Ghasem-Aghaee, N. and Ören, T.I. (2003 - In Press). Towards Fuzzy Agents with Dynamic Personality for Human Behavior Simulation, Proceedings of the 2003 Summer Computer Simulation Conference, Montreal, PQ, Canada, July 20-24, 2003, pp. 3-10

ISBN: 1-56555-268-7

Towards Fuzzy Agents with Dynamic Personality for Human Behavior Simulation

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Keywords: Personality knowledge, fuzzy logic, fuzzy agents, agents with personality

Abstract
In this article, the aim is define fuzzy agents with dynamic personality for the simulation of human behavior. Fuzzy sets are defined for personality traits and facets and the concise representation of personality knowledge is processed in fuzzy logic. This work is based on the personality knowledge as distilled from psychology [Ören and Ghasem-Aghaee 2003a].

1. INTRODUCTION

The term personality refers to the sets of predictable behaviors by which people are recognized and identified. These sets of behaviors go by the name of personality traits or factors. A contemporary view of traits considers in five dimensions, i.e., five-factor model of personality or the big five personality traits: (*Openness, Conscientiousness, Extraversion, Agreeableness, and Negative emotions*) and each has six *facets* [Costa and McCrae 1992, 1995, 2003; Howard 2000; Howard and Howard 2001a, b; Ören and Ghasem-Aghaee, 2003a].

Fuzzy sets and *fuzzy logic* are effective techniques for handling fuzzy uncertainties with well-developed mathematical properties. Imprecise concepts are attributes of which people generally have a cognitive perception, yet are impossible to define precisely like the five-factor personality model. Fuzzy logic provides an excellent way to represent and process linguistic variables. Possibly the biggest weakness of non-fuzzy methods of dealing with imprecision and uncertainty is their handling of linguistic terms. Fuzzy set theory provides a natural method for dealing with the linguistic terms by which an expert will describe a domain [Kandel and Hall 1991]. An increasing number of works now use fuzzy logic for implementing human behavior [El-Nasr et al. 2000; El-Nasr and Skubic 1998; Mitaim and Kosko 1998; Michaud 1997; Bonarini 1996; Li 1994].

Linguistic variables were introduced by Zadeh [1973] and this term is used to describe some concepts that usually have vague or fuzzy values [Durkin 1994]. The linguistic terms *low, medium, high,* are assumed to be from the term set for a linguistic variable like *negative emotionality* of personality traits and are interpreted as fuzzy subsets of some universe *U* of negative emotionality. In fact, in modeling and simulation of human behavior, we are not restricted to just absolute quantifier that represents a crisp value like one or two, but we are also concerned with relative quantifier that represents a fuzzy value, such as low, medium, high, most, or some. Table 1 shows possible values of the values of the facets of one of the traits of the five-factor model. The other personality factors and their facets linguistic variables have similar typical values.

Table 1: Linguistic variables with typical values

Linguistic variables	**Typical Values**
Negative Emotionality	low, medium, high
Worry	low, medium, high
Anger	low, medium, high
Discouragement	low, medium, high
Self-consciousness	low, medium, high
Impulsiveness	low, medium, high
Vulnerability	low, medium, high

2. FUZZY LOGIC AND FUZZY SETS RELATED WITH PERSONALITY TRAITS

The term "*fuzzy logic*" emerged in the development of the theory of *fuzzy sets* by Lotfi Zadeh [1965]. He modified conventional set theory in which an individual could have a degree of membership which ranged over a continuum of values, rather than being either 0 or 1. The definition of the fuzzy logic formalism still relies on the conventional logic. *Fuzzy logic* is concerned with the reasoning about *fuzzy* events or concepts (like old, young, worry, angry, fear, and happy). Fuzzy sets and fuzzy logic possess far greater capabilities than their classical counterparts, their use considerably improves the bridge between mathematical models and the associate physical reality [Klir and Yuan 1998].

