Recognition of Human Emotions in Reasoning Algorithms of Wheelchair Type Robots

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Abstract. This paper analyses the possibilities of integrating different technological and knowledge representation techniques for the development of a framework for the remote control of multiple agents such as wheelchair-type robots. Large-scale multi-dimensional recognitions of emotional diagnoses of disabled persons often generate a large amount of multi-dimensional data with complex recognition mechanisms, based on the integration of different knowledge representation techniques and complex inference models. The problem is to reveal the main components of a diagnosis as well as to construct flexible decision making models. Sensors can help record primary data for monitoring objects. However the recognition of abnormal situations, clustering of emotional stages and resolutions for certain types of diagnoses is an oncoming issue for bio-robot constructors. The prediction criteria of the diagnosis of the emotional situations of disabled persons are described using knowledge based model of Petri nets. The research results present the development of multi-layered framework architecture with the integration of artificial agents for diagnosis recognition and control of further actions. The method of extension of Petri nets is introduced in the reasoning modules of robots that work in real time. The framework provides movement support for disabled individuals. The fuzzy reasoning is described by using fuzzy logical Petri nets in order to define the physiological state of disabled individuals through recognizing their emotions during their different activities.

Keywords: multiple agent system, decision support system (DSS), sensing bio-robot, fuzzy logic Petri nets.

1. Introduction

The development process of intelligent systems with adaptive e-services is important for providing user-friendly decision support services for people with movement disabilities. Such systems include different intellectual components for control and monitoring sensors by supporting multi-agent activities. The systems can integrate many components for the recognition of a certain situation, diagnosis, possibilities to affect and control devices (Samanta, Nataraj, 2008; Brauers and Zavadskas, 2009; Rutkauskas and Ramanauskas, 2009; Dzemydienė *et al.*, 2010; Veikutis *et al.*, 2010; Šutienė *et al.*, 2010). The bio-robotic devices need the integration of means with different knowledge interpretation techniques for an intelligent medical diagnosis (Bernardi *et al.*, 2008; Zavadskas *et al.*, 2009; Mačiulis *et al.*, 2009).

We are looking for the possibilities of developing the integration of different types of knowledge representation techniques in this type of a bio-robot support system by running on-line sub-systems of complex mechanisms and cooperating multi-agent activities for sensing human physiological parameters and controling future actions (Bielskis *et al.*, 2009, 2010). Our framework provides an intelligent accident preventive robot-based support for people with movement disabilities. The system includes the affect sensing in Human Computer Interaction (HCI) and provides e-health care for people with movement disabilities. Human–Robot Interaction (HRI) assists distance healthcare patients to remain autonomous, and Computer Mediated Communication (CMC) provides adaptive user–robot friendly collaboration. Such systems should depend upon the possibility of extracting emotions without interrupting the user during HCI, HRI, or CMC (Wilson, 1992; Korhonen, 1997; Pentland, 2004; Villon and Liset, 2006; Bielskis *et al.*, 2009). Emotion is a mind-body phenomenon accessible at different levels of observation (social, psychological, cerebral and physiological). The continuous physiological activity of a disabled person is made accessible by use of intelligent agent-based bio-sensors coupled with computers.

The aim of this research deals with investigations of the integration of different knowledge representation techniques in order to develop a framework of multiple cooperative agents' activities in order to recognise the prediction criteria of diagnoses of the emotional situations of disabled persons. The research results present a further development of a multi-layered model of this framework, with the integration of evaluation of the diagnosis of emotional stages for further control of actions of wheelchair-type robots. Knowledge of the decision support system is represented by fuzzy logical Petri nets introduced in the wheelchair-type robot system. Such a system is planned to work in real time providing a movement support for disabled individuals. The method of fuzzy reasoning by fuzzy logical Petri nets according to Jiang and Zheng (2000) and Dzemydiene *et al.* (2008) is described with a view to define the physiological state of disabled individuals by recognizing of their emotions.

