_n$ to be simplified as follows:

$$\alpha(x_1, \ldots, x_n) \longrightarrow \beta(x_1, \ldots, x_n). \tag{3.5}$$

In a particular situation, causal constraint axiom could be the causal relationship between specific assertion formulas. The form is $A \rightarrow B$, among them, A and B are assertion formulas. In the emotion knowledge base, emotional vector quantity $E = \langle v_1, v_2, \ldots, v_n \rangle$ is an assertion formula, which stands for those emotions and intensities owned by the current intelligent main body.

Based on the above emotional knowledge base model, if we define the concept axiom C among $C \rightarrow D$ to be a series of conditional properties but define D to be a decision property (one certain emotional status), we could get the emotion knowledge base model based on granular computing.

The granular computing theory mainly regards the relationship data base as the study subject; normally we define the relationship database to be an information system abstractly. One information system S is a quadruple: $S = (U, R = C \cup D, V, f)$, among them, $U = \{x_1, \ldots, x_n\}$ is a limited subject set, which is also called the universe of discourse, $C = \{a_1, \ldots, a_k\}$ is a set of conditional properties. D stands for decision-properties set, $V = \{v_1, \ldots, v_k\}$ is the value-domain set of the properties. v_k is the value set of the property ak, f is the information function, $f : U \times R - V$. Normally, we only consider there is only one decision property; for multidecision properties problems, we could make it to be single-decision property problem to deal with.

The definition of the rough-set model of the emotional knowledge base is as follows:

Definition 3.2. One emotional computing system is a quadruple $S = \{U, R = C \cup D, V, f\}$. Among them, U is the set of the subject. R is the set of properties; C is the set of conditional properties. D stands for decision properties, that is, emotional classification, V is the set of properties value, and f is the information function, which stands for every subject X's property value on U.

Definition 3.3. The indiscernible relation on U: Assuming the property set $P \subseteq R$, subject X, $Y \in U$, for every $a \in P$, if there is $f(X, a) = f(Y, a)$, then, X and Y are indiscernible, that is, $\mathrm{IND}(P) = \{(X, Y) \in U : \forall a \in P, (f(X, a) = f(Y, a))\}$.

Obviously, $\mathrm{IND}(P)$ is an equivalence ration. Then properties set P could be regarded as a name of knowledge showed by equivalence ration. Therefore, an emotional computing system could be regarded as a knowledge base system, when there is a subject that requires analysis, according to $\mathrm{IND}(P)$ to judge that the knowledge base rule in accordance with the subject, and to make the classification according to the rule.

Therefore, based on the granular-computing theory, a new method for achieving emotional decision rules of the emotional knowledge base is presented and followed:

(1) Data preprocessing, including deleting the repeating records, a data complement of decision table, and data discretion.

(2) To adopt the method of granular-computing to process granular computing binary graining.

(3) To adopt the relative-attribute-reduction algorithm to process the attribute reduction.

(4) To delete the redundant attribute value and get the value-attribute reduction; processing for all reductions; to get the smallest reduction.

(5) To get the logic rules according to the value reduction, that is, emotion-decision rule. Referring to the logic significance of every property, to analyze the rules obtained by attribute reduction, then, we can get the relative logic rules.

4. Emotional Reasoning Algorithm Based on Granular Computing

In the past, the opinion on the brain and the strategy is to divide the people's thinking into two noninterference types of activities, that is, cognition and emotion. However, the current scientists tend to think that the cognition and emotion are interactive, overlapped, and interdependent. Therefore, we imitate the interactive process of the cognition and emotion in the way of combining the rational reasoning machine and emotional reasoning machine, so that it can be in accordance with the control mode of human being's brain, that is, the combination of the cognition and emotion can decide the behavior.

Because emotion of human is inaccurate and inconsistent, It is uneasy to make emotion reasoning by the traditional method. From a new view, granular-computing theory defines knowledge as a capability to classify concrete or abstractive objects and provides a method to deduce hiding fact from vagueness facts.

A new emotional reasoning algorithm based on granular computing theory is proposed.