2.1 Fuzzy Sets and Fuzzy Set Operations

"Let X be the universe of discourse, with elements of X denoted as x. A *fuzzy set A* of X is characterized by a membership function $\mu_A(x)$ that associates each element x with a degree of membership value in A." [Durkin 1994].

$$\mu_A(x) : X \rightarrow [0, 1]$$

In fuzzy logic, event or element x is assigned a membership value by a membership function μ. This value represents the degree to which element x belongs to fuzzy set A. For example, let us take the statement, "Mary is low worry," if the degree of Marry low worry is 30, we might assign the statement the truth value of 0.5 or with fuzzy sets as:

$$\mu_{\text{low worry}}(\text{Mary}) = 0.5$$

The membership function μ operates in this case on the fuzzy set of low worry people and returns a value between 0 and 1. The fuzzy terminology corresponds to "Mary's degree of membership within the set of low worry people is 0.3. Determination of the value of a factor based on the values of the facets and definition of the membership functions that reasonably map the personality traits value into their corresponding belief values are very important. Fuzzy mapping or membership functions can have a variety of shapes depending on how the expert relates different domain values to belief values. "A convenient way of representing a fuzzy set is through the use of a vector" [Durkin 1994, p. 368] :

$$A = (a_1, a_2, \ldots, a_n)$$

where,

$$A_i = \mu_A(x_i)$$

The vector includes the symbol "/" which associates the membership value a_i with its x_i:

$$A = (a_1/x_1, a_2/x_2, \ldots a_n/x_n)$$

As example, we may define the fuzzy sets low worry, medium worry and high worry of facet *worry* of the thirty facets of personality traits as follows; the fuzzy sets for the other facets can be defined similarly. We divide *worry* into ten degrees, and use three fuzzy sets to describe it: low, medium and high. Figure 1 graphically shows fuzzy sets on worry.

Low worry = (**1.0/10,1.0/20, 0.5/30**, 0.0/40, 0.0/50, 0.0/60, 0.0/70, 0.0/80, 0.0/90, 0.0/100)

Medium worry = (0.0/10,0.0/20, 0.0/30**, 0.2/40, 1.0/50, 0.2/60**, 0.0/70, 0.0/80, 0.0/90, 0.0/100)

High worry = (0.0/10,0.0/20, 0.0/30, 0.0/40, 0.0/50, 0.0/60, **0.5/70, 1.0/80, 1.0/90, 1.0/100**)

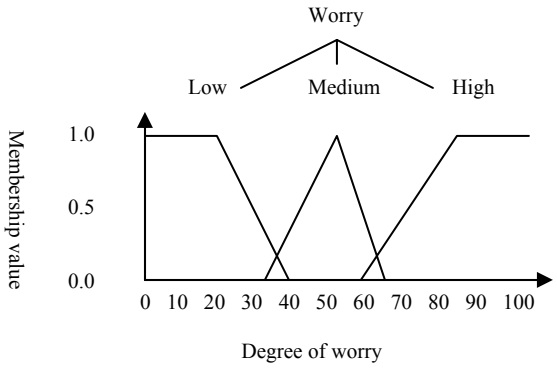

Figure 1: Fuzzy sets on worry

Another important feature of fuzzy systems is the ability to define 'hedges' (Table 2) or modifier of fuzzy values such as very, very very, somewhat, or indeed as follows [Durkin 1994, p. 369]:

Table 2. Hedges in fuzzy logic

hedges	**values**
very	$\mu_A(x)$^2
power (very very)	$\mu_A(x)$^n where n=3
somewhat	$\mu_A(x)$^0.5
indeed	2*$\mu_A(x)$^2 for 0<= $\mu_A(x)$<=0.5 1-2(1- $\mu_A(x)$)^2 for 0.5< $\mu_A(x)$<=1

Therefore, as an example, for the facet worry, we can define very low worry, very very low worry, somewhat low worry, or indeed low worry.
Although the logical operations NOT, AND, & OR from conventional Boolean logic also apply to fuzzy logic, the interpretations of these operations are slightly different as specified in Table 3.

