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An emotional humanoid partner

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Abstract. In this paper we propose an emotional humanoid robot based on Latent Semantic Analysis, that exhibits an emotional behaviour in the interaction with human. Latent Semantic Analysis (LSA) paradigm is capable to encode the semantics of words using a statistical computation of a large corpus of text. We illustrate how the creation and the use of this emotional conceptual space allows the building of "Latent Semantic Behaviour" because it simulates the emotional associative capabilities of human beings. The presented approach integrates traditional knowledge representation and intuitive capabilities provided by geometric and sub-symbolic information modelling. To validate the effectiveness of the approach we implemented the system using the humanoid robot from Aldebaran, Nao.

1 INTRODUCTION

The interaction between humans, robots and environment is a relevant topic for many entertainment applications. Classical rule based control models and totally symbolic knowledge representation systems result often too restrictive. To overcome these limitations much research involved hybrid symbolic or sub-symbolic approaches. Many attempts have been made to merge connectionist and symbolic approaches, and, often in robotics, faces the problem of linking a conceptual level to a symbolic one. On the other hand, interacting with humans means the ability to recognize and understand emotions. The interaction of the entertainment robot with the humans and the environment should be not mechanical and not deterministic in order to avoid a predictable behaviour. In order to reach this goal many approaches tried to use ethological or emotional models.

In the last years many studies have been conducted on the knowledge representation in order to provide intelligent interaction with the environment. Many of these models try to incorporate ethological or emotional models to be used in entertainment robots based on behavioural system approach.

From our point of view a robot is made for entertainment use when essentially is an emphatic robot.

The Latent Semantic Analysis (LSA) is a paradigm aimed on the extracting and representing the meaning of words by statistical computations applied to a large corpus of texts usually taken through specific queries from internet. LSA is a method based on vector spaces: words are coded in a large semantic space and the semantic similarity between them can be computed using a geometric distance between their representative vectors. The interesting feature of LSA is the capability to simulate several human cognitive phenomena as well as word categorization, sentence-word semantic priming, discourse understanding, judgments of essay quality. It has been shown that it is possible to label the basis vectors of the semantic space generated by the LSA paradigm, in order to see this space as a data-driven conceptual space where words documents and concepts, represented using a verbal description, can be mapped. Using this space it is possible to simulate some human psycholinguistic cognitive phenomena that involve association capabilities and semantic similarity measurements.

Objects in the real world, as words in sentences, are connected between them by complex relations: these can be partially captured using complex data structures and functions. A more simple way could be to let automatically emerge these latent associations from the data by the creation of an high dimensional vector space where objects can be mapped and relations among them will emerge as geometric distances in this space. Using this particular interpretation of Latent Semantic Analysis paradigm it is possible to design humanoid robots equipped with a conceptual space capable to modify the behaviours coherently with the information that the robot perceives.

In this paper is presented the use of an LSA-based conceptual space to build the emotional behaviours of an humanoid robot because the space simulates the emotional-associative capabilities of human beings. A subset of words and sentences, coded in the data driven conceptual space, is linked to specific behavioural categories.

The humanoid robot will interact with the environment by coding stimuli using an hidden semantic layer. In this layer the LSA paradigm will be used to represent the logical relations that classical rule based paradigms fail to represent.

The aim of this project is to create an emotional robotic partner for entertainment purposes. This robot should be capable to perceive emotions that emerge from environmental situation or from people behaviours and will be able, according to an empathy mechanism, to activate behaviours that are related to the inferred emotional state.

As an example of this system, let's consider a scenario in which a man talking to his robotic partner says "I love to play soccer". In this case, the humanoid, using the hidden semantic mechanism, associates the sentence with a particular behaviour, that will consist of searching for a ball and carry it to the human partner. According to the Thagard theory about empathy analogies, during the training phase the robot encodes achievable situations and their potential correlated emotions. This sub-symbolic encoding will allow the building of a map, of a set of analogies capable to bind the current situation with some aspects of the knowledge gained during previous emotional situations.