The emotional reasoning algorithm based on granular computing is followed:

Step 1. According to belief, desire, plan, and realized intention, searching subgoals that has been realized and unrealized sub-goals that should be realized since time $(i - 1)$.

Step 2. Preprocessing data, include deleting repeated record, patching decision table, and dispersing data. By the comparison, it is found that dispersing with the improved greedy algorithm is better than other algorithms in data preprocessing.

Step 3. Deleting surplus attribute and making the attribute reduction. CEBARKNC algorithm, which bases on the condition of the Information entropy, can produce a better effect in the emotion attribute reduction.

Step 4. Deleting surplus attribute values and getting the attribute-value reduction. The heuristic value-reduction algorithm can produce a better effect in the emotion reasoning problem.

Step 5. Getting the logic rule according to the attribute-value reduction. By combining each attribute's logic meaning, the logic rule is gotten by the attribute reduction.

Step 6. Making reasoning by one order logic rule and obtaining corresponding emotional vector in the knowledge emotion base.

Step 7. Calculating the highest value of every emotion vector as the current emotion in time (i).

The emotional reasoning machine implements emotion reasoning utilizing the emotional reasoning algorithm based on granular computing according to the status of agent's desire, plan, belief, emotional knowledge base, and current intention.

The emotional reasoning machine is mainly used to deal with the emotional logic reasoning based on relevant external environment, planning, wish, and the current situation of the intentions to realize the emotional reasoning. The emotional inference is based on the rational reasoning, but there are still some differences between both at the same time. In the main structure of the emotional intelligence, the rational inference machine defines the current purpose and action according to the brief, planning, and target, while the emotional reasoning machine achieves the emotional inference by using the emotional knowledge base according to the wish, plan and brief of the main body, and the situation of current purpose.

5. Emotional Agent Model Based on Granular Computing

In order to treat emotion, a new emotional agent model based on granular computing is proposed, which is illustrated in Figure 1. The emotional agent model is composed of belief, desire, intention, plan, reasoning machine, emotional knowledge base and emotional reasoning algorithm. It extends the traditional BDI agent model by adding an emotional knowledge base and an emotional reasoning algorithm.

In this model, belief, desire, intention, and emotion are represented by symbols. The rational belief of emotional agent is the basic and most important element. Some other problems such as the representation and rational deduction of mental status all base on and rely on the rational belief. The belief of emotional agent usually can be regarded as the rational knowledge base. It contains abundant contents including the basic axiom, the domain axiom familiar by emotional agent, and the understanding of facts and data in the domain, which is constructed by the facts of the outer world, the exterior environment and interior status. These facts are described by one order logic.

Desire is the initial motivation of agent. It is the state for agent to reach or state set to keep, which is the goal set to implement. The plan and action are activated by desire, which can be described as a kind of exception and judgment. The desire's implementation is judged by the state's coming into existence.

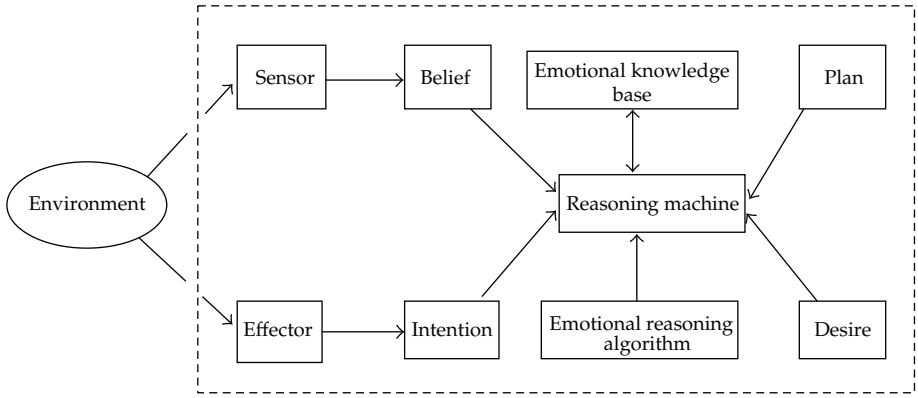

Figure 1: An emotional agent model based on granular computing.

