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A Fuzzy Inference Model for Predicting Irregular Human Behaviour During Stressful Missions

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Abstract

In this paper a hybrid fuzzy inference and transfer function modeling is used to predict the irregular human behavior during hard and stressful tasks such as dangerous military missions. A set of affecting factors such as missioner's experience, fatigue, sunshine intensity, hungriness, thirstiness, psychological characteristics, affright, etc. may be taken to account. In this regard a dynamic system model is used to predict the convolution of the timed effects of different factors on i rregular behavior of personnel during the mission. This approach of predicting irregular behavior or erroneous decision making of staff have serious usages in aerospace, military, social and similar projects where a wrong decision can have catastrophic outcome such as attempting to suicide by a pilot or killing civilians by a soldier in stressful situations. The effect of such behavior and decisions may even cause the failure of the overall project or mission. For example, killing civilians by a soldier can result to the overall failure of human terrain missions where the main objective is gaining trust between the local civilian population.

Keywords: Irregular Human Behaviour; Fuzzy Inference; Convolution; Dynamic System; Stress; Decision Making; Human Resources; Risk

1. Introduction

In recent years semi automatic and sometimes full automatic systems has gained important usage in industry. However, human resource plays the main role in performing difficult tasks such as job shop processing, rescue missions or military operations. Human is the most intelligent system but it has the drawback of getting tired or stressed; hence there is a great risk of doing faulty and dangerous undesired actions. There are two main classes of different factors affecting the human behavior during their missions: Environmental and Personal (physical or mental) causes. Environmental conditions may be detected by using different sensors such as noise sensor, pressure sensor, thermal sensors and etc. Detecting personal conditions is more difficult and more attractive for researchers. Human behavior detection and prediction is currently studied and several papers are published in this field. These studies may be classified in two classes: Facial and Body movement. Different methodologies for facial recognition

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are presented in [1], [2] and [3]. Liang Wang, Weiming Hu, Tieniu Tan has studied different works on human motion visualization [4]. Body movement recognition techniques are presented in [4], [5] and [6]. Several researches have tried to present different methodologies and algorithms for recognition of human behavior in different environments (Indoor or outdoor) individually or by groups based on facial and body movement recognitions [7, 8, 9 and 10]. In this paper by considering the existence of different facilities for face and body movement detection, a dynamic model is introduced to foresee the staff behavior in stressful conditions based on systems engineering methodologies by developing transfer functions. A hierarchical fuzzy inference system is developed for estimating the model parameters.

2. Modeling of Human Stress

Before introducing the fuzzy inference system for modelling the effects of environmental and personal causes on human stress factors, the differential equation model of human stress is introduced by equation 1

$$\tau \frac{d^2 m(t)}{dt^2} + \frac{dm(t)}{dt} = kc(t) \tag{1}$$

where τ represents the time constant of affecting factor, m(t) is dynamics of nervous tension (stress) of staff, k is the attitude of affecting factor on human stress, t is the independent variable (time), and c(t) represents the dynamics of affecting factor on stress. The transfer function of this system for the causal actions of human is

$$G(s) = \frac{k}{s(1+\tau s)} \tag{2}$$

Fig. 1 represents dynamics of stress for a step change in two causes. Cause a is affected at t=0.1 with attitude 1.5 and time constant 0.3. Cause b is affected at t=0.2 with attitude 3.5 and time constant 0.5.

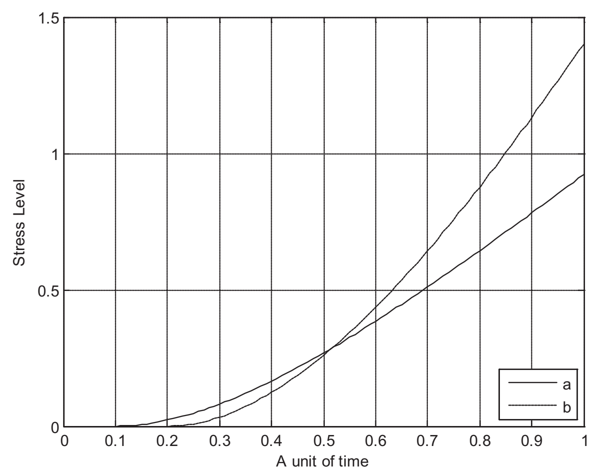

Fig. 1. Dynamics of stress for two affecting factors.

As it is seen in Fig. 1, if the maximum acceptable range for stress is unity, then factor b causes the stress of staff go out of range at about .65 units of time after imposing the cause; while factor a has no danger of overstressing. The type of causes and their dynamics are introduced in details in the following sections.

2.1. Hierarchical hybrid system

A hierarchical hybrid system consisting Fuzzy Inference System (FIS) and differential equation (transfer function) is used for modelling the human stress prediction. Eight main factors that affect the level of stress are classified as:

- Facial
- Abnormal movements
- Environmental
- Deliberated

Some facial feature points are illustrated in Fig. 2. [1].

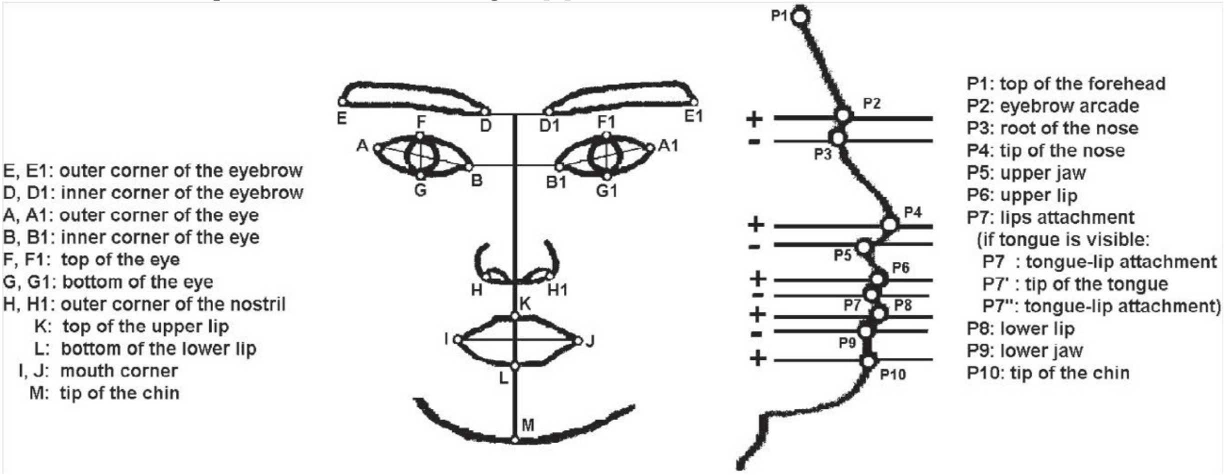

Fig. 2. Facial feature points (Retrieved from [1]).

Facial: The major facial factors, affecting on stress, which are considered in this paper are DIS: The distance between eyebrow arcade (point p2) and root of the nose (point p3) and SWT: sweats on face.

Abnormal movements: Jun Yin and Yan Meng [11] has studied the abnormal human behavior by recognizing the abnormal movements of body. In this paper the two main movement factors affecting on stress are considered as AHT: Approaching Head to Tool, and HTW: Hand Tremor during Work which is shown in Fig. 3.

Fig. 3. Hand tremor (http://www.stoptremors.com)

Environment: The two most important environmental factors that affect human stress are THM: Thermal and HUM: Humidity.

Deliberation: TSN: Time Span and QLV: Quality Level, are considered as the two main deliberating factors affecting the stress of staff during the mission.

Fig. 4 shows the hierarchical structure of the proposed system:

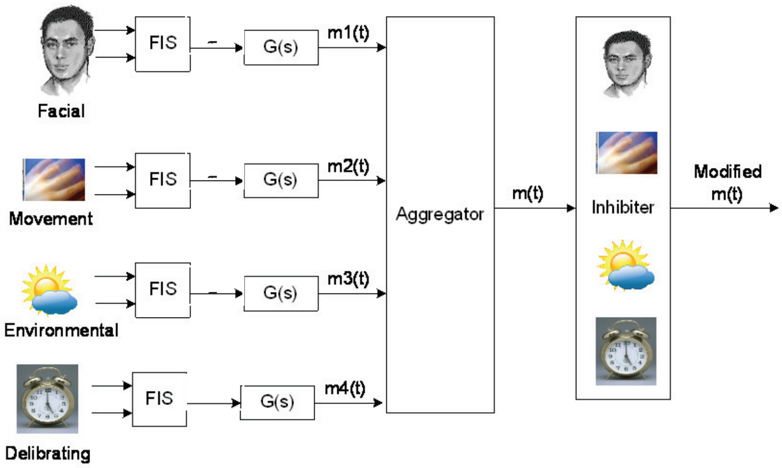

Fig. 4. Hierarchical structure of hybrid model of staff stress

In this model FIS blocks perform Fuzzy Inference, G(s) block use transfer functions with different parameters to predict the stress level as the convolution of effects of different classes of causes on stress, $m_i(t)$s. The aggregator accumulates the stress levels of effects of causes and generates the total level of stress, m(t). By imposing the inhibiter signals such as using air conditioner, increasing the mission deadline, increasing the quality tolerance and decreasing the personnel presence in certain missions such as the presence of soldiers in battlefields; the rate of stress will be decreased and modified. This way the time to be over stressed will be reduced and the staff will have the opportunity to finish the job normally.

Because of complexity of relations of stress (transfer functions) parameters with affecting factors, the estimations are performed by Fuzzy Inference Systems. Six verbal values Feeble (FE), Very Small (VS), Small (SM), Medium (MD), Large (LG) and Very Large (VL) are used in rule bases. Fig. 5 represents the Membership Functions of the System.

