Designing Intelligence Augmentation System with a Semiotic-Oriented Software Development Process

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Abstract

In this paper, the authors describe the first steps of a semiotic-oriented software development process called "Brainmerge" [1], and present a case study where the process is used to coordinate the steps required for the design of a locomotive and car assignment system, modeled as an Intelligence Augmentation Systems (IAS). IAS represent an extension of Decision Support Systems (DSS) [2] with the use of Peircean semiotics [4], intelligence augmentation techniques [3], computational agents [5] and usually dynamic decision making processes (DDMP). IAS are suitable for DDMP. Traditional software methodologies are usually inefficient when dealing with IAS, and our methodology aims at fulfilling these shortcomings. This work considers the resolution of a real world problem of tactical planning in railroads where such DDMP play a key role.

1. Introduction

Intelligence Augmentation Systems, which have their genesis in Decision Support Systems (DSS) [2], are computational systems performing some sort of intelligent decision making based on the cooperation provided by an ongoing dialogue between a human user and a computer system. The main result is that the final decision making is not provided neither by the human being nor by the computer, but is an evolutionary offspring of the collaboration of the two of them. This cooperation results in the augmentation of human intelligence by means of a computational processing power applied to specific points in the human thought process which suffer from some sort of flaw or inefficiency, leaving the human free to concentrate on other parts of the process and therefore augmenting his intellect [3]. Traditional software development processes (using traditional techniques like "use cases") are not suitable for the construction of such a system, because they do not consider how decision making is achieved, in terms of human thought processes and how a computer system may help in improving the intelligence of such decision making. This is an interesting differential of our proposal. IAS are suitable to be applied in dynamic decision making environments, where an optimization system cannot do the job of finding a solution to the problem without the cooperation of human agents in the loop. The motivation for developing a process for constructing IAS comes from the fact that it is very difficult to build software systems that have success in being applied to these dynamic environments that represent most real world problems.

"Brainwares" constitute the engines of IAS. A "brainware" is a kind of software which performs a "simile" of a mental process which would be helpful for a human being in the process of intelligent decision making. Examples of "brainware" may include techniques like fuzzy systems, neural networks, evolutionary computation, expert systems or even optimization algorithms whether they are applied in order to reproduce some sort of cognitive task. IAS have computational

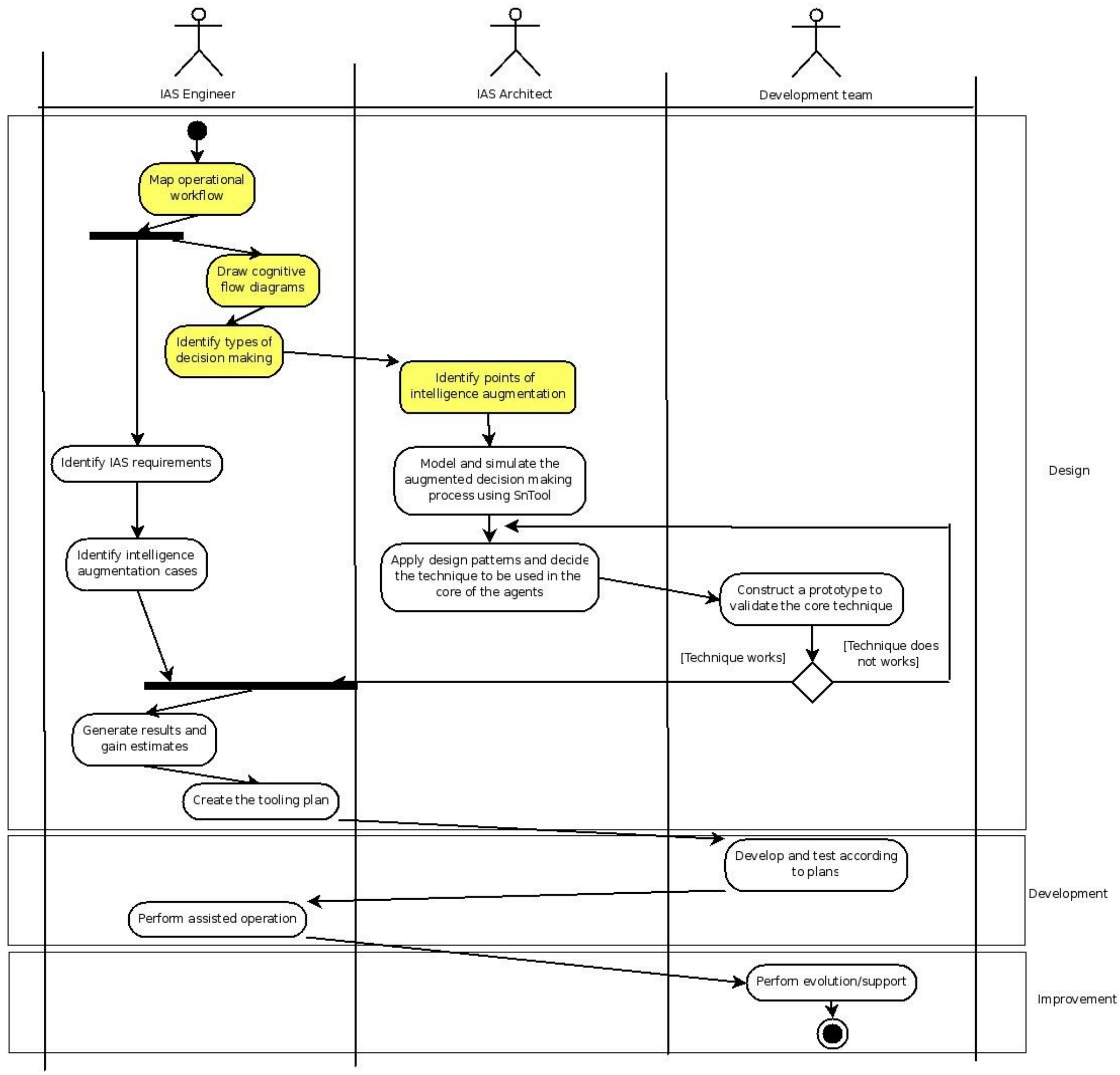

Figure 1: Steps of Brainmerge. The steps highlighted are the ones addressed in this work.

agents [5] designed to perform some of the cognitive tasks that human agents do not perform well in the decision making process. These agents carry brainwares in order to be able to do so. The use of agents is important since intelligence augmentation has to be continuous through the process. The answers found by the computational agents can therefore be confronted with the ones found by the human agents, so the final answer will be the best one or possibly a merge of both of them. To detect and treat the required brainware points within an IAS, we developed "Brainmerge", a software development process based on a Peircean semiotics theory on how thoughts are performed in the decision making processes.

The contribution of this work is meant to be in the software engineering techniques, not in the optimization and soft computing techniques used as brainwares in the agents, and also not in the development of multi-agent systems protocols of communication, techniques of cooperation, negotiation or optimization, even though these techniques play an important role in the success of IAS.

2. Brainmerge: concepts and foundation

Brainmerge was developed to coordinate the specification of IAS requirements and architecture, being complemented by traditional development processes and advanced techniques of assisted operation and support/evolution. Traditional techniques such as use cases and UML diagrams are not thrown away: they are still necessary, but not sufficient. The methodology used to develop IAS should be a hybrid of Brainmerge and a traditional development process considered appropriate.

In Figure 1, we show a diagram with all the steps of the methodology. The steps highlighted are the ones addressed in this work, necessary to model how the decision making is achieved, in terms of human thought processes. From this model, it will be possible to identify the points of the process where intelligence need to be augmented.

After mapping the operational workflow (traditional business model), there is a need to represent how decision making is achieved in terms of human thought processes. This task is accomplished by drawing the cognitive flow diagram (CFD). The CFD is a special kind of diagram developed to model human cognitive processes in searching for a solution to the problem focused. The objectives are first to understand and model the right sequence of cognitive activities and second to find among the activities represented the ones that may be performed by the IAS. These activities will be marked as points of intelligence augmentation, where the agents will be performing the action and dialoguing with the user to provide the information needed in that point of the process to keep going towards the solution. The CFD takes advantage of semiotic concepts in order to represent the cognitive activities and classify them. The concept of sign, as defined by Peirce, is central here, as the basic units of thought in the diagram are Peircean signs. This diagram is one of the original differentials of Brainmerge.

The visual elements of the CFD are alike the ones used in an UML activity diagram, but with a different semantics. In Figure 2, we detail the main elements in a CFD.

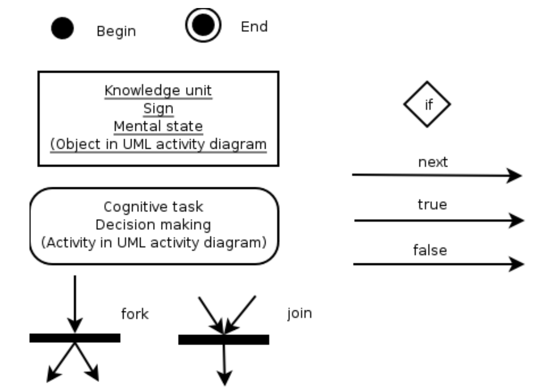

Figure 2: Components of a CFD

According to Peirce's theory, there are three categories on which cognitive tasks can be classified:

- Monadic tasks (firstness): random tasks. The generation of the first population of solutions in a GA is a monadic task. A random choice between many alternatives is also put in this set.
- Dyadic tasks (secondness): deterministic (mechanical) tasks. They consider only present information, without any estimation of future states. These can be efficient decision making processes, but are based on specific rules to be simply followed. The main activity performed by a case based reasoning system or an artificial neural network is dyadic.
- Triadic tasks (thirdness): tasks in which future state estimation is used, usually based on the formulation of a goal, plan or prediction to be achieved. These are called intelligent tasks (following Peirce). Optimization algorithms such as graph search or tabu search represent triadic processes.

After classifying the cognitive tasks in monadic, dyadic and triadic, the points of the cognitive process where intelligence augmentation is needed will be defined.

The points of intelligence augmentation are chosen in the regions of the triadic activities.

In the following section, we present Brainmerge being applied to a real world problem: locomotive and car assignment in railroads, also called railroad tactical planning. The design is based in a real case experienced in a Brazilian railroad company.

3. Case study – Railroad Tactical Planner

Railroad systems present themselves in the context of decision support as an extraordinary rich platform to different kinds of applications in different levels of decision making, specially due to the magnificent diversity and complexity of the problems, presenting a dynamic decision making environment. However, to correctly explore optimization algorithms in this scenario, it is mandatory to use the correct philosophy of decision supporting, so the tools built can be used effectively and efficiently.

The first step of Brainmerge, which corresponds to the mapping of the operational workflow, aims at analyzing human agents performing the decision making process which we want to support with the intelligence augmentation system and mapping the information flow of the process.

The tactical planning area is surrounded by other areas which provide important input data for it and which receive the outputs of it: the sells and strategical plans (provide inputs), the yards and centralized traffic control (receive the output). Another important input from the strategical planning area is the trains schedule, which is a table naming all the trains that exist in a day. The last inputs needed are the state and position of locomotive and cars and the state of the yards, provided by an external system, usually a database control system of the railroad.

Having the inputs needed, the locomotive assignment area will decide to assign each locomotive to a train from the train schedule, composing the train activities plan (TAP) with the locomotive's activities. Note that there is more than just attach and detach locomotives to the trains. The human agents solving the problem need to be aware of fuel supplying and crew changing. After these decisions are made, we have the beginning of the TAP, which will be an input to the car assignment.

The car assignment area is divided into groups of human agents. Their decisions will be considered as specifications of cars movements. These specifications will tell which group of cars will go from one place to another with specific departure and arrival times. As the work is done separately, there may exist conflicts between the decisions. These conflicts are found by another group of human agents, here named responsible for the trains' birth. If they find a conflict, they will ask for the car assignment area to solve it. The human agents in the car assignment area will go through a negotiation process to decide the priority of the movements. Once the conflicts are solved, the agents responsible for the trains' birth are able to write down the final TAP, that will be outputs of the process. The yards and the centralized traffic units will be responsible later to provide actives (locomotives, freight cars, crew, etc) to perform the plans.

