Opponent's review of the dissertation thesis

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Title:	Reducing Complexity of AI in Open-World Games by Combining Search-based and Reactive Techniques
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In the work entitled Reducing Complexity of AI in Open-World Games by Combining Search-based and Reactive Techniques the author describes three contributions to the field of AI in computer games. One of them is the introduction of behavior objects – a development tool for easier creation of ambient intelligence in games, the other two introduce classical artificial intelligence tools, namely CSP and adversarial search to the field of game AI.

Overall, the work is written in a good English and is quite easy to follow. All decisions made are well explained. The contributions are discussed from various points of view. One of the strongest arguments for the usability of the presented ideas is their implementation in the game Kingdom Come: Deliverance.

The behavior objects (BO) are described in Chapter 5. They are a generalization of the smart objects and present a way to allow for easier implementation of more complicated AI in games by moving parts of the AI to the environment. In this way, the code for some common parts of AI (like behavior in a pub) does not have to be duplicated in each NPC in the game. Moreover, the behavior object allow for relatively simple synchronization of multiple NPCs in order to create a more complex behavior. The BOs allow the developers to create more complex ambient AI in games while keeping the code-maintenance simple. I really like the discussion on the subject with the focus on practical problems encountered in the development.

Chapter 6 presents a way to use CSP in the game in order to find NPCs to play certain scenarios (like group dancing) in the game. The results show that CSP can indeed be simply used in this way. The most interesting part in my opinion is the evaluation of various CSP techniques which can be practically used in game development with strict time restrictions. The results indicate that for the specific problems encountered in the game, faster (and simpler) CSP methods actually can work better than more complex ones.

Finally, Chapter 7 describes the use of standard AI techniques (alpha-beta and Monte-Carlo Tree Search) as a way to create combat AI in games. The search is performed on a simplified model of the combat mechanics from the game and the results show that the AI techniques can actually be applied in this scenario. The main problem, as the author states, is with the maintenance of the model which adds some development effort. Artificial intelligence in such complicated environment is indeed a difficult task. In this case it is even more complicated by the fact that the AI must run in real time. I find it really interesting that the proposed methods are able to defeat the scripted AI which is actually implemented in the game, and I believe this is a very nice result not only in game AI but also in AI in general.

All the proposed methods are rigorously tested and evaluated. I really like the fact that the author made interviews with developers and players which show the applicability of the results from a more practical point of view. The author is well aware of the limitations of the methods he proposed and provide ideas how to overcome them. The methods provide valuable contribution

for game AI development. The BOs allow for easier implementation of ambient AI in games. The other two techniques introduce the methods from classical AI to games and provide the possibility of further research in the area.

I have only a few questions for the discussion:

1. The behavior objects described in Chapter 5 are used mainly for ambient intelligence. I wonder, if it would be possible to use them also e.g. for combat intelligence, in such a way that the player is able to use objects from the environment (e.g. a chair in a pub brawl) during combat. What are the main limitations of BOs in this context?

2. The formulation of the CSPs mentioned in the work are quite special in the sense that they use mostly unary and binary constraints. Is this a limitation for the developers or can most situations in the game be naturally expressed mostly with these types of constraints?

3. The model used in the adversarial search is quite simple. You also mention the problem with the extraction of the model from the actual game engine. My question is: would it not be easier to extract a more complicated model, which is more similar to the game? It seems that the search would be viable even if the evaluation was an order of magnitude slower than it is now. And a related question: do you have any idea how much slower the evaluation is, if the full combat model from the game is used (possibly without animations and other non-essential stuff)? Would it even be possible to use it?

The author proved in his thesis he is capable of high quality independent scientific work. Based on this and the reasons above, I recommend the work for defense and I believe Martin Černý should be awarded the Ph.D. degree.

In Prague August 5, 2016. Martin Pilát, opponent