The intention is the most needed or suitable one to accomplish among the desire promising to implement currently. It is the prearrangement for agent's action. Current intention directs current action. Intention differs from goal. It is the goal or subgoal to execute. The goal is stable relatively while intention is easy to change. The action intention of emotional agent is their action queue. Its execution is associated with the schedule of emotional agent. Once the action is scheduled, the intention switches to the execution of action.

Plan is the action program of emotional agent. It points out the main method for the emotional agent to realize certain requirement. Current agent itself and environment state can be connected with agent's goal. It becomes the main means leading agent to implementing the requirement. In fact, plan associates the emotional agent's rational belief and the capability of behavior description with goal organically. It points out which action will adopt to realize certain goal under certain rational belief.

Sensor is responsible for receiving the message of environment and changing the belief of agent. It performs the action and sends message to outside environment according to the belief of agent.

Emotional knowledge base stores the facts relevant with emotion, which are expressed with one order logic. In the model, the facts irrelevant with emotion are expressed with rational belief and the facts relevant with emotion are described in emotional knowledge base.

Reasoning machine is used to dealing with the logic reasoning relevant with emotion. The emotional reasoning is implemented by emotional reasoning algorithm according to surrounding environment, plan, desire, and situation of current intention. It implements emotion reasoning utilizing emotional knowledge base based on granular computing according to the status of agent's desire, plan, belief, and current intention.

In the structure of emotional agent, agent has initial desire and plan for goal to arrive at. When the surrounding environment has changed, and after it influences agent's belief, reasoning machine implements emotional reasoning according to belief, desire, plan, and realized intention. At the same time, emotional knowledge also can be the premise of rational reasoning. We build the emotional agent model with ration and emotion coexistent, dependent, and different, which can effectively implement the emotional expression and reasoning.

Table 1: Applicable experiment of emotional database.

U	HR	Breathing	Temperature	Blood pressure	Mood
1	Normal	Normal	Normal	Normal	Quiet
2	Normal	Normal	Normal	Higher	Quiet
3	Normal	Normal	Normal	Lower	Quiet
4	Normal	Shortness	Higher	Lower	Heightened
5	Normal	Shortness	Lower	Higher	Heightened
6	Shortness	Normal	Normal	Higher	Heightened
7	Shortness	Normal	Higher	Normal	Heightened
8	Normal	Normal	Higher	Lower	Downturn
9	Normal	Normal	Lower	Lower	Downturn
10	Normal	Shortness	Normal	Lower	Downturn

6. Experiments

JADE [11] is a software framework of a development source code developed by the Italian Parma University. It meets the requirement of FIPA and simplifies the development process of multi-intelligent main body system. In this paper, We use JADE as the development tool, implement a simple medical intelligent auxiliary system, which establishes an auxiliary medical emotional agent. Through emotional reasoning algorithm, it reasons out patients' moods through the emotional information granule-reasoning machine, and to ease hospitalized patients' poignant and low moods which can affect the treatment by music.

Table 1 is an applicable experiment of the emotional database, its universe of discourse $U = \{1, 2, \ldots, n\}$, the conditional attribute set $C = \{$HR, Breathing, Temperature, Blood pressure$\}$, Decision attribute set $D = \{$Mood$\}$, to express it in a convenient way, later the author uses $\{a, b, c, d, e\}$ to display every property one by one. Firstly, to do the emotional database discretion, then, to take data preprocessing, and to delete the same rows and columns and inconsistent data, to adopt the method of granular computing to process granular-computing binary graining. After the attribute reduction, we process attribute-value reduction. Firstly, to get the core-value form, the method is: to delete one row's one granular computing, and judge a logic conjunction of the rest granular computing whether included in the decision granules on this row. If included in the decision granule on this row, then the granular computing could be reduced, not a core-value; if not, the granular computing couldn't be reduced, it is a core-value. The smallest reduction obtained is the emotional decision knowledge rule.