The main objectives of this tactical planning are the followings:

1. Maximize the meeting of the client's demand;
2. Minimize the cost of the cars movements;
3. Minimize the delay in the trains' births and departures;
4. Adherence to the train's schedule;
5. Minimize the use of locomotives to meet the demand;
6. Adherence to the plan of locomotive's maintenance.

Many problems appear when the human agents are making decision, and much more after the plans are made, what leads to a strange situation: the human agents spend more time fixing their plans to stay

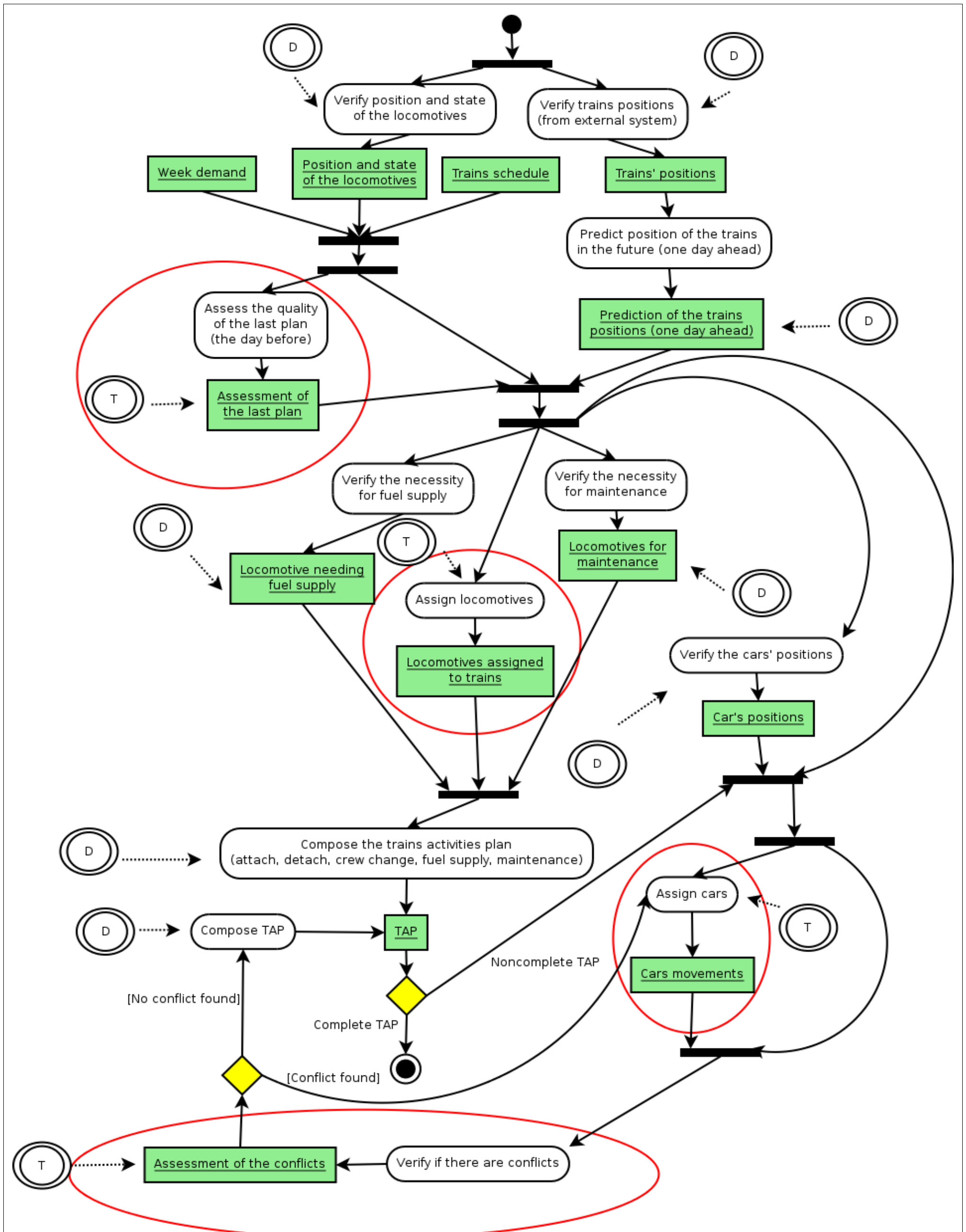

Figure 3: Railroad tactical planning cognitive flow diagram

updated with information coming from the real world than actually planning and thinking of better solutions to the problems.