2. The Framework of Adaptive Control of a Multi-Agent System Based on Emotion Recognition Components

The proposed framework is based on the interaction of intelligent remote bio-robots, localization services, embedded decision support systems and analysis of data stored in the data warehouse (Fig. 1). The data warehouse is based on distributed information systems with important personal data of the patients and sensor's data of on-line monitoring

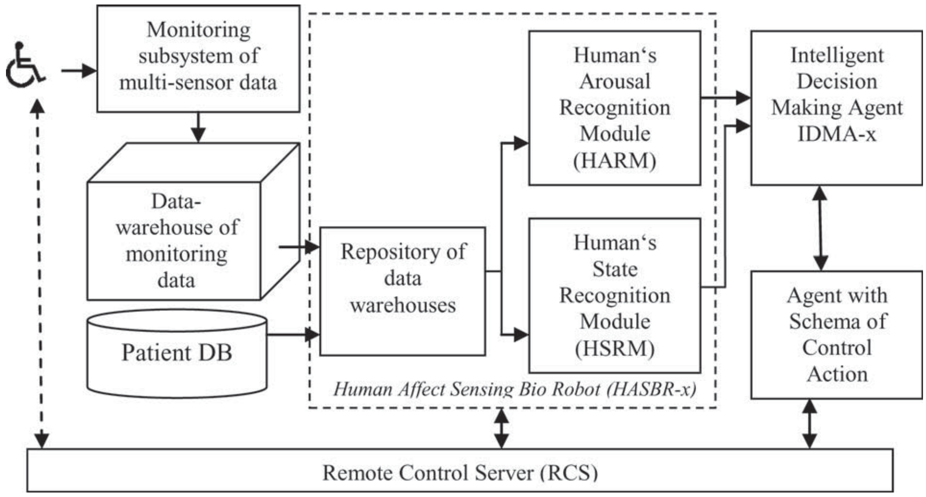


Fig. 1. The reinforcement framework of an intelligent remote agent interaction based on distributed information systems.

systems. The framework includes an adaptive moving wheelchair-type robot which is remotely communicating with a wearable human affect sensing bio-robot. For e-health care, relevant episodes are based on human affect stages (Villon, 2006). The context aware sensors are incorporated into the design of the Human Affect Sensing Bio-Robot-x (HASBR-x) of each disabled individual, and into the local Intelligent Decision Making Agent-x (IDMA-x) of each intelligent support providing robot.

This framework allows a multi-sensor data fusion before the transmission of the data to the Remote Control Server (RCS) to minimize the TCP/IP (UDP) bandwidth usage. Multi-agent based adaptive motion control of both robots relies on an adaptive Fuzzy Neural Network Control (FNNC) approach described in Bielskis *et al.* (2009).

The sensor's subsystems work as agents in parallel and the information is written in the data-warehouse of monitoring data. They can gather data in a continuous way without having to interrupt the user and may include sensors for detecting of: Galvanic Skin Response (GSR) or Electro-Dermal Activity (EDA) based on the measurements of Skin Conductance (SC), Blood Volume Pulse (BVP), Electrocardiogram (ECG), Respiration, Electromyogram (EMG), Body temperature (BT), and Facial Image Comparison (FIC) analysed by Papillo and Shapiro (1990); Korhonen (1997); Rowe *et al.* (1998); Samanta and Nataraj (2008); Wilson (1992).

The Galvanic Skin Response (GSR) is a measure of skin conductance between two electrodes that apply a safe, imperceptibly tiny voltage across the skin of subject's fingers or toes. An individual's baseline skin conductance will vary for many reasons, including gender, diet, skin type, and environment situation. When a subject is startled or experiences anxiety, there will be a fast increase in the skin conductance level, the SCL changing in a period of seconds due to the increased activity in the sweat glands (unless the glands are saturated with sweat). After a startle, the SCL will decrease naturally due to re-absorption. The sweat gland activity increases the skin capacity to conduct the current passage through it and changes in the skin conductance response. The SCR is an indicator of the level of arousal in the sympathetic nervous system. A number of wearable systems have been proposed with integrated wireless transmission, a GPS (Global Positioning System) sensor, and local processing. Commercial systems are also becoming available (Pentland, 2004).

The process which controls the subsystem of DSS must detect the following facts: what the maximum value was at a concrete time interval, the number of times a value exceeded a predefined reference value, a temporal delay between the maximum of a variable, and the maximum effect on another variable, etc.