Table 3. Fuzzy operators

AND (intersection)	Min ($\mu_A(x)$, $\mu_B(x)$)
OR (union)	Max ($\mu_A(x)$, $\mu_B(x)$)
NOT (complement)	$1 - \mu_A(x)$

2.2 Fuzzy Inference

"Rule based inference systems are too rigid in decision development, while fuzzy based inference provides a range of all possible decisions depending upon the 'soft' composition of several fuzzy variables" [Pitts 2002].

The general *fuzzy inference* process includes the following:

1. Under fuzzification, the membership functions defined on the input variables are applied to their actual values, to determine the degree of truth for each rule premise.
2. A *knowledge base* is the collection of the expert control rules (knowledge) needed to achieve the

control goal. The knowledge base usually is expressed as a number of 'IF-THEN' rules based on the domain expert's knowledge.

3. A *fuzzy reasoning* mechanism which performs various fuzzy logic operations to infer the control action for the given fuzzy inputs.
4. Under defuzzification, if the conclusions of the fuzzy rule set are fuzzy subsets themselves, then it is necessary to translate these subsets into a crisp number before the results can be used in practice.

Inference from a set of fuzzy rules involves fuzzification of the conditions of the rules, then propagating the confidence factors (membership values) of the conditions to the conclusions (outcomes) of the rules.

3. FUZZY KNOWLEDGE TO REPRESENT PERSONALITY

Zadeh [1975] has pointed out the *incompatibility principle*, which states that "complexity and precision are incompatible properties. Thus the conventional numerical-based approaches are inadequate to model human knowledge in complex processes," like human personality traits. Sophisticated knowledge and rich human experience can be incorporated into the *fuzzy knowledge ba*se in an almost natural language [Yan et. al. 1994]. The rules would depend on the application. In the sequel, the knowledge in Tables 1-5 of Ören and Ghasem-Aghaee [2003a] is used. As an example, we represent the knowledge associated with *Openness*. In Table 4, -, =, +, means low, medium and high and an additional column gives the personality descriptors.

Table 4. Personality facets

facets	value	Personality descriptor
fantasy	-	focuses on here and now
	=	occasionally imaginative
	+	imaginative
		daydreams
aesthetics	-	uninterested in art
	=	moderate interest in art
	+	appreciates art and beauty
feelings	-	ignores and discounts feelings
	=	accepts feelings
	+	values all emotions
actions	-	prefers the familiar
	=	a mixture of preference of the familiar and the new
	+	prefers variety
		tries new things
ideas	-	narrower intellectual focus
	=	moderate curiosity
	+	broad intellectual curiosity
values	-	dogmatic
		conservative
	=	moderate
	+	open to new values
		open to reexamining values

In the rules, the personality descriptors can be specified as di_"facet" where i is one of the letters (O, C, E, A, N) to indicate which personality factor, the personality facet is associated with; "facet" is the name of the facet. Examples: dC_order, dE_positive_emotions.

The rules about personalities can then be generated as follows:

1st group: Rules to represent *personality descriptors* based on the values of the facets of each personality factor. Some examples from each personality factor follow:

Openness:

IF fantasy is low
THEN dO_fantasy is **focuses_on_here_and_now**.

IF fantasy is medium
THEN dO_fantasy is **occasionally_imaginative**.

IF fantasy is high
THEN dO_fantasy is **imaginative**.

Conscientiousness:

IF order is low
THEN dC_order is **unorganized**.

IF order is medium
THEN dC_order is **half_organized**.

IF order is high
THEN dC_order is **well_organized**.

Extraversion:

IF warmth is low
THEN dE_warmth is **reserved**.

IF warmth is medium
THEN dE_warmth is **attentive**.

IF warmth is high
THEN dE_warmth is **friendly**.