Studies from Ortony, Clore and Collins show that emotions are descriptors of the people reactions about some events that

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happens in the environment, so, if the environment can be described using words it is possible to use them to in the emotional space, to infer emotions not only about a verbal communication but also from environmental stimuli. In order to do so, a set of words and sentences related to the environments knowable by the emotional robot is chosen.

The conceptual space used by the humanoid robot will be created using a training set capable to represent emotions. Each time an input stimulus is perceived, it is mapped on the conceptual space. From this mapping will emerge an emotion closely related to the stimulus, then this will activate the most suitable behaviour capable to represent the inferred emotion. In order to implement a non deterministic mechanism, each emotion will have to a set of behaviours coherent with it, so the executed action will be randomly chosen from them.

2 THE EMOTIONAL SPACE CREATION

The LSA paradigm is based on a vector space method: given a text corpus of N documents and M words, LSA defines a mapping between the M words and the N documents into a continuous vector space S, where each word, as well as each document is associated to a vector in S.

Let A be the $M \times N$ matrix whose *(i, j)-th* entry is the square root of the sample probability of the *i-th* word belonging to the *j-th* document. The Singular Value Decomposition of the matrix A is performed, so that A is decomposed in the product of three matrices: a column-orthonormal $M \times N$ matrix U, a column-orthonormal $N \times N$ matrix V and a $N \times N$ diagonal matrix Σ, whose elements are called singular values of A.

$$A = U \Sigma V^T$$

Let us suppose that A's singular values are ranked in decreasing order. Let R be a positive integer with $R<N$, and let $\tilde{U}$ be the $M \times R$ matrix obtained from U by suppressing the last $N-R$ columns, $\tilde{\Sigma}$ the matrix obtained from Σ by suppressing the last $N-R$ rows and the last $N-R$ columns and $\tilde{V}$ be the $N \times R$ matrix obtained from V by suppressing the last $N-R$ columns. Then

$$\tilde{A} = \tilde{U}\tilde{\Sigma}\tilde{V}^T$$

is a $M \times N$ matrix of rank R. It can be shown that, according to the illustrated procedure, $\tilde{A}$ is the best rank R approximation of A (among the $M \times N$ matrices) with respect to the Hellinger distance, defined by

$$d_h(X,Y) = \sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(\sqrt{x_{ij}} - \sqrt{y_{ij}})^2}$$

which allows to interpret the *TSVD* technique as a statistical estimator.

The two matrices $\tilde{U}$ and $\tilde{V}$ obtained after truncated decomposition reflect a breakdown of the original relationships identified by A into linearly independent vectors. The R columns of $\tilde{U}$ constitute a basis of a semantic space S, which can be interpreted as a "conceptual space". The term "conceptual space" may be confusing, since it recalls the well known Gardenfors conceptual spaces. Gardenfors spaces have to be "manually" built by extracting from the knowledge base the quality dimensions, so they could be not the optimal choice, for practical reasons, in order to describe the knowledge base of a robot. The conceptual interpretation of the semantic space allows the automatic building of "conceptual spaces" by sub-symbolic processing of the raw sample data, so that the fundamental "latent semantic concepts" rise spontaneously. These fundamental coordinates will be represented by the orthonormal basis generated by the application of the LSA methodology, using the Hellinger distance instead of the Frobenius distance. More formally, the independent R dimensions of the R^R space can be labelled, in order to characterize the "fundamental" concepts residing in the data driven space. The technique is to identify, for each column of the matrix $\tilde{U}$ the words associated to the components with the highest value these words will constitute a label for each axis. Emotional states and external situations can be verbally described and mapped into this semantic space. Besides, an associative capability is simulated between a generic verbal-coded stimuli s_i and a generic emotion e_j with a closeness geometric distance given by the cosine between s_i and e_j.

3 THE ARCHITECTURE

The architecture of the presented system is organized in three main areas:

A. The *Sub-conceptual Area* processes the perceptual data that comes from the sensors.
B. The *Emotional Area* contains the "conceptual space of emotional states" which constitutes the sub-symbolic representation of emotions, acquired during the training phase. This area gives to the robot emotional capabilities.
C. The *Behavioural Area* activates a non-deterministic behaviour related to the humanoid emotional state.

The Sub-Conceptual Area.

The sub-conceptual area is allowed to receive perceptions from the different modalities of the robot and carry on also the control of its actuators. This area is composed by two main modules:

A. The *MotionModule* controls the actuators of the robot in order to perform the movement requested by the Behavioural Area.
B. The *PerceptualModule* processes the raw data coming from robot sensors in order to obtain high level information about the environment.

A model as similar as possible to human beings has been prepared by considering five input channels for the Perceptual Module associable to the five human senses: sighting, touching, hearing, tasting and smelling. This framework will constitute a base for future development of real humanoid robots equipped with ad-hoc sensors in order to completely simulate human senses.

The perceptual information sensed by the processing of the raw sensor data is associated to their English description: as an example, if the system recognizes teddy bear, it will be associated to the sentence “I can see a teddy bear”. The use of a verbal description of the information retrieved from the environment allows their mapping into the emotional area in an easy way. These natural language descriptions associated to each modality will be the input of the conceptual area.

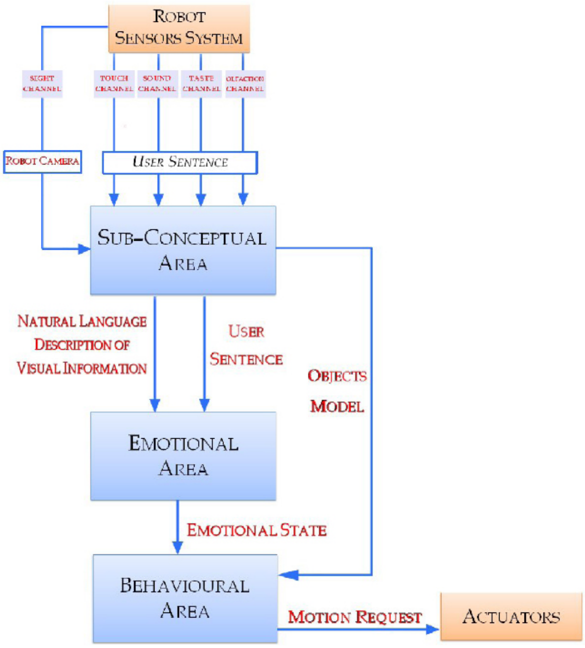

Figure 1: A sketch of the emotional robotic partner architecture.

The Emotional Area.

The emotional area makes the robot able to find emotional analogies between the current status and the previous knowledge stored on the robot using the semantic space of emotional states.

A corpus of documents dealing with emotions has been chosen in order to infer the emotional semantic space. Emotional states have been coded in this space using verbal description of situations capable to evoke emotions. Environmental incoming stimuli are encoded using the natural language and then are mapped in the space, to find analogies with the emotions encoded in it.

The set of documents used has been obtained trough an accurate selection of excerpts associated to feelings. We have selected the following emotional expressions: sadness, fear, anger, joy, surprise, love and a neutral state have been considered. These classification takes inspiration from Parrot [25].

A large amount of documents has been selected from several publicly available on-line sources. The excerpts have been organized in homogeneous paragraphs both for text length and emotion. A matrix has been organized where the 6 emotional states and the neutral state have also been coded according to the LSA paradigm. A corpus of about 1000 documents, equally distributed among the seven states, has been built. This set of documents represents the affective knowledge base of the system.

We did not use a parsing elaboration of the documents. Each document has been only processed in order to remove all words in literature named “stopwords” that do not carry semantic information like articles, prepositions and so on. The documents classification based on the 6+1 emotions was conducted from only one human expert annotator. According to the technique outlined in section two, a *87x1000* terms documents matrix (A) has been created where $M=80+7$ is the number of words plus the emotional states and $N=1000$ is the number of excerpts. The generic entry a_{ij} of the matrix is the square root of the sample probability of the *i-th* word belonging to the *j-th* document. The *TSVD* technique, with $K=150$, has been applied to A in order to obtain its best approximation according to the Hellinger distance. This process leads to the construction of a $K=150$ dimensional conceptual space of emotions S. The axes of S represent the “fundamental” emotional concepts automatically induced by *TSVD* procedure arising from the data. In the obtained space S, a subset of n_i documents for each emotional state corresponding to one of the six “basic emotion” E_i has been projected in S using the folding-in technique.

According to this technique each excerpt is coded as the sum of the vectors representing the terms composing it. As a result, the *j-th* excerpt belonging to the subset corresponding to the emotional state E_i is coded as a vector em_j and each emotional state E_i is represented in S by the associated subset of n_i vectors.

The inputs from the five sense channels are coded in natural language words or sentences describing them and projected in the conceptual space using the folding-in technique. At time t, the input from the visual channel is coded as a vector $v(t)$, the input from hearing channel is coded as a vector $h(t)$ and the input from touch channel is coded as a vector $t(t)$. The tasting and smelling channel are out of the scope of the present research and will be implemented in the future version of the system. These vectors, representative of the inputs from the channels, are merged together as a weighted sum in a single vector $f(t)$ that synthesizes the inputs stimuli from environment at instant t:

$$f(t) = \alpha \cdot vis(t) + \beta \cdot hea(t) + \gamma \cdot tou(t) + \delta \cdot sme(t) + \eta \cdot tas(t)$$

where α, β, γ, δ and η are weights that allow assigning different relevance to the specific inputs coming from each one of the three sense channels.

The emotional semantic similarity between the vector $f(t)$ and the vectors em_1, em_2, …, em_7, that code the six emotions in S, plus the “neutral” state, can be evaluated using the cosine similarity measure between each em_j and $f(t)$:

$$sim(f(t), em_j) = \frac{f(t) \cdot em_j}{\|f(t)\| \cdot \|em_j\|}$$

A higher value of *sim(f(t),em$_j$)* corresponds to an higher value of similarity between the emotion evoked from the input and the emotion E_i associated with the vector em_j.

The semantic similarity measure is calculated between *f(t)* and each em_j. The vector em_j which maximizes the quantity expressed in formula will be the inferred emotional state with an associated weight, or intensity. This emotional state will activate a behavioural stimulus with a given intensity given by *sim(f(t),em$_j$)*.

The Behavioural Area.

The purpose of the Behavioural Area is to execute and control the behaviours coherent to the emotional state inferred by the Emotional Area. A behaviour is described as a sequence of primitive actions sent directly to the robot actuators. Each emotional state is related with different behaviours in order to give to the robot a non-monotonous, non-deterministic, and non-boring response. A behaviour is selected by the evaluation of a score associated to each one of them:

$$w_{b_i} = \alpha_w r + \beta_w dt$$

where r is a random value ranging from 0 to 1, dt is the time elapsed by the instant at which the behaviour b_i has been executed and the instant at which this valuation is effected; α_w and β_w are respectively the weight assigned to the random value and to the time. The response with the highest weight is chosen and executed. The emotional stimulus is weighted, so the reaction will be executed with the same intensity: movements of the parts of the body will be faster or slower.

If the emotional state is classified as "neutral" a standard behaviour (to lie down, to sleep, and so on) is randomly selected.

