



**KTH Computer Science
and Communication**

Strategies in Hive Strategier i Hive

An AI based comparison of various strategies
En AI-baserade jämförelse av olika strategier

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Abstract

There are many strategies in Hive focusing on different points of the game. To win, a good strategy is needed and in order to develop a good strategy, a wide understanding of the game is required. This project explores the components involved in Hive strategy and resulted in a comparison of an offensive and a defensive strategy by creating an AI and letting it play the game against itself using the two strategies with small modifications. Due to the nature of the game and limitations in the AI, the majority of the games played resulted in a draw. Out of 48 games played, the defensive strategy won four and the offensive only one. The results show that the defensive strategy developed for this project is superior to the offensive one. This also shows that to break a defensive strategy such as circling, it is required to plan many moves ahead.

Referat

Det finns många strategier i Hive som fokuserar på olika punkter inom spelet. För att vinna behövs en bra strategi, och för att kunna utveckla en bra strategi så behövs bred förståelse av spelet. Detta projekt utforskar de olika delar som är involverade inom Hive-strategi och resulterade i en jämförelse av en offensiv och en defensiv strategi genom skapandet av ett AI som sedan sattes att spela mot sig själv given de två strategierna med ett fåtal modifikationer. Till följd av spelets uppbyggnad samt begränsningar i AI:t så resulterade majoriteten av matcherna i oavgjort. Den defensiva strategin vann fyra av matcherna och den offensiva en utav de 48 spelade. Resultatet visar att den defensiva strategin utvecklad för det här projektet är överlägsen den mer offensiva strategin. Detta visar också att för att besegra en defensivt fokuserad strategi, såsom skapandet av cirklar, så måste man planera många steg framåt.

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Chapter 1

Introduction

1.1 Hive

Hive is a turn based strategy board game designed for two players, one white and one black. The game is very similar to chess, except that it is played on a hexagonal limitless grid. The players goal throughout the game is to surround their opponent's queen, to do so the player has eleven pieces to his or her disposal. Each piece in the game is named after a certain kind of insect or arachnoid and, like in chess, their moveset depends on their kind. The different kinds of pieces are the Beetle, the Spider, the Grasshopper, the Soldier Ant and the Queen Bee. Two other kind of pieces have been introduced in expansions to the original game but only the five original pieces have been implemented in the case of this report. Unlike in chess, the players start with all their pieces in their hand and have to place them on the board as time goes on, the players can also choose to move their pieces anywhere they want according to their movesets. The game continues until one of the players Queen Bee is completely surrounded¹. If both players are forced to repeat the same moves without any possibility of resolving the stalemate, the game is considered a draw. Each player has one Queen, two Beetles, two Grasshoppers, three Spiders and three Ants. Other pieces exist as expansions to the original game, but they have been ignored for the sake of time constraints for this report.

1.2 Rules of the game

Basic rules - Players take turns placing new pieces or moving pieces already on the board. The pieces on the board make up the hive, and the One Hive Rule states that all pieces always have to stay connected. The game is won when the opposing Queen is completely surrounded. If a player is unable to place or move they will have to forfeit their turn.

¹J. Yianni, Hive: a Game Buzzing With Possibilities, Gen42, http://www.gen42.com/downloads/rules/Hive_Rules.pdf, 2010.

1.2.1 Placement

Pieces may only be placed next to those of the same colour with the exception of the first ones placed during the players first turns. The Queen may not be placed on the first turn, but must be on the board by the fourth.

1.2.2 Movement

The players may not move any of their pieces until their respective Queen is on the board. The pieces may move next to any piece on the board as long as they move in a sliding movement which means that they have to be able to physically move to the hex for it to be an accepted move (with the exception of the Grasshopper, and the Beetle in certain cases).

