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Session 2 - Advances in Control Theory and Control Engineering

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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A. Gonzalez / H. Fernlund / J. Ekblad

After Action Review by Comparison – an Approach to Automatically Evaluating Trainee Performance in Training Exercise

ABSTRACT

After-action Review (AAR) is an effective tool to evaluate and improve human performance in tactical training exercises. However, when the exercises grow in size, and possibly reside in several locations, providing feedback to the majority of the participants can be complicated. It requires extensive time and resources, and the review might be limited to the few most important tactical decisions made. To get the most out of AAR, it should be complemented with automated systems that help the instructor/operator (I/O) generate the appropriate feedback for each individual trainee. To improve the ability of the I/O to provide we investigated the development of intelligent tools to compose a *Smart After-Action Review* (SmartAAR) technology suite. This approach is based upon the concept of AAR-by-comparison. That is, we seek to build agents that represent expert human performance and then use them as benchmarks during execution of the tactical exercise, to which the trainee performance is compared continuously and possibly in real time. By pairing each trainee with his own 'personal' expert agent counterpart, individual feedback can be provided to each trainee. This paper presents a novel concept based on two dimensions: 1) comparing the spatio-temporal location of the trainee and 2) comparing the context in which the trainee finds himself. These could serve as a basis for automatic and self-instructing AAR.

Introduction

Evaluation of human performance against stated objectives is an important function in successful organizations. There are several different areas where evaluation of human performance is particularly important, such as sporting events (e.g., football), rescue operations (e.g., fire fighting) or military operations. In such actions, a human must perform against other humans acting as adversaries, often in a life-or-death struggle. Especially challenging is evaluation of teamwork performances. We describe our research effort that has developed a novel approach for automatic support of human performance evaluation. The area of interest in this research was military exercises but the results are applicable to many different domains that employ simulator and/or live exercise training for its participants, such as sports training, etc. Particularly applicable are tasks that are tactical in nature, even if not adversarial, such as for example, driver training or flight training However, in this paper, we refer only to the military training domain.

In military training, it is important that the trainee be provided with timely and individual-specific feedback in order to improve his performance in future missions. *After-Action Review* (AAR) is the process through which this feedback is traditionally provided. AAR is an important tool to evaluate the individual as well as collective task performances for trainees after the training session is completed. The *observer/controller* (OC) who normally provides the feedback must be aware of the actions executed by the trainee, and be able to determine their correctness. However, it is unrealistic to expect the OC to continuously monitor every single individual participant in the exercise [1]. This is especially true for large training exercises with many participants. The approach to deal with this problem is to conduct informal reviews by the leaders in the internal chain of commands, prior to the formal AAR. However, the leaders typically do not have a complete picture of all the events and the trainees' actions therein. The art of AAR is then to get each participant to perform accurate self-evaluations [2], in order to obtain a complete, high quality AAR experience. There is increasing interest in virtual simulations where the participants can be either real or virtual and in different training locations. Conducting constructive AAR in such exercises becomes even more difficult.

To get the most out of AAR, we believe it should be complemented with automated systems that generate the appropriate feedback for each individual trainee. To improve the ability of the OC to provide feedback, this research investigates the use of intelligent tools to compose a Smart After-Action Review (SmartAAR) technology suite. This approach is based upon the concept of AAR-by-comparison. That is, we build agents that represent expert human performance and then use them as benchmarks during execution of the tactical exercise, to which the trainee performance is compared continuously and possibly in real time. By pairing each trainee with his own 'personal' expert agent, individual feedback can be managed for the benefit of the trainee.

The method used here to build the personal expert agents is a machine learning algorithm that builds the knowledge within the contexts, by observing human experts in action. It is called *Genetic Context Learning* or GenCL [3]. No matter how profoundly one might study a subject, it seems that actual experience is essential for perfecting a behavior. Experience increases the expertise level of a trainee beyond that provided by doctrines, manuals and regulations. If the agent could gain knowledge by observing experts with real experience performing the task to be taught to the trainees, the implicit knowledge might be effectively captured. We refer the reader to Fernlund et al. [3] for details on how to build these expert agents using GenCL. Nevertheless, our approach is designed to work regardless of how these expert agents are built, as long as they are built on a context-driven paradigm.

Today, there are many support systems for AAR in military exercises. Some of them record the actions of all actors during an exercise that could be re-played and viewed by the instructors and actors in an AAR session. These AAR aids are important to the individual participant to gain a more complete view of his actions during the exercise [2]. Extending such a support system for AAR with expert agents can then serve as the basis for a more detailed as well as personal evaluation as a result of AAR-by-comparison. If the expert agent receives the same inputs as its assigned trainee, its resulting action could be played in the simulated environment of the AAR support system and the discrepancies between the behavior of the trainee and of the expert agent could be identified, viewed and logged.

AAR by Comparison

Teaching guidelines and doctrines to military trainees has its drawback in that it is unrealistic to expose the trainee to all possible scenarios or actions that can happen in combat. The solution space is infinite in that sense. There is often no specific correct action to take for a given situation. More realistic would be to have models of the expertise at hand against which to compare the trainee’s action.