No optimization algorithm is capable of finding the optimal solution to be used in this case.

What is needed is an IAS capable of augmenting human intellect in the points where the activities towards a solution are inefficient and providing a way for the team formed by the locomotive assignment group, car assignment group, train's birth group and the IAS to find a solution as good as they can in less time for the railroad, facilitating the communication between the parts involved, providing optimization answers and relevant data in the right time, dealing with imprecise information and negotiating the solutions with other agents. In other words, even though the IAS will use optimization algorithms and soft computing techniques, it will be meant to be a tool of intelligence augmentation of the planners, instead of trying to put everything inside an optimization system which will substitute the planner and find a solution intending to be optimal to the problem by itself. In order for the system to do so, it would have to embody a cognitive capacity similar to all human agents that participate in the process and also have access to the information they have, what seems to be very hard, not to say impossible.

A CFD was developed in order to complement the understanding of the problem in terms of human thought processes. It is presented in figure 3.

The next step of the methodology is to classify the activities in monadic, dyadic or triadic cognitive tasks. They are represented respectively by the letters M, D and T in the diagram in Figure 3.

After classifying the activities, the points of intelligence augmentation are marked. In this case, we found four points of intelligence augmentation, around the triadic (intelligent) cognitive tasks. brainwares will perform these tasks and suggest a solution to these activities that will be confronted and negotiated with the solution provided by the human planners.

In the next step of the methodology, modeling and simulating the work of the computational agents will help design different kind of agents with different skills for each of the spots marked as intelligence augmentation points. The human agents operating the system will be able to criticize the solutions found by the computational agents by inserting mandatory movements.

The brainwares carried by these agents will be chosen among traditional and sophisticated optimization and soft computing techniques. A prototype is used to validate that the brainwares are capable of performing the tasks,.

This and other steps of Brainmerge will be addressed in future work.

4. Conclusions

Brainmerge is an original software development process to build IAS. We believe that the semiotic-oriented framework used to model how decision making is achieved, in terms of human thought processes, represents a new paradigm for software development processes suitable for the specification of a system that aims to augment human intellect performing some cognitive tasks. The concepts of brainware and the CFD are very relevant in this sense. Brainmerge have been used with success in other applications, such as the one shown in [1].

The development of a methodology to build IAS brings maturity and trust to the field, being an important motivation to attack real applications and achieve gains in many sectors of the economy, in operational, tactical and strategical levels.

5. References

[1] – A. Paraense, R. Gudwin, and R. Gonçalves, “Brainmerge: a Semiotic-Oriented Software Development Process for Intelligence Augmentation Systems”, Integration of Knowledge Intensive Multi-Agent Systems KIMAS '07: Modeling, EVOLUTION and Engineering April 29 – May 3, 2007 Waltham, Massachusetts.

[2] – J.P. Shim, et al, “Past, present and future of decision support technology”, Elsevier, Decision Support Systems 33 (2002) 111-126.

[3] – D. C. Engelbart, “AUGMENTING HUMAN INTELLECT: A Conceptual Framework”, Summary report.

[4] – Joseph Ransdell, "The Relevance of Peircean Semiotic to Computational Intelligence Augmentation". SEED Journal (Semiotics, Evolution, Energy, and Development), Volume 3, No. 3, 2003

[5] - S Franklin, A Graesser, “Is it an Agent, or Just a Program?: A Taxonomy for Autonomous Agents”. Proceedings of the Workshop on Intelligent Agents III, Agent Theories, Architectures, and Languages, Budapest, Hungary, 1996.