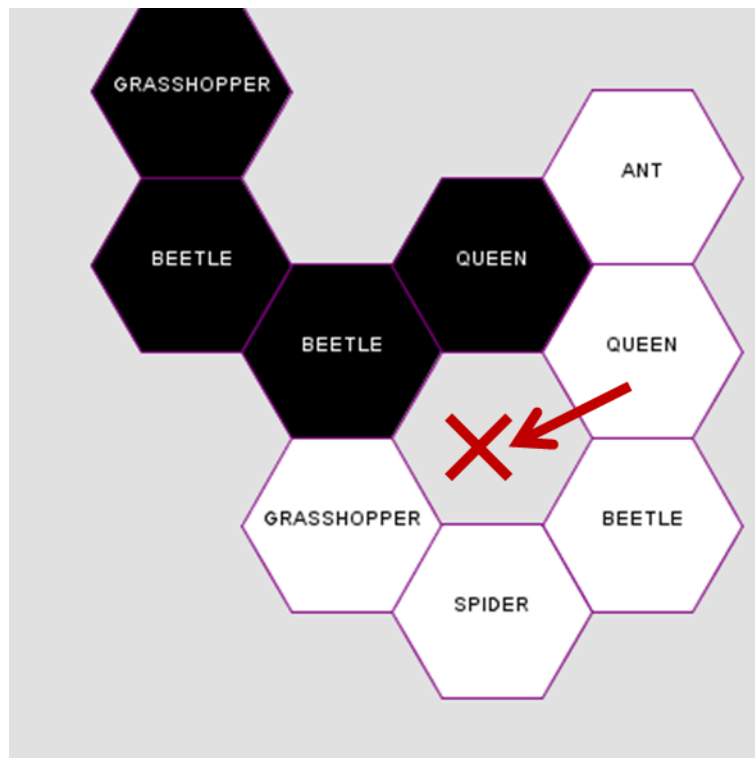


Figure 1.1. The Queen is unable to slide past the narrow gap.

Queen

The Queen is the most valuable piece and must be protected at all times. It is a slow moving piece and can only move one hex per turn. If the player's Queen is completely surrounded, the game is lost.

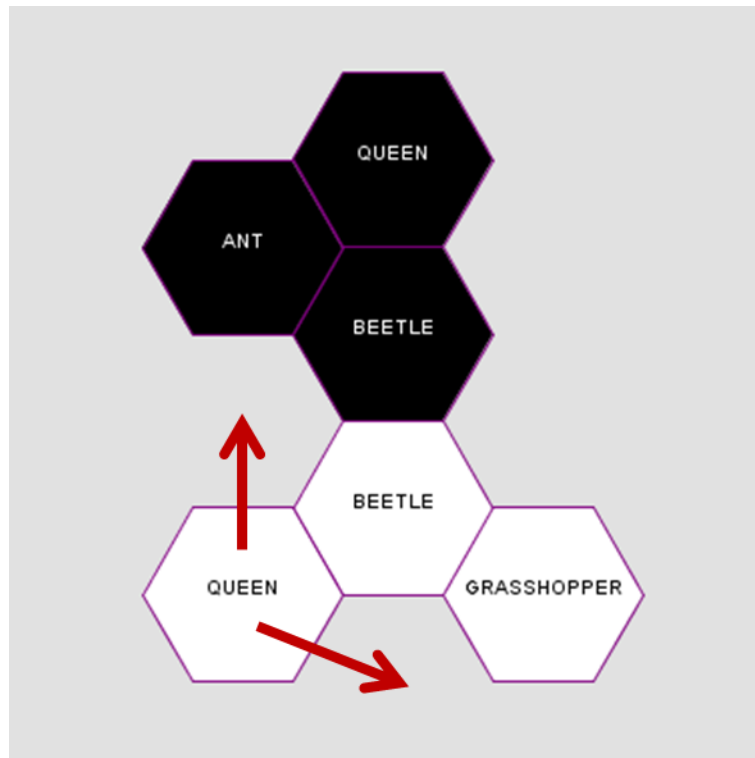


Figure 1.2. The Queen can move to adjacent unoccupied hexes that are connected to the hive.

Beetle

Beetles may move one hex per turn, but unlike the Queen they may also move on top of the Hive. For placement purposes the hex is considered to be the color of the beetle on top. Multiple beetles may be stacked on top of each other. Beetles may jump from on top of the Hive into a surrounded hex that it otherwise cannot slide into. Many strategies involve the Beetle as it is able to lock down any piece under it, making it unable to move.

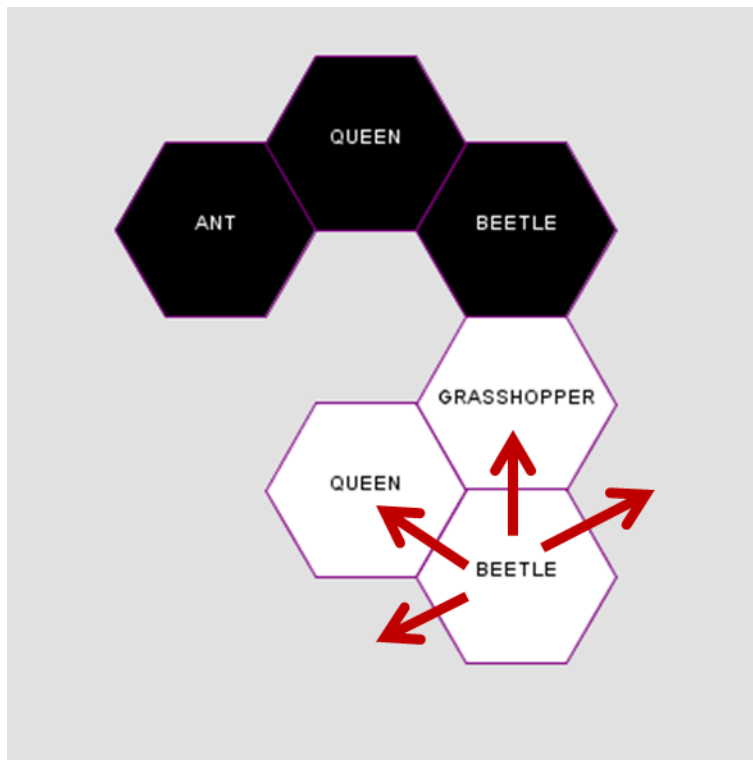


Figure 1.3. The Beetle can move like the Queen and also on top of other pieces.

Grasshopper

Grasshoppers jump over the Hive in a straight line of joined pieces and land in the next available hex. It does not have to slide and is required to jump at least two hexes. The grasshoppers ability to jump makes it a valuable piece as it can not be blocked in one position.

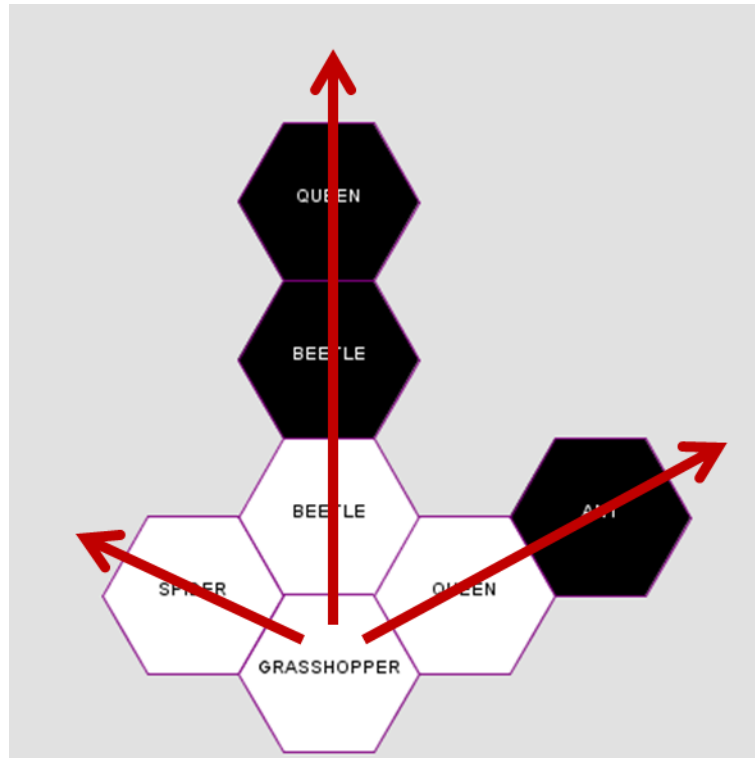


Figure 1.4. The Grasshopper jumps over everything in a straight line. It has to jump over at least one piece.

Spider

Spiders always have to move exactly three hexes. They may not backtrack and must always be connected to at least one other piece every step of the way.

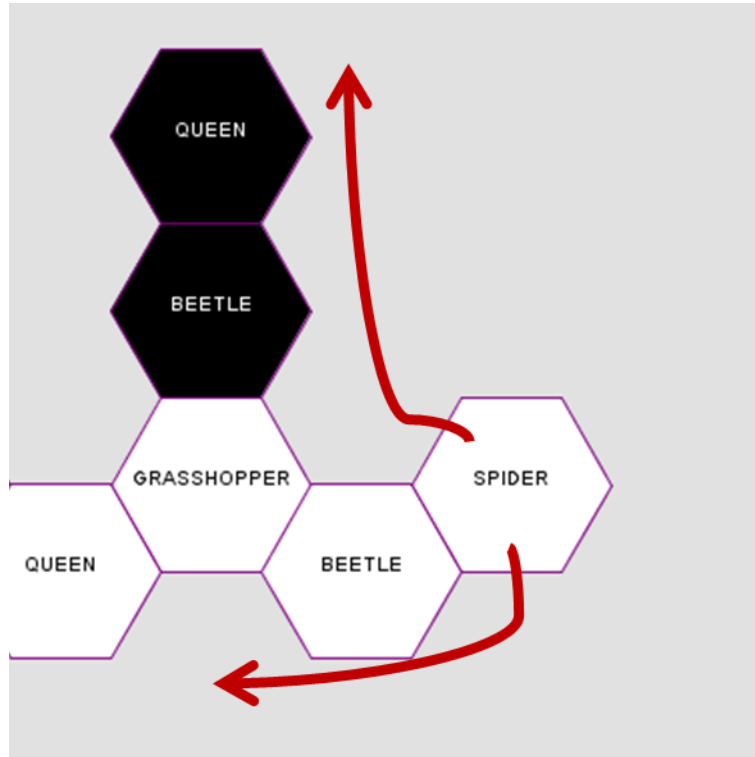


Figure 1.5. The Spider moves exactly three hexes. It may not move two hexes in one direction and then backtrack to the first one.

Ant

Ants are fast moving and may move any number of hexes across the Hive as long as they can slide all the way and do not break the One Hive Rule.

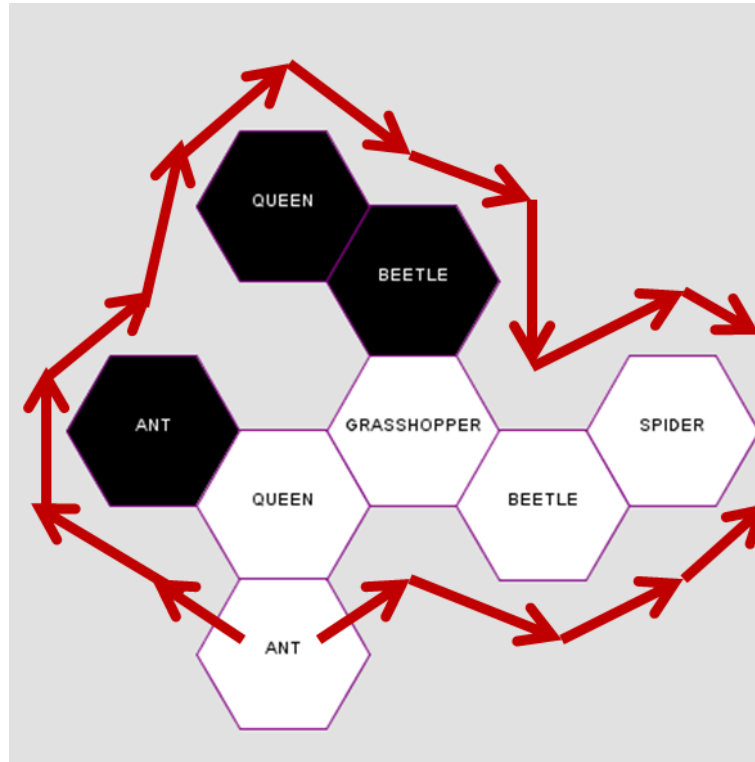


Figure 1.6. The ant can move to any position around the Hive that it can slide to.

Chapter 2

Problem statement

The use of strategies is not uncommon when playing games, and Hive is no exception. There are many different strategies involved when playing a game of Hive. Some focus on a certain combination of moves, others on the capabilities of certain pieces. Some are offensive while others are defensive. The purpose of this report is to find and analyze several of these strategies to find out which is the best. To do, so a playable version of Hive has been constructed using the Processing language and environment. As human testing of these strategies would be problematic and prone to errors, the construction of an AI capable of playing the game was necessary to test the strategies as fair as possible. The playable version that was created features an AI that can play using different strategies against itself or against a human player. This way it may show which is best for which situation. As an added limitation, the AI is not allowed to calculate all possible moves all the way to victory, as that would take an unreasonably long time. It has to make its move within a few seconds.

Chapter 3

Background

Games started to rise when computers began to become more popular during the 1950s and one of the first fields of research was to create an artificial opponent which the player could play with and against. Since then, games have been one of the largest fields of research within AI technology. One of the first popular video games was Pong, designed by Atari.² It had a simple AI which was able to move the opposite paddle and act as a computerized opponent. Since Pong, we have experienced many games with advanced artificial intelligences. Lionhead Games' breakthrough Black and White, released 2001, had an impressive AI where the player had control of a massive creature that made decisions based on the player's actions and at the time it was one of the worlds most advanced AI.³ AIs playing board games are largely famous for their success within the world of chess, as whole tournaments have been held where the top ranked human players have been up against the most advanced AIs. The results have gone both ways, but as computers processing power increases, the human win ratio against computers is decreasing.⁴

Hive has had many iterations since its inception. Aside from the actual board game there are mobile versions for android and iPhone, an Xbox Live version and several others online. One of the most popular is the one available at Board-Space.com. It pits the player against either another player or a computerized opponent.

3.1 Strategies

Strategy theorycrafting has a large following in board games and Hive is no exception. There are many forums on the internet discussing the best strategies for different situations and approaches to the game. Many books have also been re-

²A. Alcorn, Pong, Atari, 1972.

³J. Wexler, Artificial Intelligence in Games: A look at the smarts behind Lionhead Studios Black and White and where it can and will go in the future, University of Rochester, <http://www.cs.rochester.edu/~brown/242/assts/termprojs/games.pdf>, 2002.

⁴Wiki, Human-computer chess matches, Wikipedia.org, http://en.wikipedia.org/wiki/Human%E2%80%93computer_chess_matches, retrieved April 12, 2013.

leased on the subject. Randy Ingersoll is a pioneer within the subject and has released a series of books to his name about various strategies within Hive.⁵

Similarly to chess, Hive is a game of reaction. Every move is an immediate reaction to the previous move, this also means that the strategies involved are ever-changing. It is next to impossible to keep to one strategy throughout an entire game if the goal is to win. Below, many of the concepts that are involved in the strategic points of a game of Hive are discussed.

