

I. IDENTIFICATION DATA

Thesis name:	Artificial Intelligence Methods for Playing Collectible Card Games
Author's name:	Patrik Brezina
Type of thesis :	<input type="text"/>
Faculty/Institute:	<input type="text"/>
Department:	Department of Graphics and Interaction
Thesis reviewer:	Lasse Blaauwbroek
Reviewer's department:	Czech Institute for Informatics Robotics and Cybernetics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment	<input type="text"/>
<i>Evaluation of thesis difficulty of assignment.</i>	
The assignment poses an open ended question of exploring Machine Learning methods to play card games. This can be approached from many angles and is a difficult problem.	

Satisfaction of assignment	<input type="text"/>
<i>Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.</i>	
The student has implemented several variations of MCTS and designed an experiment to evaluate the algorithms. The algorithms are appropriate and it appears that they work. The new players are able to convincingly defeat some of the built-in players in certain conditions. This is not consistently the case, and some of the built-in players seem consistently stronger. However, it cannot be expected that a completely optimized player is created in the timespan of a bachelor thesis. The Neural Network used to evaluate a players position does not appear to be very effective and could have used some more work.	

Method of conception	<input type="text"/>
<i>Assess that student has chosen correct approach or solution methods.</i>	
All of the methods used by the student are based on variations of Monte Carlo Tree Search extended with some other methods such as Neural Networks. MTCS is applicable to this problem, especially given the resent results from DeepMind. Other methods could conceivably also have been used, but this is certainly a good approach.	

Technical level	<input type="text"/>
<i>Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.</i>	
The student has gained general knowledge about ML for games. Specifically for the card games the student has learned how to apply MCTS and with a number of modifications such as neural networks. I am unable to evaluate the code itself, since I do not know which code was written by the student. The experiments carried out are interesting and although the results are not always the best, the student is able to give a believable explanation them.	

Formal and language level, scope of thesis	<input type="text"/>
<i>Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.</i>	
The thesis organization is good. It provides a good narrative of the problem to be solved. The flow of the text from paragraph to paragraph and section to section is decent. I question why there is such a detailed description of the rules of Hearthstone, especially since most of those rules are not referenced later. Tables and Figures are satisfactory, but it is not possible to interpret them only	

from their captions. The reader needs to refer to the surrounding text to find out what numbers and axes mean. The pseudocode is readable, but only is one is familiar with Java-like programming syntax. The biggest problem with the text is basic grammar. Although a couple of typo's here and there are not a problem, grammatical errors occur very frequently and basic mistakes are made repeatedly. This is a problem because it disrupts the flow of reading and becomes a major source of distraction for the reader. The overall look of the thesis is acceptable but not outstanding.

Selection of sources, citation correctness

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

The thesis contains a description of the Machine Learning techniques used in this work, such as MCTS, Neural Networks and Chance Event Bucketing. These descriptions are informative but not entirely complete. This is especially true for the Neural Networks section. What is missing from the thesis is a survey of the broader ML-techniques that were not employed by the student, or the existing Hearthstone AI's. It would be good to have an overview of these techniques and wether or not they are applicable to Hearthstone. The work contains a sufficient amount of citations, but no abundance. However, the bibliography is not very consistent. For example, just a link is not a proper citation. Additionally, references for published works are not always complete.

The student has implemented several algorithms himself. However, this has been done withing the framework of Metastone. In addition, for some parts of the implementation existing code was reused. It is not entirely clear how much the student needed to implement himself and how much was provided by Metastone and other code. I was unable to find any guide to the provided source code. Therefore, I was not able to inspect the code written by the student and was also unable to run his code.

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

Please insert your commentary (voluntary evaluation).

**III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION
SUGGESTION**

Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.

Some decent work has been done in this thesis, although it is difficult for me to assess how much programming work this actually entailed, and how much was off the shelf. The results are reasonable but not revolutionary. The thesis text contains most but not all needed information. The presentation of the thesis is acceptable, but the text itself leaves a lot to be desired. This translates into a recommendation of C - good.

Questions:

- In the Game State Value player, how does the threat based heuristic work and how is it converted into a score for actions?*
- Can you explain how the UCB formula is derived, or why it has this form?*
- What activation function was used for the Neural Network and why?*
- How does the backpropagation of the result of a rollout to visited nodes work?*
- The Chance Bucketing groups drew cards based on their manacost. What is the reason for this grouping, and why is it more appropriate than another grouping?*
- For the parameter optimization of Vanilla MCTS three parameters need to be optimized. They are all optimized separately. Is there a reason to assume that these parameters are independent? When optimizing the parameters, the other parameters are fixed with some value. How did you arrive at those values? Would it not be more appropriate to perform a grid search of some sort?*
- How do your players decide to end their move? Do they just keep playing until they run out of mana?*

I evaluate handed thesis with classification grade

Date: 07-06-2019

Signature: