

# Enhancements for Monte Carlo Tree Search in The Mario AI Framework

Emil Juul Jacobsen  
ejuu@itu.dk

Rasmus Greve  
ragr@itu.dk

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## Abstract

(Bare copy/paste-ish fra projektbasen, skal skrives om!) In this experiment we explore different implementations and enhancements of the Monte Carlo Tree Search algorithm for an AI, in order to evaluate their performance and results in the Super Mario AI Benchmark tool. We have implemented the basic MCTS algorithm in the Mario AI Framework and characterised the performance and identification of the strengths and weaknesses of the algorithm relative to the framework. We have identified a set of refinements and alterations of the algorithm and through implementation and evaluation of these individually we came up with compositions that greatly increase the performance of the AI.

## **1 Introduction**

In this experiment we explore different implementations and enhancements of the Monte Carlo Tree Search (MCTS) algorithm for an AI, in order to evaluate their performance and results in the Super Mario AI Benchmark tool. The MCTS algorithm has shown great results in various classical board games but has (to our knowledge) not been tested on a real-time physics-based game like Super Mario. Like some of the games that MCTS has proven effective in, Super Mario has a great branching factor of the state space but differs in that simulating actions is quite computationally heavy. These differences make several modifications of the core algorithm interesting for our experiment because they can help build the tree in a manner that uses the simulations more effectively.

## 2 Background

### 2.1 Monte Carlo Tree Search

Monte Carlo Tree Search has shown surprisingly good results in solving problems with large branching factors. MCTS is a tree search algorithm, where evaluation of a node is done by random sampling in the decision space until an outcome can be determined. A very nice quality of MCTS is that it is an *anytime* algorithm, meaning that it can be halted when a time budget is reached and give the result that looks the most promising at the given time. Furthermore it often requires no or very little domain knowledge as a naïve implementation only require knowledge of the action space and a means of simulating the outcome of an action.

### 2.2 Upper Confidence Bounds for Trees

Choosing which node to expand can be done in multiple ways. Upper Confidence Bound (UCB) is a bandit based approach to choosing the most urgent node to expand. The quality with UCB is that it allows for prioritizing between exploration of less tried nodes, and exploitation of seemingly promising nodes. **OBS! Præcis hvilken ligning skal vi skrive her????**

$$UCB_j = \bar{X}_j + \sqrt{\frac{2 * \log(n)}{n_j}} \quad (1)$$

Here  $\bar{X}_j$  is the average (i.e. expected) reward.  $n$  is the total number of plays and  $n_j$  is the number of times action  $j$  was tried. Since the exploration term of the equation depends on how explored the node is compared to the parent, the confidence in a node will increase steadily until the node is eventually explored. The exploitation term will, however, make sure that good nodes will be explored more frequently than less promising ones.

### 2.3 The Mario AI Framework

The Super Mario implementation we use to test our enhancements in, is a framework

### 2.4 Foundation

Vi tager simulationen fra Baumgarten

## 3 Approach and Enhancements

In this section we will go over the different implementations and enhancements that we have experimented with. For enhancements including a value that can be tweaked we have tried finding the optimal setting, and in the end we have combined enhancements which complement each other well.

### 3.1 Monte Carlo Tree Search with UCB

#### 3.1.1 Description

To have a baseline for comparison and an implementation to build on, we started by implementing the basic Monte Carlo Tree Search algorithm with Upper Confidence Bounds for selection of nodes. Source [1]

#### 3.1.2 Implementation

#### 3.1.3 Behaviour

### 3.2 Domain knowledge

While MCTS on it's own does show some intelligent behaviour, we felt like we had to introduce some domain knowledge to the algorithm to make it perform better. Otherwise most of the enhancements to make wouldn't really show much difference, as it in any case would lead to quite a large amount of random behaviour.

#### 3.2.1 Description

**Down button** The absolute first piece of domain knowledge that we introduced was to remove the possibility of pressing the down arrow making Mario duck. In a very few cases it indeed does make sense to duck - under a bullet or a flying monster - but while it can be of use, it also doubles the action space from 16 to 32 possible actions which reduces the reachable depth significantly. Another important factor that made us disable the down button was that while the down button is pressed, pressing left or right does not make Mario move.

**Specific actions** Blablabla om specifikke actions

**Hole Detection** Blablabla om hole detection

#### 3.2.2 Implementation

**Down button and specific actions** Blablabla om specifikke actions

**Hole detection** Blablabla om hole detection

#### 3.2.3 Behaviour

**Down button and specific actions** Blablabla om specifikke actions

**Hole detection** Blablabla om hole detection

### 3.3 Softmax Backup

#### 3.3.1 Description

$$exploitation = Q * maxReward + (1 - Q) * averageReward \quad (2)$$

We use equation 2 to calculate the exploration part for the confidence of nodes

#### 3.3.2 Implementation

#### 3.3.3 Behaviour

### 3.4 Macro actions

[3]

#### 3.4.1 Description

#### 3.4.2 Implementation

#### 3.4.3 Behaviour

### 3.5 Heuristic Partial Tree Expansion Policy

#### 3.5.1 Description

#### 3.5.2 Implementation

#### 3.5.3 Behaviour

### 3.6 Checkpoints

#### 3.6.1 Description

#### 3.6.2 Implementation

#### 3.6.3 Behaviour

### 3.7 (Combination)

#### 3.7.1 Description

#### 3.7.2 Implementation

#### 3.7.3 Behaviour

## 4 Results

Method	Score
Softmax backup $q = 0$ (UCT)	34,162
Softmax backup $q = \frac{1}{8}$	-
Softmax backup $q = \frac{1}{4}$	34,387
Softmax backup $q = \frac{1}{2}$	34,147
Softmax backup $q = 1$ (Max)	26,842

Table 1: Results of using Softmax backup with different  $q$  values

Method	Avg. number of nodes	Score
MCTS w/ UCT, limit = 0	-	-
MCTS w/ UCT, limit = 1	-	-
MCTS w/ UCT, limit = 2	-	-
MCTS w/ UCT, limit = 4	-	-
MCTS w/ UCT, limit = 8	-	-
MCTS w/ UCT, limit = 16	-	-
MCTS w/ UCT, limit = $\infty$	-	-

Table 2: Results of using UCT with a different limit for random moves

Her er noget mere tekst, reference til figur 1

Method	Score
MCTS w/ UCT, $cp = 0$	-
MCTS w/ UCT, $cp = \frac{1.5}{8}$	-
MCTS w/ UCT, $cp = \frac{1}{4}$	-
MCTS w/ UCT, $cp = \frac{1}{3}$	-
MCTS w/ UCT, $cp = \frac{1}{2}$	-
MCTS w/ UCT, $cp = \frac{1}{\sqrt{2}}$	-
MCTS w/ UCT, $cp = 2$	-
MCTS w/ UCT, $cp = 5$	-
MCTS w/ UCT, $cp = 10$	-

Table 3: Results of using UCT with different weight between exploration and exploitation



Figure 1: Mario being followed

## **5 Conclusion**



## References

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