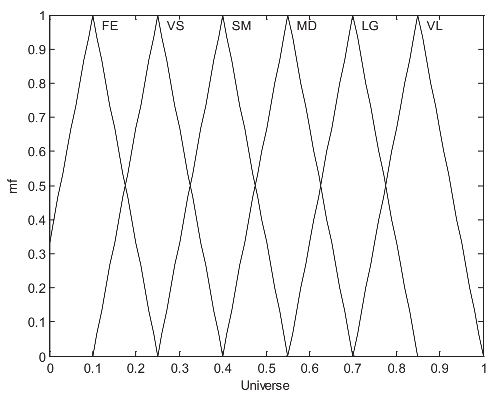

Fig. 5. Memberships of different verbal values

The fuzzy rules used in this system are as follows:
If x is A and y is B then k is C and τ is D Where x and y are DIS and SWT for facial, AHT and HTW for abnormal movement, THM and HUM for environment, and TSN and QLV for deliberation factors respectively. k and τ are attitude and time constants of transfer function. A, B, C and D are the verbal values presented in Fig. 5.

3. Illustrative Example

Table 1 represents the crisp values of different parameters causing the stress at time t=0. Parameters k and τ are generated by appropriate FIS for each cause.

Table 1. Data for illustrative Example

Affecting factors	First Parameter	Second Parameter	k	τ	Sensing Time
Facial	DIS = 0.5	SWT = 0.6	3.7727	0.2943	0.3
Abnormal Movement	AHT = 0.5	HTW = 0.8	4.25	0.25	0.5
Environment	THM = 0.7	HUM = 0.3	2.50	0.50	0.4
Deliberation	TSN = 0.2	QLV = 0.6	2.50	0.25	0.2

Fig. 6 shows the dynamics of effects of different causes, determined by transfer function, on increasing the level of stress during a time unit.

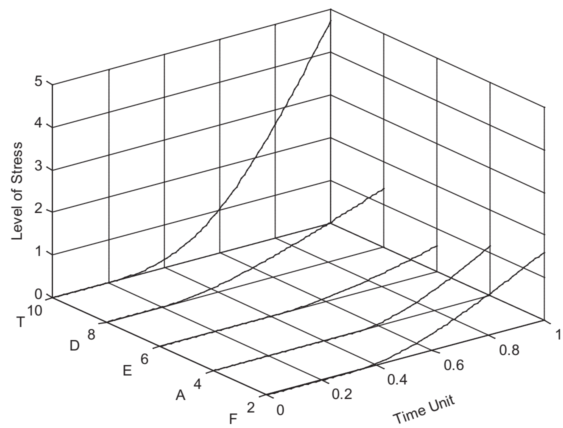

Fig. 6. Dynamics of effects of different causes on stress: F) Facial A) Abnormal Movement E) Environment D) Deliberative T) Total

As it is seen in Fig. 6, the stress level passes the standard level (unity) after about half of the time unit and reaches to the catastrophic level of about six times of the standard level at the end of time unit. Individual prediction of stress caused by environment shows that it has no dangerous effect on stress (stress line E does not pass standard level). However, the facial cause (DIF, SWT) shows that the stress will pass over standard level after time t=0.8; but curve T shows that globally the stress level will be dangerous after t=0.6 time units.

As an inhibiting strategy, using air conditioner will cause inhibitive effect on SWT, THM and HUM. Consider a simple first order differential equation for air conditioner with transfer function Gc(s) = 10/(1+0.1S).

Consider three strategies:

a) ST1: No inhibiting action.

b) ST2: Turning on air conditioner at time t=0.8

c) ST3: Turning on air conditioner based on aggregated stress level at time t=0.6

Fig. 7 shows the effect of three strategies in aggregated dynamics of stress level.

As it is shown in Fig. 7, by using the third strategy based on the prediction of aggregated stress level, there is a significant decrease in level of stress and the condition becomes from 3.75 units of over stress to only 1.8 units of over stress in time unit.

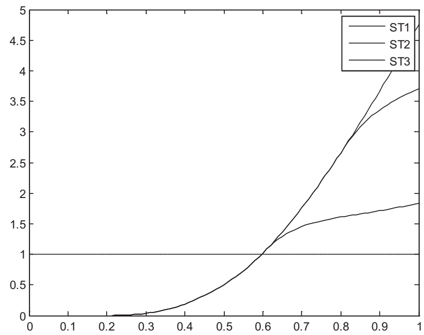

Fig. 7. Effect of three strategies in aggregated dynamics of stress level, Modified m(t)s

4. Conclusion

In this paper a hierarchical hybrid system based on fuzzy inference system and transfer function is used to predict the level of stress for staff during mission caused by different stressful factors. The prediction strategy helps the system to perform suitable action (tactic) in appropriate time. In future works a decision making analysis by several criteria will be used to decide for suitable action between different alternatives based on dynamics of total and individual stress levels. The main difference between the procedure introduced in this paper and the classic human behavior analysis is considering the convolution of effects of different parameters in time domain, which helps the system designers to predict the time and level of critical conditions and perform preventive actions to inhibit the undesired human actions during stressful missions.

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