4 THE HUMANOID ROBOT NAO

The humanoid robot Nao is the robotic platform used. It is from Aldebaran Robotics corporation from Paris. It is 60cm tall and its weight is 4,3 Kg. It has 25 degrees of freedom distributed along the body: 4 joints for each arm; 2 for each hand; 5 for each leg; 2 for the head; one used to control the hip.

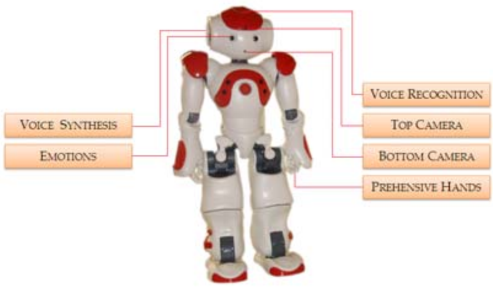

Figure 2: The humanoid robot Nao, from Aldebaran robotics.

Nao uses some force sensors called "Force Sensitive Resistors" to measure the resistance versus the quantity of pressure applied. In other words, it calculates the distribution of the force along the foot area in order to measure the inertial moment. Each time the robot makes a step, the gravity acceleration is calculated and summed to the acceleration that comes from the robot step itself, calculated in order to balancing the reaction force from the contact surface.

The robot has four ultrasonic sensors posed on the chest in order to calculate distances with objects inside the range between 25cm and 100cm.

Nao is capable to calculate its position respect the floor using the Inertial Measurement Unity (IMU), through an accelerometer and a gyroscope. In this way it is possible to check if the robot falls during the accomplishment of a behaviour.

Two cameras integrated in the head of the robot are present: with a maximum resolution of *640x480* and with a maximum frame-rate of *30fps* it is possible to capture the environment and to recognize objects.

In order to improve the emphatic capabilities of this robot, different coloured led are present along the body, from the hears, to the eyes and also on the chest and on the foots. Colours can be used to express emotion. For example red as rage, blue or green as joy, and so on.

Also some buttons are present on the robotic platform, on the head and on the chest. In particular the big button on the chest is used to turn on and turn off the robot, and also to modify standard behaviours of the robot itself.

Nao carries on a x86 AMD Geode CPU capable to work with 500 MHz, an internal memory SDRAM of 256 MB, 1 GB of flash memory, two speakers, a vocal synthesizer, WiFi, Ethernet and uses an embedded 32 bit Linux. It is possible to control it using C/C++ libraries, but also Python and the Gostai's framework Urbi.

The robot Nao uses a lot of sensors and an high number of degrees of freedom and this is justified because the wide capabilities of using it in different missions, for many purposes and in several environments.

5 THE EMOTIONAL ROBOT

The emotional humanoid robot presented in this paper is an Aldebaran's Nao supplied with empathy capabilities. The emotional robot follows the empathic model based on the emotional conceptual space, yet described. Components running on the robot or on a support computer have been implemented in order to distribute the computational weight of the entire system. Three modules, running on a computer, are the *Perceptual module*, that implements the Sub-conceptual area, the *Emogen module*, that realizes the Emotional Area, and the *Controller*, that carry on the Behavioral Area.

The humanoid behaviours are implemented inside the robot Nao, in the *NaoMotion module*. This module is capable to accept request of behaviours and to execute them by controlling the joints of the robot. Two kinds of behaviours have been implemented: walks and actions. The walking algorithm used has been supplied by Aldebaran instead of the action behaviours that are implemented as interpolation of different poses of the robot. The actions implemented are greeting, clapping, looking around and kicking. Other actions are used to express the six emotions: fear, angry, sadness, joy, love and surprise.

Inside the Perceptual module a vision system has been implemented in order to sense objects and translate them in symbolic instances. It uses the data captured from the camera posed on the head of the robot to recognize objects of the world using colours and geometric features. This information is used by the Controller module and, as verbal description, by the EmoGen module.

A human user can also realize an interaction with the robot through an user-friendly interface. It accepts sentences from the user by a computer keyboard, sentences that are sent to EmoGen module. In the future development the keyboard will be replace with voice recognition as functionality of the robot.

