Believable Decision Making in Large Scale Open World Games for Ambient Characters

Evaluation of Ph.D. thesis by Tomáš Plch

Evaluation by: Michal Čertický

Thesis presented by Mr. Plch is closely related to his experience as lead game AI designer in Warhorse Studios, where the results of his research were successfully applied. There are five main contributions present in this work: First, the author introduced co-called Stateful Behavior Trees – an extension of the “behavior trees” method and a language that can be used to express and implement them. These SBTs constitute a part of three-tiered architecture of non-player characters (NPCs) for the open-world computer games. Next, the author introduces his concepts of intelligent environment and smart constructs, which provide a means for the NPCs to interact with the virtual game world. Finally, the author proposes a specific semantic network to represent the relations between numerous entities within the world.

In my review, I will first comment on several parts of presented text and present my conclusions after that. My comments contain a few questions which the author should address during his defense (the questions are highlighted and numbered for easy reference).

In section 1.1, the author writes about the problem of Uncanny Valley. While I found the section quite interesting, it is hard to believe that this problem is the real motivation behind the his research. Believability of NPCs is still not at the “uncanny valley” levels and it's not their behavior that's holding it back the most.

Section 1.2 is written like a marketing pitch more than an academic publication.

[Question 1] How does this thesis relate to population models and non-game modeling or simulation in general? Specifically, activity-based multi-agent models seem to be quite relevant, since they also generate daily plans of synthetic agents, composed of activities like "work", "sleep", etc.

Section 1.4 presents five goals of the thesis. Since no metrics are proposed, it's not possible to conclusively decide whether they've been accomplished or not (the text only says they need to reach the "production grade quality").

Section 2.2 introduces the formalisms used to represent the world states and actions. There are many different ways to represent this kind of knowledge and I feel like they should be mentioned. In addition to countless logic-based languages and formalisms, there are also others like MDPs etc. Also, further subsections about deliberative action selection or planning should contain more exhaustive and up-to-date overview.

I would prefer more emphasis on the work related to artificial intelligence, planning and knowledge representation in chapter 2 - possibly at the expense of design
patterns and industry examples. Subsections discussing common design patterns and problems in game design, seem to be unnecessarily exhaustive and detailed for the thesis with “Theoretical Computer Science” specialization (but that might just be my subjective opinion).

- Chapter 4 introduces what I consider the most important contribution: author's language for behavior description called Stateful Behavior Tree (SBT). I would expect a Ph.D. thesis in Theoretical CS to contain a proof of some formal properties of any new language. There aren't any proofs present in the text – but I'm not sure if it's considered a problem at this department.

- From a technical perspective, the concept of SBT and their usage is well-thought out to the lowest level. The author wrote about everything, including parallelism, budgeting, data storage and messaging, synchronization, etc. The thesis is quite detailed here and presented SBTs can be a significant contribution. This leads us to a question: **[Question 2]** Is author's SBT implementation available for the research community or for the game industry? If it isn't, and if there are no formal results presented here, can the thesis be viewed just as a technical report describing a proprietary software?

- Chapter 5 provides an overview of the NPC’s higher-level decision making mechanism that was used in a game the author was working on. I suspect that there are many alternatives to this approach - if not in AAA games, at least in the game AI research publications. There is also a big number of published results related to very similar problem of “activity-based modeling”. The thesis should compare the author's approach to these alternatives more extensively than it does.

- In chapter 6, I particularly like the notion of behavior injection in context of SBTs and the concept of “intelligent environment” areas. They both seem useful end elegant and are explained well.

- Chapter 7 describes so-called Relation Knowledge Network - a semantic network used to annotate the virtual world. It is definitely a good idea to apply this to open-world RPG game. The network and its use are described well, using comprehensive in-game examples. However, a lot of research on semantic networks exists and this approach is not connected to any of it. It's unclear how author's approach fits among the related work on semantic networks.

- Chapter 8, entitled “Evaluation” studies the author's approach from usability standpoint.
  - First of all, author proposed two specific scenarios and had his colleagues in Warhorse Studios implement them using the SBT approach and two older variants of behavior trees. He shows that SBT allows for more manageable implementation. There are no metrics presented here, but that's understandable. However, the author hand-crafted the scenarios himself, instead of using some existing scenarios that have successfully been realized by behavior trees in the past. This only tries to confirm that SBT is more expressive than common behavior tree, which is not at all surprising - it's an extension of it.
  - Next, the author tested his SBT implementation on several in-game scenarios and measured the computation times. It's hard to conclude much from this, since the times are not compared to any alternatives. One possible conclusion is that the implementation can indeed be successfully applied in a commercial game.
  - Additionally, a usability analysis was performed with a small group of 6 people, in order to find out how easy it is to use SBT compared to another method proposed by Mr. Plch in the past - "smart areas".
  - Author also briefly describes how his methods are used by Warhorse Studios and talks about his experience from the interviews with selected Warhorse Studios developers.
[Question 3] Could the SBT be used to easily write an autonomous player character that would finish the KCD game?

Final critique and conclusions:

My first concern is that the connection between the thesis and the alternative approaches and results is missing at a few places.

Second drawback is the lack of validation of the resulting NPC behavior. I realize that the research contribution lies in the underlying tools and methods, not the actual game, but it's a common practice to evaluate the quality of modeling tools by demonstrating their ability to produce valid models. In this case, the presented methods are designed to produce realistic behavior of NPCs. This in fact sounds a lot like behavior modeling. The resulting behavior should therefore be statistically validated against real-world data, or at least against some other existing model.

Also, as I already hinted in my 2nd question, the author might have emphasized a little bit more how his results help anyone who is not an employee of Warhorse Studios. After all, the transfer of knowledge should be the motivation behind any research publication.

However, despite these drawbacks, the author has clearly done a great deal of non-trivial work and there is no doubt that his methods can be (and already are) directly applied in the industry, which is positive and rare. Therefore, I recommend accepting this thesis and awarding the author a title of doctor of philosophy (Ph.D.).

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