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Simulation Results for the ARS-PA Model

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***Abstract*— The project ARS (Artificial Recognition System) develops a novel approach to decision making in the domain of building automation systems. Concepts from neurology, psychology, and psychoanalysis are used for this approach. We give a short overview about this decision making concept, the simulation environment, and results from simulation experiments. These simulation runs consist of several autonomous agents grouped to two teams which are competing for restricted resources. ARS deals with agents as an intermediate step towards buildings. For some resources cooperation among team mates is necessary. One team is using the ARS approach including concepts like emotions, drives, and desires. Further, it uses a value system inspired by social levels to stimulate cooperation among the team mates. The other team—as a reference—is realized by using a simple rule based decision making approach. The simulation results show an improvement in team-survival due to the introduction of social levels.**

I. Introduction

BUILDING automation systems are expected to be equipped with hundreds of thousands of sensors [1]. To be able to cope with this flood of data new approaches towards data processing and decision making are needed. As [2] suggests, the introduction of psychoanalysis to AI can be one of these new approaches. A psychodynamic architecture for decision making based partially on Freud's psychoanalysis is described in [3], [4], and [5]. The intended usage of this architecture is for robots.

We are intending to use such an architecture not only for robots but also for building automation. The article [6] gives a first introduction to the basic concept combining knowledge from the fields of neurology, psychology, and psychanalysis. It is derived from the work done in [1] and [7]. This concept is divided into two parts:

PC (Perception) is a bottom-up approach using concepts of the neurology for the condensation of sensor data to higher level symbols. [8]

PA (Psychanalyses) is a top-down approach, based upon the functional model of the brain as defined by the psychoanalyses. [9] and [10]

In the following, we will give a brief overview of the concept. A more in depth description can be found in [11], [12], and [13].

Figure 1 shows the first step of the symbolization. The sensor data is compressed to a preliminary symbol. This is compared with a set of template symbols. The best matching templates are then used for further data processing. This includes the generation or update of higher level symbols. These symbols reduce the amount of data but increase the richness of the content. We define three symbol levels [8]:

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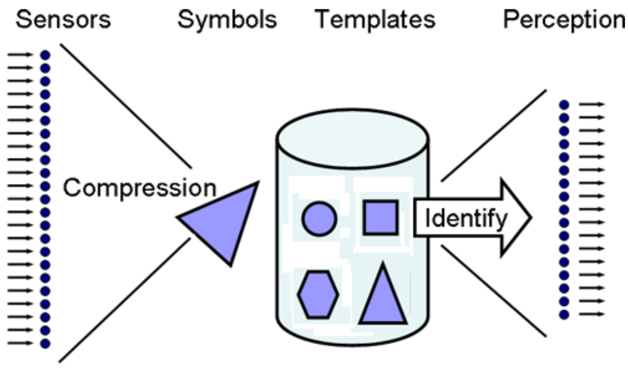

Fig. 1. Symbolization [8]

- Micro symbols,
- Snapshot symbols, and
- Representation symbols.

The first ones are generated directly out of the sensor data. Snapshot symbols are short living symbols which are generated out of micro symbols. For example, two adjacent floor pressure sensors which are activated within a short period are generating a food step snapshot symbol. Finally—as the highest level—the representation symbols are used for long term purposes. For example, a person that enters an office building in the morning, works all day, and leaves it at night would produce thousands of micro symbols, hundreds of snapshot symbols, but only one representation symbol. This whole process is the perception of the system.

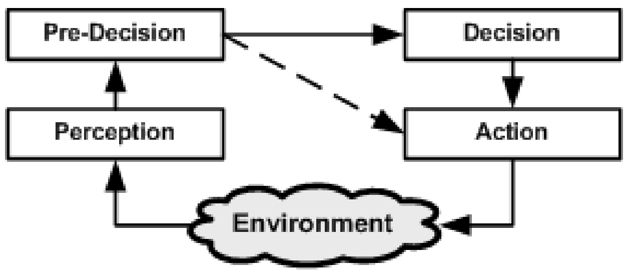

Fig. 2. Operation Cycle

In the decision making (Figure 2) the perception is only the first step towards selecting and executing the corresponding actions. The symbols are emotionally evaluated in the pre-decision in a two-way evaluation. On the one hand, the symbol is evaluated in context of the actual emotional state of the system. In case of an emergency, an immediate action can be evoked. On the other hand, the perceived symbol influences the emotions. A symbol depicting a dangerous situation may increase the emotion Fear. This feedback influences the previously mentioned symbol evaluation against the emotional state. Thus, the system will become more sensitive for e.g. danger if many "frightening" situations have been perceived shortly.