3.1.1 Pinning and blocking

The main goal of the game is to surround the opponent's Queen and prevent the opponent from doing the same to the player. For this purpose most strategies focus on two important points, pinning and blocking. The One Hive Rule states that the hive must always be connected, following this by moving a piece next to a single piece of the opponent, the player is able to lock the opponents piece, pinning it to its current position. Doing this to the opponents Queen may be one of the most important moves in the whole game as a moving Queen will be difficult to surround. Blocking is a natural follow-up to pinning, by surrounding an enemy piece the player blocks it from moving away. It is worth noting that most pieces have to slide to move, and thus it is not necessary to completely surround a piece to block it. Also note the fact that neither the Beetle nor the Grasshopper can be blocked as their movement allows them to move over other pieces. The Ant is highly adapted at pinning and blocking other pieces as it is able to move all around the Hive in just one turn. The Spider is also good but its limited movement of always three hinders it from being as good as the ant. The Grasshopper can quickly move to positions across the board to either block or pin, but can only move straight which in many cases might not be beneficial. The Beetle is able to pin down pieces by moving on top of them and by doing this it can move across the entire board into locations otherwise unreachable. The Beetle is slow however, and a large part of the game is centered around speed. Playing to pin the opponent's pieces is important but the player also has to consider that every pin requires pieces and moves to perform, knowing when to pin and when not to is an important part of the game. An opponents Beetle can be dangerous next to the players pieces, but being on the other side of the board makes it no real threat and easily ignored.

3.1.2 Stealing turns

Hive is a game focusing on speed. To win the players need to be the first to surround their opponents Queen and to do so they need to be quick. Both the Ant and the Beetle can move around the board but the Ant does it a lot quicker. Now think about the game as a sequence of turns. Say the opponent places a piece the player wants to pin, to do so a piece needs to be moved next to it so that it is affected by

⁵R. Ingersoll, Play Hive Like a Champion, Lulu, <http://www.playhivelikeachampion.com/>, 2012.

the One Hive Rule. Moving to this certain location, the player may choose between six turns with a Beetle, two turns with a Spider or one turn with an Ant. Clearly the Spider is more effective than the Beetle, and the Ant more so than the Spider. Randy Ingersoll describes this as tempo in his book *Play Hive like a Champion*. The players play to gain tempo and make their opponent lose it. As an example, the opponent places a bug next to their Queen. By moving a piece next to it to pin it down the player manages to steal a turn, thus making the opponent lose tempo. Had the player just moved a piece next to the opponents Queen, it would have required a minimum of two turns, one to place the piece on the board and one to move it. By pinning one of the opponents pieces, the player makes sure that piece is unusable and by doing so wastes the opponents turn. As Ingersoll talks about this in his book, he also mentions that the starting player always has an advantage of one turn. This makes it impossible for the second player to win unless he manages to steal turns during the game. Similar concepts exist in many other games. Chess players and theorists in particular generally agree that the player with the first move has some advantage, and there is a lot of statistics to back this up.⁶

⁶Wiki, First-move Advantage in Chess, Wikipedia, http://en.wikipedia.org/wiki/First-move_advantage_in_chess, retrieved April 4, 2013.

Chapter 4

Method

The algorithm chosen for the AIs decision making is Minimax⁷. It is used to maximize the worst result of the move that is about to be made. Briefly explained, it creates a decision tree where a node represents a state in the game and an edge represents a possible move. The root of the tree is the current state and all the leaf nodes are states where one of the players has won. Leaf nodes are assigned values of positive infinity if the game is won by the evaluating player and negative infinity if it is won by the opponent. All other nodes are assigned values by a heuristic function describing the strategy used. Generating the whole decision tree would take an incredibly long time, so instead only a few levels are generated and evaluated. The size of the tree can be reduced further by using alpha-beta pruning⁸. It works by detecting if a branch will end in a result worse than a previously evaluated branch. If so, it can be discarded and the algorithm can continue onto another one.

⁷E. Mayefsky, F. Anene, M. Sirota, Algorithms - Minimax, Stanford, <http://www.stanford.edu/~msirota/soco/minimax.html>, retrieved April 12, 2013.

⁸E. Mayefsky, F. Anene, M. Sirota, Algorithms - Alpha-Beta Pruning, Stanford, <http://www.stanford.edu/~msirota/soco/alphabeta.html>, retrieved April 12, 2013.

Chapter 5

Analysis

For the sake of this study a fully playable version of Hive was created on the Processing platform, allowing a human to play against the AI or let the AI play against itself. Processing was chosen as it is an easy to use and fast environment that lets the user build graphical prototypes easily. It is also highly similar to Java, a language the writers of this report have vast experience in. Processing was chosen over Java because of its graphical properties as the authors wanted to focus on the strategy and game aspects of the project.

5.1 Assigning values to pieces

Each piece is important for different reasons in different roles. Ants and Beetles are great for pinning pieces in one location, the latter do it completely so that the pin can not be broken, and the former do it quickly from almost any location on the board. It is important to know when to use which piece and for what reasons.

5.1.1 Queen

The Queen is the centerpiece of the game. If the player does not protect it, the game is lost. The Queen is therefore the most valuable piece. Being able to move the Queen might very well be the difference between winning or losing. By itself it is not a strong piece as it may only move one hex per turn, but placing it allows the player to move any of their other pieces which gives the Queen a high value of 50 as a reference to the AI.

5.1.2 Beetle

The ability to move on top of the Hive is the Beetles greatest strength. It can move to any possible location on the board and has the ability to perfectly pin any piece it stands upon. Many strategies involve getting a Beetle on top of the opponents queen to make it unable to escape, this also lets the player place pieces directly

next to the opponents Queen which hastens the encircling process quite a bit. The Beetles only disadvantage is its slow movement. Beetles are given a value of 20.

5.1.3 Grasshopper

The Grasshopper, like the Beetle, is able to move into hexes otherwise inaccessible. Being able to jump over the Hive, it can ignore the rules about sliding which is a great strength. But the ability to only move in straight lines hinders it from doing many of the things needed to win. Both the Grasshopper and the Beetle are pieces designed to be able to fill otherwise inaccessible hexes and while they both fill different roles, they are considered to be of the same value.

5.1.4 Spider

While being fast, the Spider is constrained to always move three steps. This makes it hard to coordinate in a way that is advantageous and results in the Spider possibly being the hardest piece to use in many cases. Its three-step movement is both its greatest strength and weakness. Because of this the Spider is considered the weakest piece and given a value of 10.

5.1.5 Ant

The Ant does everything the Spider does, only better. It can move to any location around the Hive but is unable to move on top of it like the Beetle or jump over it like the Grasshopper. Despite that, being able to move to any hex around the Hive makes the Ant a very versatile piece and it has many uses. It is excellent for pinning down newly placed pieces by the opponent or quickly helping to block one of the opponents pieces. Because of this, the Ant places second highest on the value scale with a value of 30.

5.2 Early game

The first four turns of the games are considered early game. During these the player may place up to four pieces, or move those already placed after the Queen has been placed. The purpose of the early game to set up pieces for later use, every placement is as important as the next and it is possible to lose the game within these turns by making bad choices.

5.2.1 Opening move

Queen - While a popular move and great from a strategic view, placing the Queen first is prohibited in many versions of the game and in official tournaments.⁹ The

⁹Boardspace, Rules Change, Boardspace.net, http://www.boardspace.net/english/about_hive.html, 2008.

reason for this is the high chance of the game ending in a stalemate if both players place their Queen on their respective turns. Spider - Placing a Spider is an aggressive opening, considering that the Queen is almost always placed second, it will now have a spider pinned next to it for a long time, taking up one of the six hexes that should be protected at all costs. The Spider is usually placed first for one reason, saving the better pieces for later. The value of the Spider is much less than that of any of the other pieces and considering that the first piece placed will be locked in place for a long time, it will act as a sacrifice. Beetle/Grasshopper - Both of these are defensive openings. By placing a Beetle or a Grasshopper and then the Queen the player instantly has a piece that will be able to move away and leave the spot open should the need arise, which might save the Queen from total encirclement and the player from losing the game. Ant - An Ant should never be used as an opening. The Ants strongest side is its ability to move across the entire board, by using it first an effectively locking it in place for a large part of the game, the player sacrifices a piece that could be more useful elsewhere.

5.2.2 Second move

Queen - The Queen should be placed as fast as possible to prevent the opponent from preparing pieces to move directly next to the player's Queen when it is placed. It is important to note that the players should never place pieces next to their Queen after it has been placed, doing so will give the opponent an opportunity to pin them in place and by doing so will steal tempo. Spider - Placing the Spider as the second move is a very aggressive play. This opens up for an instant pin in the following moves, forcing the opponent to place his pieces next to each other. The Ant and sometimes the Grasshopper can perform the same move, but since Spiders are hard to use later on in the game this could be their only fast and easy use. It is worth noting that the player is still unable to move this piece until the Queen has been placed which means that the opponent has time to prepare for whatever move this piece will be able to perform.