The *sensor* listens to updates from sensors which are located on is stored in distributed sensor nodes. Then the information collected by the *sensors* the database. A direct sensor access approach is often used in devices with sensors locally built in. The client software gathers the desired information directly from these sensors, i.e., there is no additional layer for gaining and processing sensor data.

The first layer consists of a collection of different sensors. Note that the word “sensor” not only refers to sensing hardware, but also to every data source which may provide usable context information. Many hardware sensors are available nowadays which are capable of capturing almost any physical data.

There exist many different methods for recognizing the physical state or behaviour by using the data of wearer’s emotion recognition sensors (Mandryk and Atskins, 2007; Pentland, 2004). A modified Arousal – Valence model proposed by Mandryk and Atskins (2007) was used here for discovering information in real time and providing friendly advice for a person with movement disabilities during relaxation and activation periods.

The framework, presented in Fig. 1, uses four recognition sensors for each of disabled individuals’:

- the electrocardiogram (ECG);
- the skin conductance response (SCR);
- the skin temperature of head ST_H;
- the skin temperature of fingers (ST_F).

These groups of parameters from sensor devices are used to provide HR (heart rate), HRV_H (heart rate variability for the range of 0.15 to 0.4 Hz), HRV_L (heart rate variability

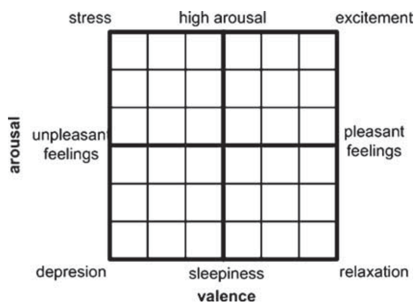


Fig. 2. Interpretation of the Affect Grid having six levels of arousal and valence (according to Mandryk and Atkins, 2007).

for the range of 0.015 to 0.15 Hz), SCR, ST_H, and ST_F inputs for further defining fuzzy values of arousal and valence (Fig. 2).

The number of membership functions applied to that input or output follows the input/output labels. Within each input and output, there is a schematic representation of the location and form of the membership functions. All the membership functions are triangular or trapezoidal, exhibited by the flat ceilings, rather than the peaked ceiling of a triangular membership function. The system uses 67 rules proposed in Mandryk and Atkins (2007) to transform the 2 inputs (the arousal and valence) into the 5 outputs (fun, challenge, boredom, frustration, and excitement).

3. Fuzzy Logical Petri Nets Used in Reasoning Algorithms of Human Arousal Recognition Agents

The computing results of fuzzy reasoning were obtained by applying fuzzy logical Petri nets (Jiang and Zheng, 2000). The classical Petri nets are defined as a structure $N = \langle S, T,\ F \rangle$ where S means the set of locations, T is set of transitions and F is function of transition works, $F \subseteq (S \times T) \cup (T \times S)$, where $(\forall t \in T)\ (\exists p, q \in S)\ (p,t),\ (t,q) \in F$.

Graphical representation of Petri nets is set up by the following symbols: *locations* – by rings, *transitions* – by rectangles, and *relations* – by pointers between transitions and locations or locations and transitions. In the classical Petri nets, there is a token placed if the expression is true (1) or not, if it is false (0).

Let $FLPN = (P, T, F, M_0, D, h, \alpha, \theta, \lambda)$ be a fuzzy logical Petri net.

The set of locations $P_0 = \{p|M_0(p) > 0,\ \forall p \in P\}$ is called a set of locations of initial true propositions. D_0 corresponding to P_0 is called a set of initial true propositions. The function h_s: $P_s \rightarrow D_s$ is an association function that represents a bijective mapping from locations to propositions. Propositions, such that $h_s(p) = h(p),\ \forall P_s$. The function α_s: $P_s \rightarrow [0, 1]$ is an association function, representing a mapping from locations to real values between 0 and 1, such that $\alpha_s(p) = \alpha(p),\ \forall p \in P_s;\ \theta_s, \lambda_s$: $T_s \rightarrow [0, 1]$ are association functions, representing a mapping from transition to real values between 0 and 1, such that $\theta_s(t) = \theta(t),\ \lambda_s(t) = \lambda(t),\ \forall t \in T_s$. The firing rules are the same as in the classical Petri nets.

Any *IF-THEN* rule is given in the form of:

IF X_1 is A_1 AND ... AND X_n is A_n THEN Y is B,

where $A_1, \ldots, A_n$ and B are certain predicates that characterize the variables $X_1, \ldots, X_n$ and Y. The set of *IF-THEN* rules forms a linguistic description:

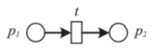
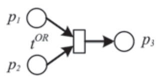
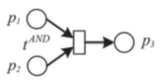
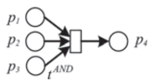
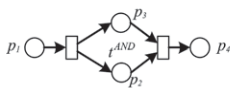
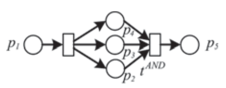
R_1: = IF X_1 is A_{11} AND ... AND X_n is A_{1n} THEN Y is B_1,

....

R_m: = IF X_1 is A_{m1} AND ... AND X_n is A_{mn} THEN Y is B_m,

where each transition corresponds to one rule of the linguistic description.

Table 1
Models of Logical Petri nets applied to transforming 89 Fuzzy inference rules for support the reasoning

No.	Applied LPN model	Fuzzy computing	Applied transitions
1		$\alpha_2 = \lambda_t \alpha_1$ if $\alpha_1 \geqslant \theta_t$	$T_1,\ T_3,\ T_{26},\ T_{59},\ T_{60},\ T_{61},\ T_{65},\ T_{84},\ T_{85},\ T_{86},\ T_{87},\ T_{88},\ T_{89}$
2		$\alpha_3 = \lambda_{t^{\mathtt{OR}}} \max\limits_{\substack{\alpha_t \geqslant \theta_{t^{\mathtt{OR}}} \\ i=1\vee 2}} \{\alpha_1, \alpha_2\}$	$T_2^{\mathtt{OR}},\ T_4^{\mathtt{OR}},\ T_{20}^{\mathtt{OR}},\ T_{21}^{\mathtt{OR}},\ T_{22}^{\mathtt{OR}}$
3		$\alpha_3 = \lambda_{t^{\mathtt{AND}}} \min\limits_{\substack{\alpha_t \geqslant \theta_{t^{\mathtt{AND}}} \\ i=1\wedge 2}} \{\alpha_1, \alpha_2\}$	$T_{5-18}^{\mathtt{AND}},\ T_{23-25}^{\mathtt{AND}},\ T_{27-50}^{\mathtt{AND}},\ T_{62-64}^{\mathtt{AND}},\ T_{66-83}^{\mathtt{AND}}$
4		$\alpha_4 = \lambda_{t^{\mathtt{AND}}} \min\limits_{\substack{\alpha_t \geqslant \theta_{t^{\mathtt{AND}}} \\ i=1\wedge 2\wedge 3}} \{\alpha_1, \alpha_2, \alpha_3\}$	$T_{19}^{\mathtt{AND}}$
5		$\alpha_2 = \lambda_t \alpha_1$ if $\alpha_1 \geqslant \theta_t$ $\alpha_3 = \lambda_t \alpha_1$ if $\alpha_1 \geqslant \theta_t$ $\alpha_4 = \lambda_{t^{\mathtt{AND}}} \max\limits_{\substack{\alpha_i \geqslant \theta_{t^{\mathtt{AND}}} \\ i=2\wedge 3}} \{\alpha_2, \alpha_3\}$	$T_{51-52},\ T_{55-58}$
6		$\alpha_2 = \lambda_t \alpha_1$ if $\alpha_1 \geqslant \theta_t$ $\alpha_3 = \lambda_t \alpha_1$ if $\alpha_1 \geqslant \theta_t$ $\alpha_4 = \lambda_t \alpha_1$ if $\alpha_1 \geqslant \theta_t$ $\alpha_5 = \lambda_{t^{\mathtt{AND}}}\ m \min\limits_{\substack{\alpha_i \geqslant \theta_{t^{\mathtt{AND}}} \\ i=2\wedge 3\wedge 4}} \{\alpha_2, \alpha_3, \alpha_4\}$	T_{53-54}

Transition schemas of Logical Petri nets applied to transforming 89 fuzzy inference rules to constructing support of rules in the information system for robots are proposed in Table 1.

In the Table 2, the set of 22 rules and corresponding transitions are proposed in concerting the galvanic skin response, the GSR, heart rate, the HR, heart rate variability high, the HRVH, heart rate variability low, the HRVL, skin temperature of head, the STH, and skin temperature of finger, the STF into arousal and valence. In the Table 1, the corresponding transitions of logical Petri nets are prescribed following to the set of 67 rules used by Mandryk and Atkins (2007) in concerting of transforming of arousal-valence space into five modelled emotional states to converting arousal and valence into boredom, challenge, excitement, frustration, and fun.

Table 2

Examples of the rules and corresponding transitions for recognition of the degree of emotional states

No	Rules	Transitions
1	If (GSR is *high*) then (arousal is *high*)	T_1
2	If (GSR is *high*) or (HR is *high*) then (arousal is *high*)	$T_2^{\mathtt{OR}}$
3	If (GSR is *mid-low*) then (arousal is *mid-low*)	T_3
4	If (GSR is *low*) or (HR is *low*) then (arousal is *low*)	$T_4^{\mathtt{OR}}$
5	If (GSR is *low*) and (HR is *high*) then (arousal is *mid-low*)	$T_5^{\mathtt{AND}}$
6	If (GSR is *high*) and (HR is *low)* then (arousal is *mid-high*)	$T_6^{\mathtt{AND}}$
7	If (GSR is *high*) and (HR is *mid*) then (arousal is *high*)	$T_7^{\mathtt{AND}}$
8	If (GSR is *mid-high*) and (HR is *mid*) then (arousal is *mid-high*)	$T_8^{\mathtt{AND}}$
9	If (GSR is *mid-low*) and (HR is *mid*) then (arousal is *mid-low*)	$T_9^{\mathtt{AND}}$
10	If ($\mathrm{HRV_H}$ is *high*) and ($\mathrm{HRV_L}$ is *low*) then (valence is *very-high*)	$T_{10}^{\mathtt{AND}}$
...	...	...
20	If ($\mathrm{ST_H}$ is *high*) or ($\mathrm{ST_L}$ is *low)* then (valence is *low*)	$T_{20}^{\mathtt{OR}}$
21	If ($\mathrm{ST_H}$ is *low*) or ($\mathrm{ST_L}$ is *high*) then (valence is *high*	$T_{21}^{\mathtt{OR}}$
22	If ($\mathrm{ST_H}$ is *medium*) or ($\mathrm{ST_L}$ is *medium*) then (valence is *medium*)	$T_{22}^{\mathtt{OR}}$

The computer-based agents *HARA-x* and *IDMA-x* (Fig. 1) are used to determine the emotions of users during the parameter sensing in the situation recognition stages. The entire set of rules is presented in Bielskis *et al.* (2009).

This algorithm obtains a fuzzy Petri net as an input and creates the set of linguistic descriptions corresponding to each output location of the fuzzy Petri net.

The human arousal recognition agents *HARA-1* and *HARA-2* (see Fig. 1) were programmed to use these reasoning algorithms for creating some friendly advice to disabled individuals who are taking part in the model of the system.

The set of rules and corresponding transitions of logical Petri nets of transforming the arousal-valence space into emotional stages were programmed by using the reasoning algorithm of fuzzy logical Petri nets, following Pavliska (2006). Here we present the fragment of such algorithm:

```
Input: fuzzy Petri net: fpn
Output: set of linguistic descriptions: lfln
lfln = ∅;
foreach output location op of fpn do \\ creat a linguistic description
  \\ create set of input variables (locations) on whose op depends
  inputs = ∅;
  foreach input transition it of op do
    \\ add all inputs of tansition it to inputs set
    inputs = inputs ∪ it.inputs;
  end
  \\ construct linguistic description (set of rules)
  rb = ∅;
  foreach input transition it of op do
    \\ consruct rule corresponding to transition it
    rule = ∅;
    foreach element in from inputs do
```

if rule $\neq \varnothing$ **then** $rule = rule +$ AND;
if $in \in it.inputs$ **then**
$rule = rule + in.name$ is $edge(in, it).value$;
else
$rule = rule + in.name$ is UNDEF;
end
end
$rule = rule +$ THEN $op.name$ is $edge(it.op).value$;
$rb = rb \cup rule$: \\ add rule to rule base
end
$lfln = lfln \cup rb$: \\ add rule to set of linguistic descriptions
end

Such rules are introduced in the framework and they control the actions of the adaptive robot system. The Fuzzy logical Petri nets used in Black boxes as the scenarios for supporting the on-line situation recognition stages and activate next actions of wheelchair-type robots. The main components of agent HARA-x and its interaction with the agent IDMA-x are presented in Fig. 3.

BLACK BOX 1 implements transitions $T_1 - T_{22}^{\mathtt{OR}}$ (see Table 2), and *BLACK BOX 2* represents $T_{23}^{\mathtt{AND}} - T_{89}$ (see Table 3) transitions of the Petri net. Human Computer Interaction (HCI) in the system realized in adaptively providing the necessary e-health care support actions for users discovered in the *Personal Information Databases* of patients (see Fig. 1).

The accessible degree of values affects other parameters, that are time dependent. When the causal facts occur (e.g., the temperature exceeds the limits and/or the pulse reach the greatest permissible limitations), the dependent fact gets a status, e.g., Alarm = on. Such a fact entered in IDMA-x activates another agent the function of which is to

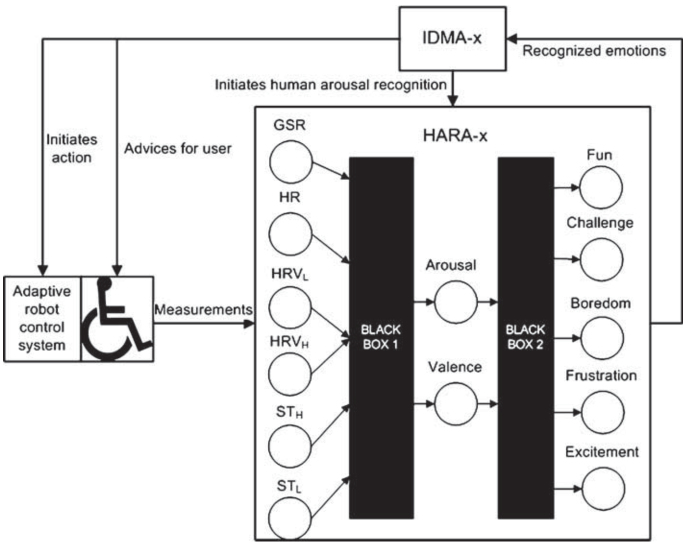


Fig. 3. Interaction schema of components of the adaptive robot control system.

Table 3

Examples from the set of rules and corresponding transitions of logical Petri nets of transforming the arousal-valence space

No.	Examples of rules	Transitions
23	If (arousal is *not very low*) and (valence is *mid-high*) then (fun is *low*)	$T_{23}^{\mathtt{AND}}$
24	If (arousal is *not low*) and (valence is *mid-high*) then (fun is *low*)	$T_{24}^{\mathtt{AND}}$
25	If (arousal is *not very low*) and (valence is *high*) then (fun is *medium*)	$T_{25}^{\mathtt{AND}}$
26	If (valence is *very high*) then (fun is high)	T_{26}
27	If (arousal is *mid-high*) and (valence is *mid-low*) then (challenge is *low*)	$T_{27}^{\mathtt{AND}}$
28	If (arousal is *mid-high*) and (valence is *mid-high*) then (challenge is *low*)	$T_{28}^{\mathtt{AND}}$
29	If (arousal is *high*) and (valence is *mid-low*) then (challenge is *medium*)	$T_{29}^{\mathtt{AND}}$
34	If (arousal is *mid-low*) and (valence is *low*) then (boredom is *medium*)	$T_{34}^{\mathtt{AND}}$
35	If (arousal is *low*) and (valence is *low*) then (boredom is *medium*)	$T_{35}^{\mathtt{AND}}$
54	If (valence is *very high*) then (challenge is *very low*) and (boredom is *very low*) and (frustration is *very low*)	T_{54}
55	If (valence is *mid-high*) then (boredom is *very low*) and (frustration is *very low*)	T_{55}
56	If (arousal is *very low*) then (challenge is *very low*) and (frustration is *very low*)	T_{56}
71	If (arousal is *high*) and (valence is *low*) then (challenge is *low*)	$T_{71}^{\mathtt{AND}}$
81	If (arousal is *very high*) and (valence is *very high*) then (excitement is *high*)	$T_{81}^{\mathtt{AND}}$
82	If (arousal is *high*) and (valence is *very high*) then (excitement is *high*)	$T_{82}^{\mathtt{AND}}$
83	If (arousal is *mid-high*) and (valence is *very high*) then (excitement is *high*)	$T_{83}^{\mathtt{AND}}$
84	If (arousal is *mid-low*) then (excitement is *very low*)	T_{84}
85	If (arousal is *low*) then (excitement is *very low*)	T_{85}