The emotionalized symbols are afterwards distributed to three different modules:

- *Reflexive action module*—As written earlier, this module receives symbols from the pre-decision which evoke an immediate action. For example, a detected large, open fire activates the fire alarm immediately.
- *Routine action module*—A routine is a sequence of actions. The correct execution of such a sequence is depended on information from the world. We distinguish between two different types of routines: 1. instinctive routines and 2. intentional routines. The first ones are induced by perceived symbols directly. The latter ones are triggered by the decision module.
- *Reactive decision module*—This module is responsible for the high level decision making. Perceived and emotionally evaluated data is processed and actions are taken considering actual desires and needs.

The advantage of this three-folded approach is that obviously dangerous situations are resulting in an immediate action response, whereas unclear situations can be evaluated in a longer lasting process.

The data perceived by the system, representing the environment and the internal state, is first evaluated in the pre-decision unit. Drives are representing the agents homeostasis. The evaluation process is highly influenced by the basic emotional systems implemented in the pre-decision. In analogy to the human, basic emotions would be rage, fear, panic and a seeking system [14] that persuades the individual for exploration. According to its drives and basic emotions, first actions can be initiated as described above.

The evaluated information is encapsulated in a container that is called perceived image. A defined sequence in time of perceived images is called scenario. Selected scenarios can influence the value of complex emotions that would be social afflicted emotions in analogy to a human mind like joy, hope, pride, shame. Complex emotions arise within the decision unit analog to basic emotions. When a scenario is recognized, a corresponding desire can be triggered. This means, that a number of actions has to be executed or a number of images has been perceived in a sequence of the correct order that are representing an object of desire, evoking a desire. The desire includes a predefined action plan that leads to the satisfaction of a need. Like the drives contained in the pre-decision unit that are reflecting the bodily needs, desires are the analog to the drives within the decision unit.

By perceiving the correct image as a transition condition, the next state of the action plan is reached. Each state of the action plan within desires can influence one or more assigned complex emotions and can cause the system to execute an action. In an example-scenario as described in this article, where an agent is waiting for help, the complex emotion hope would be positively influenced. The value of complex emotions can influence (amplify or suppress) drives and complex emotions. During time, the value of a complex emotion is decreased.

The reached state of a desire can fall back to the previous state, if a defined time threshold has been reached. When the desire state has reached the first state by several fall-backs, the desire will be discarded and has to be evoked by a corresponding scenario. A desire can also be discarded by receiving a corresponding, predefined abort condition. When the complete action-plan is passed through, the desire is accomplished and the need has been satisfied.

Using the introduced concept, the following article shows an implementation of the model within an autonomous agent in a simulated environment. Various scenarios are evoking desires, that are affecting the behavior of the agents and are influencing their emotions, drives and complex emotions. It will be shown, that the social influence of the complex emotions is leading the agents to cooperate with other agents and work within a team.

We are looking at autonomous agents as an intermediate step towards a building automation system. For development of a concept based on psychoanalysis, it is advantageous to work with agents modeled as simplified humans. This makes it easier to translate terms like emotion and drive from the psychoanalytic human oriented point of view to a general technical point of view.

II. Simulator

FOR a traceable implementation and functional ARS-PA model test, a simulator called the Bubble Family Game (BFG), similar to Masano Toda's Fungus Eater [15], has been designed and implemented. This simulator contains Autonomous Embodied Agents(AEA) roaming and interacting with their artificial environment. Even there exists a number of capable autonomous robot simulating programs, like the MissionLab [16], Teambots [17], MARIE [18] or PYRO [19], a new simulator has been generated. This implementation reasons in the fact that the focus never laid on developing a well working program for mobile autonomous robots but on implementing intelligent, distributed and interacting sensor systems for building automation. For this reason the requirements differ from already developed simulation programs. In contrast to mobile robot simulators the focus will not be laid on position finding or side stepping obstacles, but on effective interaction and system information exchange among AEAs. Even, as the next sections will show, the simulator works on a rather high and abstract level, the realised results should help to take a step forward to an implementation of an intelligent building automation sensory system.

The generated simulator is grouped in three functional blocks whereas the 'World Simulator' forms the artificial environment and consists out of basic knowledge about the AEAs. Moreover the 'Behavior Architecture' is implemented in a separate module for each agent realizing its behavior and the 'Agent Body' providing the interface between 'inner' and 'outer' world. Controlled by the 'Behavior Architecture' the AEA is able to act out four modes of operation called promenade, attack, flee and eat. Every action or idleness the AEA takes will result in a decrease of its energy level which has to be refilled. For this reason Energy Sources (ES) are randomly placed above the environment and have to be found and consumed by the AEA.

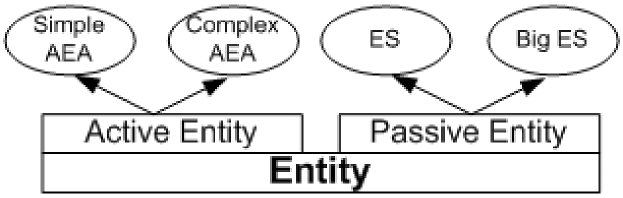

Fig. 3. Entity Realization

Of particular importance is the fact that these decisions are not influenced by the environment only, but by an internal valuation system too. Currently two types of AEAs, called simple AEAs and complex AEAs, are implemented, differing in the level of development of its internal constitution. Because of the reason that they base on a common fundament, they are derived from one entity (Figure 3). Both types of AEAs are operating on the base of drives and basic emotions which are mentioned above. These valuations interact with each other and are influenced by the environmental configuration too. As shown in Figure 3 ESs are derived from the same entity as both types of AEAs. They share the same basic attributes and differ in a higher implementation layer. While AEAs are defined as active objects which means they are able to roam their environment and contain the 'Behavior Architecture', ESs belong to a group of passive and immobile energy producers. The reason for this combination of two rather different objects to one entity, bases on the implementation of a predator-prey relationship among AEAs for a prospective level of development. For this scenario AEAs will not simply be energy consumers. They will become energy producers too which enables the possibility for hunting opponents in case of searching for food. Due to these changes social coherence and interaction among AEAs will become more complicated and therefore harder to get handled by the ARS-PA model.

The conventional model operates on the base of simple rules implemented by if/then clauses. While the simple AEA holds this level of development a further improved one has been generated for the complex AEA, integrating the actual ARS-PA model. In addition to the basic emotions, implemented by the simple AEA, the further developed model includes complex emotions and desires. This extension results in an increase of ability as well as complexity and leads to a more powerful model. The complex AEA's 'brain' is influenced by numerous internal valuations which boost a sensitive recognition of condition changes. This may result in a faster reaction on external changes by the 'Behavior Architecture'. In addition this further developed model enables the AEAs to exchange experiences by communicating with each other. This attribute will become important for future development due to improve the possibilities for complex AEAs' to cooperate with each other, to find ESs and to stand up to rival teams of AEAs. Every single AEA has the intention to survive as long as possible in a team. It has to be shown that this 'mission' has a higher chance to be accomplished by the complex model.

For controlling the ARS-model's function and ability to

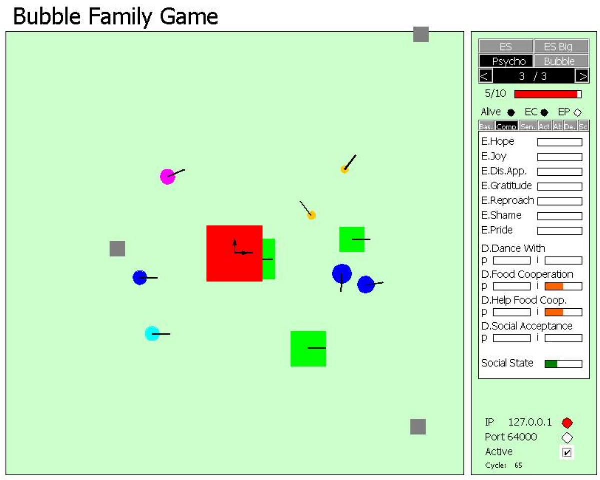

Fig. 4. Bubble Family Game 2D Visualisation

pursue improving system intelligence, the model has to be tested carefully. To present the simulation results in a concrete way a test-bench and 2D environments have been created. The test-bench has been created to help concentrating on emotion values of single AEAs. Furthermore influences among emotional states, environment configuration and behavior can be reconstructed in a traceable way. To be able to keep the overview in spite of increasing the agent number and simulation complexity, an additional 2D visualization has been implemented. An additional included interface offers the possibility to construct the simulator as a distributed system. This procedure will allow to deal with increasing complexity and system requirements, expected for further development.

AEAs get the assignment to solve problems by themselves and in cooperation with their teammates. During their 'life' AEAs have to be able to deal with different environment configurations. Specifically generated test scenarios (Section III) aim at testing the ARS-PA model's function and intelligence (Figure 4).

III. Test-Case

FOR a significant functional test of the ARS-PA model, test-cases have to be generated. For an easier understanding on the AEA behaviour, the generated testcases are rather simple. The AEA starts from an initial situation aiming at achieving a special goal like reducing hunger (testcase 'Cooperation for Food') or defending against antagonistic AEAs(testcase 'Call for help'). When increasing the simulation complexity a numerous number of AEAs will run parallel and will take effect on each others' actions. To reach a specific goal, an AEA has to perambulate an array of states which is predifined and called scenario. The next state will be reached by fullfilling certain external and internal conditions saved as so called Template Images (TI). TIs are predefined too and consist of a percieved environment configuration and an internal AEA constitution. The number of actions, aforementioned in section II, enable the AEAs to interact with their environment and forward them to the next states. If a specific goal has been reached the sequence of events will be saved as realization of a scenario, called episode. Every scenario can be realized by a number of episodes, depending on internal and external conditions. Further work will aim at triggering to already saved episodes for trying to reconstruct them and achieving a successful scenario execution more rapidly. If the simulation complexity rises it is for sure that situations will occure which interrupt the AEAs in their current scenario realisation. Depending on its importance, this interaction will be ignored, saved as event in the episode or will force the AEA to achieve a more prior objective by triggering to a new scenario.

The test-cases 'Ask for a dance', 'Cooperation for food' and 'Call for help' are chosen to be discussed here, because of their specific feature testing social interaction among AEAs.

Every AEA implies an abstract concept called the social level which represents the social status of its teammates. This includes a value table implementing a personal social level for all teammates. All AEAs are able to communicate with each other if they stay within the so called hearing range (figure 5). If one or more teammates are praised or reproached by another one the social level of these specific ones will increase or decrease. Those AEAs which do not remain within the hearing range area will not get the information about the praised or reproached AEA and hence will not change the social level of the affected AEAs. This circumstance leads to different opinions about the reliability of teammates and will affect their interaction. During the simulation the AEAs have to interact with their teammates, for instance by expressing desires towards them. The probability that someone's desires get fulfilled increases in case that the AEA which is asked to help holds that the AEA in need has a high social level.

1) *Ask for a dance* In test-case 1 the complex AEA 'A'

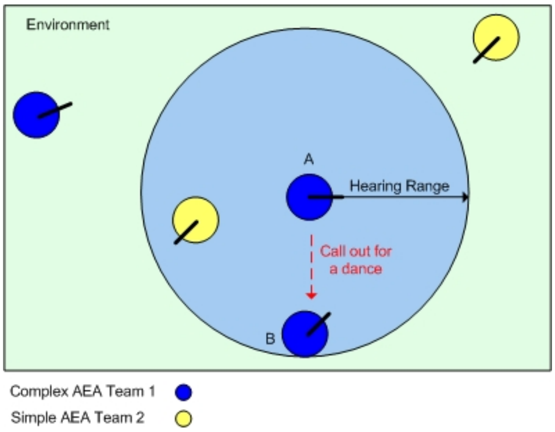

Fig. 5. Test-Case 1 'Ask for a Dance'

has the desire, as shown in Figure 5, to dance with one another. So it calls out towards its teammates who are placed within a hearing range of constant radius. Depending on the height of the complex AEA's social level and the others emotional states the desire gets confirmed or rejected. In case of receiving a rejection by complex AEA 'B', 'A' calls out a reproach which leads to a decrease of 'B's' social level and strongly lowers the chance of getting help later on. As a consequence of confirming 'A's' desire, 'B' moves towards 'A' and starts to dance. 'B' gets praised by 'A' which leads to an increase in 'B's' social level.