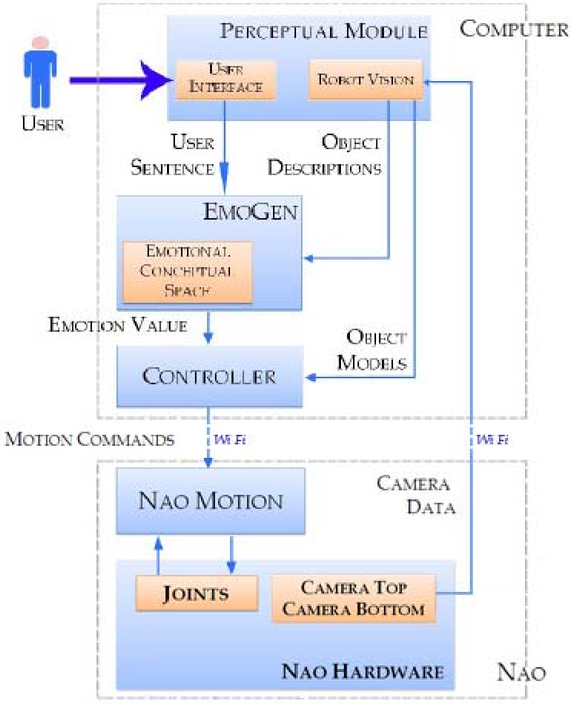

Figure 3: The different modules of the system.

The EmoGen module elaborates sentences from user and from visual information and infers, according with the emotional conceptual space, the correct emotional state.

At last, the emotional state and the information about the objects recognized are used by the Controller module to generate the most coherent action. The controller will send through TCP-IP connection this information to the robot. The NaoMotion module will respond to this command by the activation of one of the correspondent emotional behaviours.

6 EXPERIMENTAL RESULTS

Different experiments have been conducted using the robot Nao in order to test the emotional capabilities of the robot by reproducing various emotive situations.

In a first experiment the robot is posed in front of a Robovie-M from VStone corporation, a yellow robot simply to recognize as a puppet, and an orange ball. Visual stimulus is converted in a small and simple sentence as "*The puppet throws the ball*". The dominant emotional state activated in the emotional conceptual space of the robot is "Surprise" and the robot executes a "Surprise" behaviour.

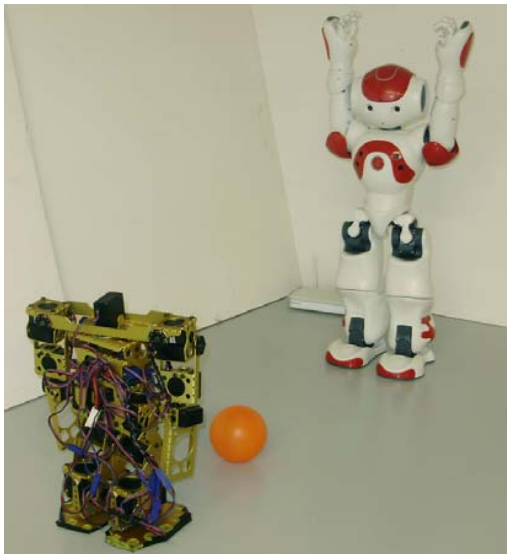

Figure 4: In the first trial the robot express a Joy behaviour.

In a second experiment the input phrase provided by an naïve human user is "*brother and sister play with the dog*". The dominant emotional state activated in the emotional conceptual space of the robot is "Love" and the robot executes a "Love" behaviour.