Agreeableness:

IF trust is low
THEN dA_trust is **skeptical**.

IF trust is medium
THEN dA_trust is **cautious**.

IF trust is high

THEN	dA_trust	is **see_other_as_honest**.

Negative emotionality:

IF	worry	is low
THEN	dN_worry	is **calm**.

IF	worry	is medium
THEN	dN _worry	is **worried_calm**.

IF	worry	is high
THEN	dN _worry	is **worried**.

IF	anger	is low
THEN	dN _anger	is **composed**.

IF	anger	is medium
THEN	dN _anger	is **some_anger**.

IF	anger	is high
THEN	dN _anger	is **quick_to_feel_anger**.

2nd group: Rules to represent the value of the *personality factors* based on the values of its facets

IF	fantasy	is low
AND	aesthetics	is low
AND	feeling	is low
AND	actions	is low
AND	ideas	is low
AND	values	is low
THEN	openness	is **preserver**.

Here in addition to assert that the openness is preserver, one could also express the degree of preserver and accordingly its membership value.

IF	fantasy	is medium
AND	aesthetics	is medium
AND	feeling	is medium
AND	actions	is medium
AND	ideas	is medium
AND	values	is medium
THEN	openness	is **moderate**.

IF	fantasy	is high
AND	aesthetics	is high
AND	feeling	is high
AND	actions	is high
AND	ideas	is high
AND	values	is high
THEN	openness	is **explorer**.

Similar rules for conscientiousness, extraversion, agreeableness, and negative emotionality are possible.

A more general way to determine the value of a trait is to consider the degree (value) of a trait, which is the degree (value) of the current dominant facet. The degree of a facet is its weighted value (equal to the product of its measured value by its weight factor as determined from factor analysis). This way of determination also covers the special cases where all facets have same values.

El-Nasr and Skubic [1998] also propose that the agent acts on the emotion with the highest intensity and Gadanho and Hallam [1998] use the current dominant emotion.

As an example for the determination of the value of a trait from the dominant values of its facets, let's consider the weighted values of the facets as follows: Low<45, 45<=medium<=55, high>=55). Then the fuzzy rule follws:

			degree*
IF	fantasy	is low	20
OR	aesthetics	is medium	50
OR	feeling	is high	80
OR	actions	is low	20
OR	idea	is high	90
OR	values	is high	85
THEN	openness	is high	90

IF	worry	is low	10
OR	anger	is medium	50
OR	discouragement	is high	80
OR	self-consciousness	is low	20
OR	impulsiveness	is low	10
OR	vulnerability	is medium	55
THEN	negative emotionality	is high	80

* degree is given for descriptive purposes and is not included in the current version of the rules. For example, openness is high with a degree of 90 can be translated that openness is preserver with a degree of 90.

3rd group: Representation of *compound personality characteristics*; some examples follow:

The following abbreviations are used to represent personality characteristics:

c_style:	conflict style.
d_style:	decision style.
l_style :	learning style.
ls_style:	leadership style.
ps_style:	problem solving style.

The following rules are gleaned from psychology literature. To each rule, one can associate the degrees and fuzzy sets which can then be used in specifying the membership values.

IF	openness	is low
AND	conscientiousness	is low
THEN	ps_style	is **generator**.

IF	openness	is low
AND	conscientiousness	is high
THEN	ps_style	is **implementer**.

IF	extraversion	is high

AND	negative emotion	is low
THEN	l_style	is **independent**

IF	openness	is high
AND	agreeableness	is low
THEN	ls_style	is **visionary**.

IF	conscientiousness	is medium
AND	extraversion	is high
AND	agreeableness	is medium
AND	negative emotion	is medium
THEN	c_style	is **negotiator**.

IF	conscientiousness	is low
AND	agreeableness	is medium
AND	negative emotion	is low
THEN	d_style	is **diplomat**.