The explanation for using emotional decision rules achieving method to obtain emotional decision rule knowledge is as follows:

The First Type of Decision Rule

If there are three physical signs among individual's HR, breathing, temperature, and blood pressure are normal, then the mood decision we will make is quiet.

The Second Type of Decision Rule

If individual's HR is normal but temperature and blood pressure are higher, or breathing is normal but temperature and blood pressure are higher, or HR is normal but temperature is

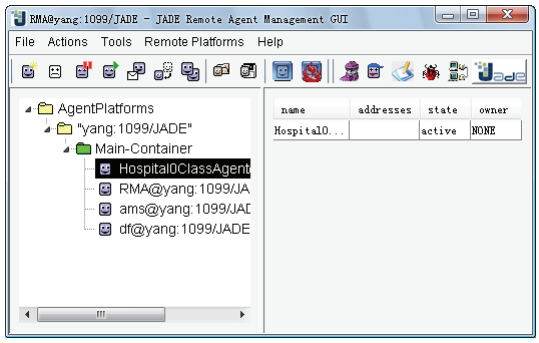

Figure 2: Agent management user interface.

lower and blood pressure is higher, or breathing is normal but temperature is lower and blood pressure is higher, or breathing is short and blood pressure is higher, or the HR is normal but breathing is short and temperature is higher, or breathing is normal but breathing is short and temperature is higher, or temperature and blood pressure is higher, or temperature is lower and blood pressure is higher, or HR is short and blood pressure is higher, or breathing is normal but HR is short and temperature is higher, or blood pressure is normal and HR is short and temperature is higher, or temperature and blood pressure are normal but HR and breathing are short, then the mood decision we will make is heightened.

The Third Decision Rule

If individual's HR and breathing are normal but temperature is higher and blood pressure is lower, or HR is normal but temperature and blood pressure are lower, or breathing is normal but temperature and blood pressure are lower, or temperature is normal but breathing is short and blood pressure is lower, or blood pressure is normal and breathing is short and temperature is lower, or breathing is short but temperature and blood pressure are lower, or temperature is normal and HR is short and blood pressure is lower, or blood pressure is normal but HR is short and temperature is lower, or HR is short and temperature and blood pressure are lower, or HR and breathing are short and blood pressure is lower, or temperature and blood pressure are lower, then the mood decision we will make is downturn.

Figure 2 shows that an emotional agent named Hospitaloclassagent is established.

Figure 3 is the working interface of medical intelligent and auxiliary system.

7. Conclusion

Research results of neurobiology show that emotions play an important and active role in human-like intelligence. Emotions are essential to intelligence and makes human more creative and flexible in the aspects of solving problem. In order to make agent have the ability of transact emotions, a new model structure of emotional agent is presented. In this paper, based on the granular computing and the traditional BDI agent model, the author initially puts forward a new emotion knowledge base, proposes a new emotional reasoning algorithm, and presents an emotional agent model based on granular computing. Finally, based on the model, an emotional agent for assistant patient in hospital is realized,

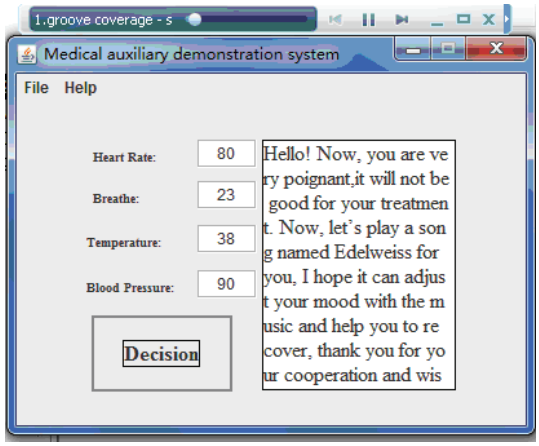

Figure 3: Medical intelligent and auxiliary system interface.

experiment results show that it is good to transact simple emotions. We are doing further research on the complicated emotion expression and reasoning for effective computing.

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