2) *Cooperation for food*

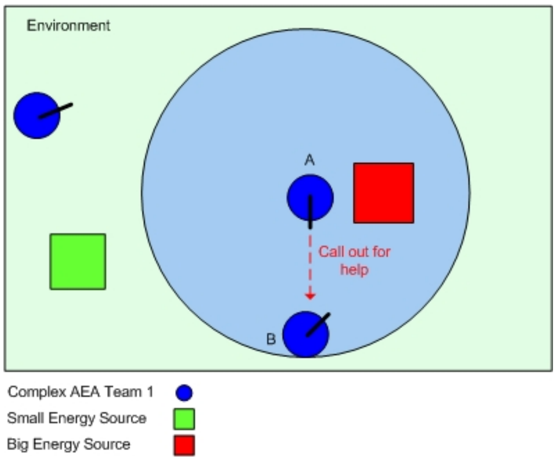

Fig. 6. Test-Case 2 'Cooperation for Food'

The environment for test-case 2 is configured as shown in Figure 6. A detailed explanation will follow after mentioning a fact which hasn't been considered up to now. Every action an AEA takes will lead to a decrease of its energy level. As a consequence the AEA has to refill its energy depot by 'eating' so called Energy Sources (ES) which are grouped into two types. ES 1 can be 'consumed' by one AEA whereas for cracking ES 2, two AEAs are required.

As shown in Figure 6 an ES Type 2 is placed within the environment. 'A' tries to crack the ES and calls out towards 'B' after recognizing the need for help. As in test-case 1 a rejection of assistance will lead to 'B's' social hostility while an affirmation increases its social level.

3) *Call for help*

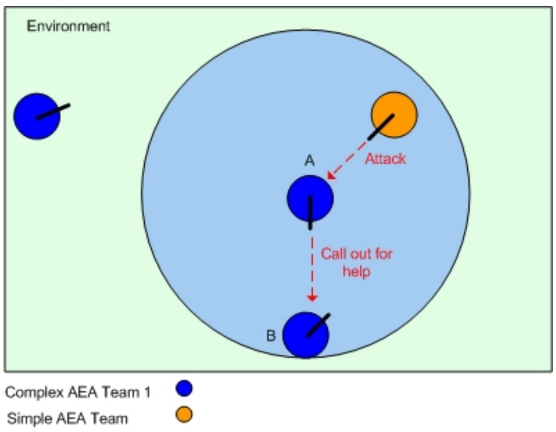

Fig. 7. Test-Case 3 'Call for Help'

Illustrated in Figure 7 the complex AEA 'A' gets attacked by a simple AEA. Because of its ability for social interaction, 'A' will have a high chance to survive. The complex AEA gets to flee or to defend himself with the help of its teammates. It calls out for help towards them; in this case only 'B' stays within the defined hearing range.

As a consequence of rejection the complex AEA 'A' calls out a reproach which leads to a decrease on 'B's' social level. In case of confirming help, 'B' moves towards 'A' and helps to defend against the offender. As a consequence 'A' praises 'B' whose social level increases within the team.

As shown in the test-cases above the model's operation on social interaction among AEAs is extremely important for 'surviving' the simulation run and additional of high interest for the project. In Section IV an experiment is conducted showing the advantage of the latest level of model development versus the primitive form of AEAs. Each of this test-cases is—for its own—a simple problem, but when using several of these, complex situations can be described.

IV. Experiment

To evaluate the above described test-cases 25 simulation runs have been executed. The average survival rate of AEAs of a team has been selected as the comparison parameter. In each run, four simple AEAs competed against four complex AEAs for the available energy sources. One big and two small energy sources were distributed on the area. All AEAs were placed at uniformly distributed positions. Further, the energy level of every agent is set to a random value inside the range from 35%—86% of their maximum level.

TABLE I
SURVIVAL RATE FOR 25 RUNS

	simple AEA-team	complex AEA-team
min	0.00	1.00
avg	2.79	3.44
max	4.00	4.00
std.dev	0.52	0.65

Table I shows the number of AEAs which survived a whole simulation run. The simple team did not manage to keep at least one AEA alive for one of the runs. When comparing the average results for both teams, the complex team succeeded a better result. The standard deviation is better for the simple team, but in overall the complex team wins this comparison.

TABLE II
UTILIZATION OF TEST-CASES

	Ask for a dance	Cooperation for food	Call for help
min	49%	22%	0%
avg	76%	59%	6%
max	85%	95%	19%
std.dev	9%	21%	5%

An overview about the utilization of each of the three test-cases is given in Table II. The numbers show how much time of a simulation run a complex AEA recognized one of the test-cases. There can be more than one test-case at a moment. For example, while an agent received a call for help it asked for a dance. What can be seen is that most of the time an complex AEA experienced no need for food or a frightening situation. Thus, the activity 'Ask for a dance' is the most popular one. The strong standard deviation for 'Cooperate for food' can be explained when looking at simulation runs where at least two complex AEAs died early. In this case, the call 'Cooperate for food' was not or late answered. The sparse population of the area together with a non aggressive configuration for the AEAs resulted in little occasions where a complex AEA called his team mates for defence.