Here we wish to establish a method whereby simulated expert agents experience the same situations, in a simulated environment, as does the human trainee in the simulated or real world military exercise. Drawing upon some of the basic tenets of Model-based Reasoning for equipment diagnosis, we can say that as long as the actions of the trainee agree with those of the agent, the trainee is considered to be performing correctly. However, upon observation of a discrepancy from the benchmark expert agent, the discrepancy is noted and logged if the discrepancy is determined to be of enough importance. Such a system could be regarded as an evaluation support system. If the system juxtaposes the performance of the expert agent with the environmental data apparent to the agent, it will give the trainee an excellent platform for self-evaluation and learning.

Discrepancies between the Trainee and the Expert Agent

There can be different types of discrepancies in training exercises between the trainee and the expert agent, and with different severity. If the trainee and the agent for some reason chose different paths (physical or tactical) at a decision point, the discrepancy might become large. However, if neither encounters problems along the way, the discrepancy may be unimportant. Conversely, very small discrepancies in performance might have severe implications. The two entities could behave almost identically but, one might expose itself to the opponent's firing line of sight and be destroyed. Such a small discrepancy may have been the result of two completely different tactics applied to the same situation. It could be the difference between *seek cover* and *attack*. Hence, the investigation of any discrepancies between the expert agent and the trainee needs to be investigated with some intelligence. Therefore, we regard a discrepancy to be of two different types (not mutually exclusive): 1) the position, movement or firing action of the trainee is significantly different from the agent's; 2) the context of the human trainee is different from that of the agent. The first is rather easy to determine by merely overlaying the locations and actions of the trainee and of the expert agent. However, given the many possible moves and micro decisions, this type of discrepancy is likely to be only a very coarse filter that will result in many logged discrepancies. Many of these discrepancies will turn out to be of little tactical consequence.

The second type of discrepancy (Contextual Discrepancy) is more significant but more difficult to discover. First of all, the modeling paradigm of the expert agent must support contextual knowledge representation. To make a useful comparison, the SmartAAR system must also be able to infer the context in which the trainee is currently operating. Inferring a trainee's intentions and the set of skills being used at the time of the comparison can provide a very useful means of reviewing his performance. The problem, of course, is how to infer the context in which the human is operating. One approach is to use a pattern matching technique that compares the trainee's action with that of the expert agent under various contexts simultaneously. The comparison that results in the closest match will indicate the context likely to be that of the trainee. This matching of patterns can be said to infer the context in which the trainee is operating. This is further described ahead.

It is our opinion that people in tactical situations behave in a context-based fashion. Several researchers in cognitive psychology promote models that are based on context-like structures, most notably Endsley [4] in her study of situational awareness, and Klein [5] in his recognition-primed decision making approach.

It is our assertion that the most important discrepancies between the expert agent and the trainee occur when they are in different contexts. While discrepancies in time and location may be common throughout an exercise, they may not always represent serious tactical misbehaviors. However, a discrepancy in the contexts of the expert agent and a trainee will nearly always be the result of inappropriate actions by the trainee and will also likely result in more future inappropriate actions. Hence, in order to facilitate this comparison, the modeling paradigm for the expert agent is context based.

When comparing the agent and the trainee, the expert agent executes in a simulated environment and acts upon the situation that the trainee encounters in the real world. Hence, the context model structure needs to be tailored for human behavior representation in simulated agents. This is fully in compliance with the way the expert agents are modeled according to the *Context-based Reasoning* (CxBR) behavior modeling paradigm. See Gonzalez and Ahlers 919980 for details on CxBR.

Summary and Conclusion of our Research

We propose an automatic self-evaluation approach called the SmartAAR technology suite that is applicable in military training, as well as in wide range of training and evaluation applications. The approach is able to detect both physical and contextual discrepancies between a trainee and an expert agent capable of acting as would an expert human performer. We refer to this approach as AAR-by-Comparison. Applying AAR-by-comparison could enhance the evaluation process and possibly be advantageous to more of the participants during an exercise. Giving each participant individualized feedback that focuses on their behavior by comparing it with an expert agent forms the basis for an automatic and self-instructing AAR. For training evaluation, the process of creating take-home packages or web portals can now be automated. This would also ease conducting AAR in exercises with actors in different locations (live, virtual or mixed).

We assert that contextual discrepancies can be detected by comparison. This can be done by inferring the trainee's context and comparing it to the expert agent's context. If we can infer the context of a trainee, we can also say something about his intent. The comparison between the expert agent's active context and the context of the trainee then becomes a comparison of their intentions. The detection of contextual discrepancies is an important feature of the SmartAAR system. The prerequisite in doing such a comparison is the use of a modeling technique, such as CxBR, that models the context of the agent.

By detecting both contextual and physical discrepancies at the same time, SmartAAR provides full feedback to the trainee. Furthermore, by analyzing the contextual and physical discrepancies together, it could be possible to consolidate a number of discrepancies because it is likely that they correlate with each other. This correlation is left for future research, however.

We emphasize that the SmartAAR system is not a tutoring system that tells the trainee what to do or grades him in any way. It would be a risky to assume that the trainee and the expert agent at any moment would interpret the situation in the same manner (because of different inputs, view angles, assumptions, misinterpretations, stress, etc.). The SmartAAR system is a support system for self-evaluation that can help the trainee to make better evaluations of his behavior during the exercise. In this manner, the system fits, supports and enhances the way AAR is conducted today [2].

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