4th group: Personality is a pattern of behavioral, temperamental, emotional, and mental traits that distinguish people from one another. Behavior can change through adaptive processes [Allbeck and Badler 2002]. From the terms in the Table given by Howard [2000, p. 364], we can generate the following emotional rules about the **personality modifications** (PT: abbreviation for personality trait):

IF	emotional_state	is fear
THEN	PT_expression	is **timid**.

IF	emotional_state	is anger
THEN	PT_expression	is **quarrelsome**.

IF	emotional_state	is joy
THEN	PT_expression	is **affectionate**.

IF	emotional_state	is sadness
THEN	PT_expression	is **gloomy**.

IF	emotional_state	is acceptance
THEN	PT_expression	is **trusting**.

IF	emotional_state	is disgust
THEN	PT_expression	is **hostile**.

IF	emotional_state	is expectation
THEN	PT_expression	is **demanding**.

IF	emotional_state	is surprise
THEN	PT_expression	is **indecisive**.

From the terms in the table [Howard 2000, p. 364], we can generate the following rules about the **behavioral approach to emotions**.

IF	emotional_state	is fear
THEN	behavioral_expression	is **withdraw**.

IF	emotional_state	is anger
THEN	behavioral_expression	is **attack**.

IF	emotional_state	is joy
THEN	behavioral_expression	is **mate**

IF	emotional_state	is sadness
THEN	behavioral_expression	is **distress signal**.

IF	emotional_state	is expectation
THEN	behavioral_expression	is **examine**.

IF	emotional_state	is surprise
THEN	behavioral_expression	is **freeze**.

Personality changes over time - From age 20 to age 30, negative emotionality, extraversion, and openness tend to decrease, while agreeableness and conscientiousness tend to increase [Howard and Howard 2001a, p.17]. Another way of saying this is that as we enter adulthood and the world of work, we become more emotionally stable, somewhat less sociable, a little more conservative, a little easier to get along with, and a little more goal-oriented [Howard 2000, p.439].

IF	PT_agreeableness	is low
THEN	behavioral_expression	is **challenger**.

IF	PT_conscientiousness	is low
THEN	behavioral_expression	is **flexible**.

4. FUZZY AGENTS WITH PERSONALITY

An important aspect of modeling human behavior is to take into account dynamic personality. When at least any one of the 30 facets changes its value, the personality is affected and the model should be updated, i.e., the personality should be re-evaluated. This corresponds to a discontinuity and model update. For a generalized view and implications of discontinuity and model update see Ören [1987, 1991]. "In addition for the classic properties of agents, like autonomy, social ability, reactivity and pro-activeness, some researches consider that an agent is either conceptualized or implemented using characteristics usually applied to human-like entities [Bates 1994; Shoham 1993]. A way of giving agents human-like attributes in a computational system is to take accounts the incertitude of theirs beliefs. In this case, the use of the theory of fuzzy sets [Zadeh 1965] is appropriated to model the agent intentional system according with the environment possibilities." [Campos and Hill 1998].

Some definitions follow:

Agents: Agents are autonomous software modules with perception and social ability to perform goal-directed knowledge processing, over time, on behalf of humans or other agents in software and physical environments.

The knowledge processing abilities of agents include: reasoning, motivation, planning, and decision making. Additional abilities of agents are needed to make them intelligent and trustworthy. Abilities to make agents intelligent include anticipation, understanding, learning, and communication in natural language. Abilities to make agents more trustworthy as well as assuring the sustainability of agent societies include being rational, responsible, and accountable. These lead to rationality, skillfulness and morality (e.g., ethical agent, moral agent).

Fuzzy agents are agents that can perform qualitative uncertainty reasoning with *incomplete and fuzzy knowledge* in some environment that contains linguistic variables.

Agents with personality are fuzzy agents with characteristics such as openness, conscientiousness, extraversion, agreeableness, and negative emotions in line with the five-factor personality theories to model human behavior.