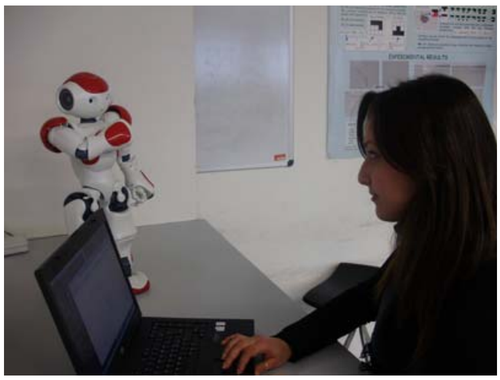

Figure 5: The robot express a Love behaviour.

The Table 1 shows four experiments results. Different sentences are elaborated by the system in order to achieve the highest emotion value.

My sister and my dog are running together			
Sad -0.0098	Angry -0.2417	Fear -0.1077	
Joy **0.0842**	Surprise -0.1219	Love 0.0343	Neutral -0.0377
Brother and sister play with the dog			
Sad 0.1509	Angry -0.0032	Fear -0.0371	
Joy 0.1794	Surprise 0.0624	**Love** **0.2548**	Neutral -0.0962
The child is sad while he look at the window			
Sad **0.4566**	Angry 0.0821	Fear 0.2377	
Joy -0.2512	Surprise 0.0481	Love 0.2366	Neutral -0.0654
The puppet throws the ball			
Sad 0.0132	Angry -0.0413	Fear 0.0056	
Joy -0.0423	**Surprise** **0.0139**	Love -0.0259	Neutral -0.0241

Table 1: The Numerical results of different experiments.

7 CONCLUSIONS & FUTURE WORK

The results shown in this paper confirm that it is possible to generate spontaneous and non trivial behaviour for entertainment humanoid robot by the creation of **a** high dimensional sub-symbolic representation of concepts and emotions. The robot is capable to perceive utterances and visual stimulus and to respond in an empathic way.

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REFERENCES

[1] Takahashi M., Suzuki T., Cinquegrani F., Sorbello R., Pagello E.: *A mobile robot for transport applications in hospital domain with safe human detection algorithm*. In: 2009 IEEE International Conference on Robotics and Biomimetics (ROBIO 2009). Guilin, Guangxi, Cina, 18-22 December (2009).

[2] Chella A., Pilato G., Sorbello R., Vassallo G., Cinquegrani F., Anzalone S. M.: *An Emphatic Humanoid Robot With Emotional Latent Semantic Behavior*. On: First International Conference, SIMPAR 2008, Simulation, Modeling, and Programming for Autonomous Robots, 3-6 November, Venice, Italy (2008).

[3] Menegatti, E., Silvestri, G., Pagello, E., Greggio, N., Cisternino, N., Mazzanti, F., Sorbello, R., Chella, A.: *3D models of Humanoid Soccer Robot in USARSim and Robotics Studio simulators*. In: IJHR 2008, International Journal of Humanoid Robotics (2008).

[4] Chella A, Barone R.E, Pilato G, Sorbello R.: *An Emotional Storyteller Robot.* In: 2008 AAAI Spring Symposium on. Stanford University, April (2008).

[5] Chella A, Pilato G, Sorbello R., Vassallo G, Cinquegrani F, Anzalone S.M.: *An Emphatic Humanoid Robot With Emotional Latent Semantic Behavior in Microsoft Robotic Studio.* In: . Cittadella dei Musei, Cagliari, Italia, 11-13 September (2008).

[6] Chella A, Pilato G, Sorbello R., Vassallo G, Barone R.E.: *The Latent Semantic Analysis as a Framework for Behaviours of EmphyBot Robot in Entertainment Application.* In: 13th IEEE/IFAC International Conference on Methods and Models in Automation and Robotics. Szczecin, Poland, 27-30 August (2007).

[7] Chella A., Sorbello R., Anzalone, S.M., Cinquegrani, F., Caccìa, D.: *A New Architecture Based on a Simulation Environment for Four Legged and Humanoid Robots*. In: 13th IEEE IFAC International Conference on Methods and Models in Automation and Robotics, MMAR 2007, August (2007).

[8] Ortony A., Clore G., Collins A.: *The Cognitive Structure of Emotions*. Cambridge University Press, Cambridge (1988).

[9] Chella A., Frixione M. and Gaglio S.: *An Architecture for Autonomous Agents Exploiting Conceptual Representations*. In: Robotics and Autonomous Systems 25, pp. 231–240 (1998).

[10] Agostaro F., Augello A., Pilato G., Vassallo G., Gaglio S.: A *Conversational Agent Based on a Conceptual Interpretation of a Data Driven Semantic Space.* In: Lecture Notes in Artificial Intelligence, Springer-Verlag GmbH, vol. 3673, pp 381-392 (2005).

[11] Landauer, T. K., & Dumais, S. T.: *A solution to Plato's problem:The Latent Semantic Analysis theory of the acquisition, induction, and representation of knowledge*. In: Psychological Review,104, 211-240 (1997).

[12] Landauer, T.K., Foltz, P.W., Laham, D.: *Introduction to Latent Semantic Analysis*. In: Discourse Processes, 25, 259-284 (1998).

[13] Thagard, P., Shelley, C.P.: *Emotional analogies and analogical inference*. In: D. Gentner & K. H. Holyoak & B. K. Kokinov (Eds.), The analogical mind: Perspectives from cognitive science, pp. 335-362. Cambridge, MA: MIT Press (2001).

[14] Berry, M.W., Dumais, S.T., Gavin W. O'Brien: *Using Linear Algebra for Intelligent Information Retrieval*. In: SIAM Review, Vol. 37, No. 4, pp. 573-595 Dec., (1995).

[15] Peters, S. , Widdows, D.: *Word vectors and quantum logic experiments with negation and disjunction*. In: Mathematics of Language, 8, Bloomington, Indiana, June, (2003).

[16] P. Gardenfors. *Conceptual Spaces*. MIT Press, Bradford Books, Cambridge, MA, (2000).

[17] Ultsch, A.: *The Integration of Connectionist Models with Knowledge based Systems: Hybrid Systems.* Proc. of the IEEE SMC 98 International Conference, 11-14 October, San Diego, pp. 1530-1535. (1998).

[18] Zhu, H.: *Bayesian geometric theory of learning algorithms*. In: Proceedings of the International Conference on Neural Networks (ICNN'97), vol. 2: pp. 1041–1044. (1997).

[19] Landauer, T. K., Laham, D., & Foltz, P. W., *Learning human-like knowledge by Singular Value Decomposition: A progress report*. In: M. I. Jordan, M. J. Kearns & S. A. Solla (Eds.)Advances in Neural Information Processing Systems 10, pp. 45-51. Cambridge: MIT Press (1998).

[20] Dautenhahn, K., Billard, A.: *Bringing up robots or psychology of socially intelligent robots: From theory to implementation.* In: Proc. 3rd Int. Conf. on Autonomous Agents. Seattle WA My (1999).

[21] Fujita, M.: *Digital Creatures for Future Entertainment Robotics*. In: IEEE International Conference on Robotics and Automation, pages. 801-806.San Francisco, California (2000).

[22] Arkin R., Fujita M., Takagi T., Hasegawa R.: *Ethological Modeling and Architecture for an Entertaiment Robot*. In: IEEE Int. Conf. on Robotics & Automation, p.p. 453-458. Seoul. (2001).

[23] Lakemayer, G.: *On Sensing and off-line interpreting in GOLOG*. In: Logical Foundations for Cognitive Agents, Contributions in Honor of Ray Reiter, pages 173-187, Springer, Berlin, (1999).

[24] Colon, E., Sahli, H., Baudoin, Y.: *CoRoBa, a Multi Mobile Robot Control and Simulation Framework*. In: Int. Journal of Advanced Robotic Systems, (2006).

[25] Parrott, W. (2001), Emotions in Social Psychology, Psychology Press, Philadelphia.