influence the assistance supporting processes. If such a situation does not occur, then the dependent fact will not occur.

4. Conclusions

An approach for developing the interaction architecture of remote server systems with additional functionalities of contextual information transmission is proposed. Some sensing bio-robots solutions are included for recognition of the state of person emotional diagnosis in the process of monitoring remote sensing agents. The recognition of the diagnosis of the emotional situation of disabled persons is based on a multi-layered model which integrates several techniques of knowledge representation: neural networks, fuzzy logic Petri nets, and evaluation of fuzzy neural control of wheelchair type-robots working in real time. This was done by implementing the movement support for disabled individuals using information based on the emotional state of the disabled persons.

The proposed framework uses four emotion recognition sensors for each disabled individual: the ECG (Electrocardiogram), the SCR (Skin Conductance Response), the $\mathrm{ST_H}$ (Skin Temperature of Head), and the $\mathrm{ST_F}$ (Skin Temperature of Finger) to provide HR (Heart Rate), $\mathrm{HRV_H}$ (Heart Rate Variability for the range of 0.15 to 0.4 Hz), $\mathrm{HRV_L}$ (Heart Rate Variability for the range of 0.015 to 0.15 Hz), SCR, $\mathrm{ST_H}$, and $\mathrm{ST_F}$ inputs with a view to define fuzzy values of arousal and valence of disabled person.

The method of fuzzy reasoning by means of fuzzy logical Petri nets is described based on transforming arousal-valence space into five modelled emotional states to convert arousal and valence into boredom, challenge, excitement, frustration, and fun. The method allows to define the physiological state of disabled individuals, and gives them online advice, based on the recognition of their emotions during their activities.

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Samprotavimo algoritmai žmogaus emocijų atpažinimui neįgaliųjų vežimėlio tipo robotuose

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Šio mokslinio tyrimo tikslai siejasi su intelektualių įrenginių kūrimu, teikiant e-rūpybos paslaugas žmonėms su judėjimo negalia, užtikrinant jų būklės stebėseną ir darnaus judėjimo valdymo aplinkoje galimybes. Sprendžiami uždaviniai skirti pagrindinių neįgaliųjų diagnozės komponenčių tyrimams, sudarant lanksčius sprendimų priėmimo modelius, kurie integruojami į specialių įrenginių valdymo mechanizmus, kurie priskiriami bio-robotų klasei. Straipsnyje pateikiami metodai kaip konstruoti tokio tipo bio-robotų sistemas, įgalinant skirtingų žinių vaizdavimo priemones integruoti sistemoje, kad būtų sukurta bendradarbiavimo aplinka skirtingas emocinės būklės neįgaliųjų diagnozes analizuojantiems intelektualiems agentams. Neįgaliųjų emocinės būklės diagnozė reikalauja plačios skalės daugelio parametrų atpažinimo metodų, kurie grindžiami skirtingais žinių vaizdavimo formalizmais. Sensorinės sistemos fiksuoja pirminius stebėsenos duomenis, tačiau atpažinimas nenormalių situacinių būklių reikalauja sudėtingų išvedimo metodų, įvertinamų, taikant lanksčias neuroninių tinklų valdymo priemones. Tyrimo rezultatai pateikiami per daugelio lygių darbo infrastruktūrą, kuri integruoja Petri tinklų valdymo būdus. Miglotos logikos Petri tinklų taikymas leido pademonstruoti galimybes atpažinti neįgaliojo psichologinės būsenos įverčius laike, stebint neįgaliųjų skirtingą veiklą.