V. Conclusion

We have presented a simulator for testing the fitness of the ARS model. The ARS model was implemented in autonomous agents and controlled by generated test-cases which show the system's basic functions. The achieved simulation results show that the complex AEAs are better able to cope with the expirement configuration. We suggest that the influence of the social level on the survival rate of a team should be examined in further experiments.

References

[1] G. Russ, "Situation-dependent behavior in building automation," Ph.D. dissertation, Vienna University of Technology, Institute of Computer Technology, 2003.

[2] S. Turkle, "Artificial intelligence and psychoanalysis: A new alliance," in *The Artificial Intelligence Debate: False Starts, Real Foundations*, S. R. Graubard, Ed. Cambridge, MA: MIT Press, 1989, pp. 241–268, iSBN 0-262-57074-2.

[3] A. Buller, "Volitron: On a psychodynamic robot and its four realities," *Pro-ceedings Second International Workshop on Epigenetic Robotics: Modeling Cognitive Development in Robotic Systems*, vol. 94, pp. 17–20, 2002.

[4] A. Buller, M. Joachimczak, J. Liu, and K. Shimohara, "ATR artificial brain project: 2004 progress report," *Artificial Life and Robotics*, vol. 9, no. 4, pp. 197–201, 2005.

[5] A. Buller, "Building brains for robots: A psychodynamic approach," *Invited talk on the First International Conference on Pattern Recognition and Machine Intelligence, PReMIT'05*, pp. 17–20, 2005.

[6] G. Pratl and P. Palensky, "Project ARS - the next step towards an intelligent environment," *Proceedings of the IEEE International Workshop on Intelligent Environments*, pp. 55–62, 2005.

[7] C. Tamarit, "Automation system perception - first step towards perceptive awareness," Ph.D. dissertation, Vienna University of Technology, Institute of Computer Technology, 2003.

[8] G. Pratl, "Processing and symbolization of ambient sensor data," Ph.D. dissertation, Vienna University of Technology, Institute of Computer Technology, 2006.

[9] T. Deutsch, R. Lang, G. Pratl, E. Brainin, and S. Teicher, "Applying psychoanalytic and neuro-scientific models to automation," *The 2nd IET International Conference on Intelligent Environments*, pp. 111–118, 2006.

[10] C. Rösener, B. Lorenz, G. Fodor, and K. Vock, "Emotional behavior arbitration for automation and robotic systems," *Proceedings of 2006 IEEE International Conference of Industrial Informatics*, pp. 423–428, 2006.

[11] G. Pratl, D. Dietrich, G. P. Hancke, and W. T. Penzhorn, "A new model for autonomous, networked control systems," *IEEE Transactions on Industrial Informatics*, vol. 3, pp. 21–32, 2007.

[12] C. Rösener, R. Lang, T. Deutsch, and A. Gruber, "Action planning model fpr autonomous mobile robots," *Proceedings of 2007 IEEE International Conference of Industrial Informatics*, 2007, to be published.

[13] W. Burgstaller, R. Lang, P. Pörscht, and R. Velik, "Technical model for basic and complex emotions," *Proceedings of 2007 IEEE International Conference of Industrial Informatics*, 2007, to be published.

[14] J. Panksepp, *Affective Neuroscience, the Foundations of Human and Animal Emotions*. Oxford University Press, Inc. 198 Madison Avenue, New York, 1998, iSBN 0195096738.

[15] M. Toda, *Man, Robot and Society*. Martinus Nijhoff Publishing, 1982, iSBN 089838060X.

[16] D. MacKenzie, R. Arkin, and J. Cameron, “Multiagent mission specification and execution,” *Autonomous Robots*, vol. 4(1), pp. 29–52, 1997.
[17] T. Balch, “Teambots,” 2007. [Online]. Available: http://www.cs.cmu.edu/ trb/TeamBots/
[18] C. Cote, Y. Brosseau, D. Letourneau, F. Michaud, and C. Raievsky, “Robotic software integration using marie,” *International Journal on Advanced Robotics Systems*, vol. 3(1), pp. 55–60, 2006.
[19] D. Blank, D. Kumar, and L. Meeden, “Pyro: A python-based versatile programming environment for teaching robotics,” *Journal on Educational Resources in Computing*, pp. 1–15, 2003.

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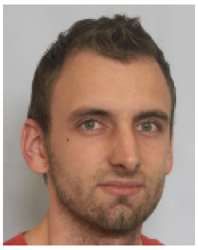

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