Agents with dynamic personality are fuzzy agents with personality where personality knowledge is updateable.

Figure 2 shows highlights of a framework for agents with personality.

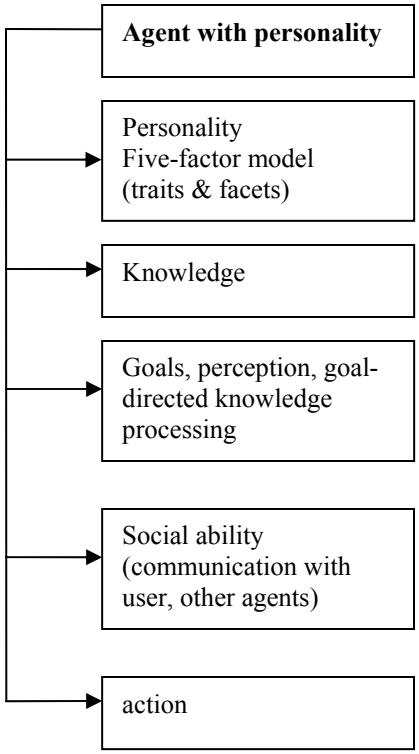

Figure 2. Highlights of a framework for agents with personality

5. DECISION MAKING WITH FUZZY AGENTS REPRESENTING INTELLIGENT ENTITIES

El-Nasr, et al. [2000] describe fuzzy logic adaptive model of emotions. The model uses a fuzzy-logic representation to map events and observations to emotional states and from emotions to behaviors. Emotion models are important in human decision making. El-Nasr and Skubic [1998] present a fuzzy emotional agent for decision-making in a mobile robot. They present fuzzy logic model to capture the inherent uncertainty of emotion. Their model deals with three negative emotions: fear, pain, and anger. Rousseau and Hayes-Roth [1997] proposed a social- psychological model that enables an author to define a character's personality influenced by moods and interpersonal relationships. In the research area of human social behavior, Martinez-Miranda and Aldea [2002] provide a social agent model to simulate human behavior in teamwork. They use multi-agent system to simulate the expected behavior in a teamwork.

Urban and Schmidt [2001] present a model called PECS (Physic, Emotion, Cognition, Social Status) to simulate human behavior. The goal of Bazzan and Bordini [2001] is to develop a framework for the modeling and simulation of agents with emotions. Their study allows the design of such agents, which interact with neighbors or their social groups. Also, a detailed description of a computational framework for emotion-based control can be found in Velásquez [1997, 1999].

In multi-agent simulation a new paradigm with high potential can be modeled: agents can be taken as equipped with more sophisticated behavior and enabled with methods of adaptation, in comparison with process-oriented models [Adamatti and Bazzan 2002]. Bates [1994] proposed the role of emotion in believable agents. Bates examines the notion of producing believable agents based on how animation artists have attempted to make their characters more believable. A complete functioning agent, whether biological, or simulated in software, or implemented in the form of a robot, needs an integrated collection of diverse but interrelated capabilities, i.e., an architecture [Sloman, 1997]. The authors are elaborating on, in another article, a functional decomposition for intelligent agents with personality [Ören and Ghasem-Aghaee 2003b].

5. CONCLUSIONS:

In this article, the personality knowledge as specified by thirty facets clustered in five traits of the current personality theory is used as a basis to represent the behavior of fuzzy agents. The modifications of the values of personality facets can be used to re-evaluate the personality knowledge of an agent to allow personality updates and hence representation of dynamic personality. Once, such a discontinuity is processed, the behavior of the fuzzy agent can be based on the updated personality.

ACKNOWLEDGMENT:

This article and several other publications are based on research done by the authors while one of the authors was spending his sabbatical leave –from the University of Isfahan, Iran– at the Ottawa Center of the McLeod Institute for Simulation Sciences at the School of Information Technology and Engineering of the University of Ottawa. The authors would also like to thank to the anonymous referees for their valuable comments.

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