5.2.3 Third move

Queen - If it has not been placed, it should be now. If the Queen was placed during the second move the player is now able to move it. Doing so is in no way at all beneficial to the player and should not be done. Spider - It is able to move across most of the board because of the lack of currently placed pieces. Because of this the Spider is ideal as the player is able to place it in a hex that will let it move to a much more ideal place that would otherwise not be possible later on in the game. Beetle - Beetles should be placed early for one reason, their lack of speed. The Beetle can only move one hex per turn and will take a long time to move across the board. Placing them early will increase the chance that they will actually reach their goal. Grasshopper - Considering that the board will be small and probably spread at this time, the Grasshopper might not be a good piece to place. It is better to save it

until an ideal opportunity shows itself. Ant - Not unlike the grasshopper, placing the Ant this early might be redundant considering the small size of the board this early, as a Spider is able to perform most of the same moves. Saving it for later when it is harder to move across the board might be a better choice.

5.2.4 Fourth move

Queen - Must be placed if it has not already been. By this time the only piece the opponent could have moved is the Queen, which means that the players Queen should either be next to one of the players own pieces or next to one of them and the opponents Queen. If the opponents Queen was moved next to the player, the player gained tempo as the opponent used one turn to move his Queen and gained one piece next to the players Queen. The player on the other hand, gained a piece next to the opponents Queen without using a turn. By moving the Queen the player would lose that tempo, and by this logic the Queen should never be moved during the fourth turn. Spider - Placing a Spider on the fourth turn is about as good a move as placing it on the third, only slightly less valuable since the board has grown a bit and the Spider might have a harder time moving around. Moving an already placed Spider is a very aggressive move by the fourth turn. The Spider should be moved next to one of the opponents pieces to pin it in its location, or next to the opponents Queen to work towards victory. Pinning one of the opponents pieces next to their Queen is ideal. Beetle - Similar to earlier turns, placing a Beetle now would be a good choice as it will not have to move as far to get across the board. One common tactic is to move the Beetle on top of the opponents Queen as the player is then able to place new pieces directly next to it. By doing so, the player will gain a lot of tempo that otherwise would have been used to move the pieces there. Grasshopper - The Grasshopper is still an opportunistic piece and should only be placed or moved if the opportunity shows itself. Ant - Placing an Ant during the fourth turn is a good move to open up pinning opportunities for later. An already placed Ant can be moved to the other side of the board to pin the opponents pieces, or moved next to the Queen to work towards victory.

5.3 Mid game

This is the build up phase where players tend to either pin their opponents pieces as much as possible or try to build defensive structures with their own pieces. Many strategies exist in this phase and we will go through a few in the following paragraphs.

5.3.1 Beetle dropping

This move has already been mentioned several times above. It is a rather simple but lengthy move, where the player places a Beetle and then moves it until it is on top of the opponents Queen. When on top it not only pins the Queen in place,

hindering it from trying to escape, but also allows the player to place or drop pieces directly next to the opponents Queen saving a lot of tempo that would otherwise be spent on moving the pieces.

5.3.2 Circling

The goal of the game is to encircle the opponents Queen entirely while at the same time preventing the opponent from doing the same to the players Queen. One way of hindering the opponents advancement is by circling. The rules of the game state that no piece may enter a hex if it can not slide into it (with the exception of the Beetle and the Grasshopper) which means that if the player is able to encircle one of the hexes next to his Queen, the opponent may not move a piece to that place. This is to prevent pieces like the Ant or the Spider from being placed on the other side of the board and then moved a great distance into a certain hex. Instead, the opponent is forced to either spend several turns getting a slow moving Beetle to the location or get a Grasshopper to jump into the hole in the circle. Both of these solutions take a lot of time, the Beetle has to move great lengths which takes several turns, and the Grasshopper can only move in straight lines which might be hard to coordinate with already placed Grasshoppers.

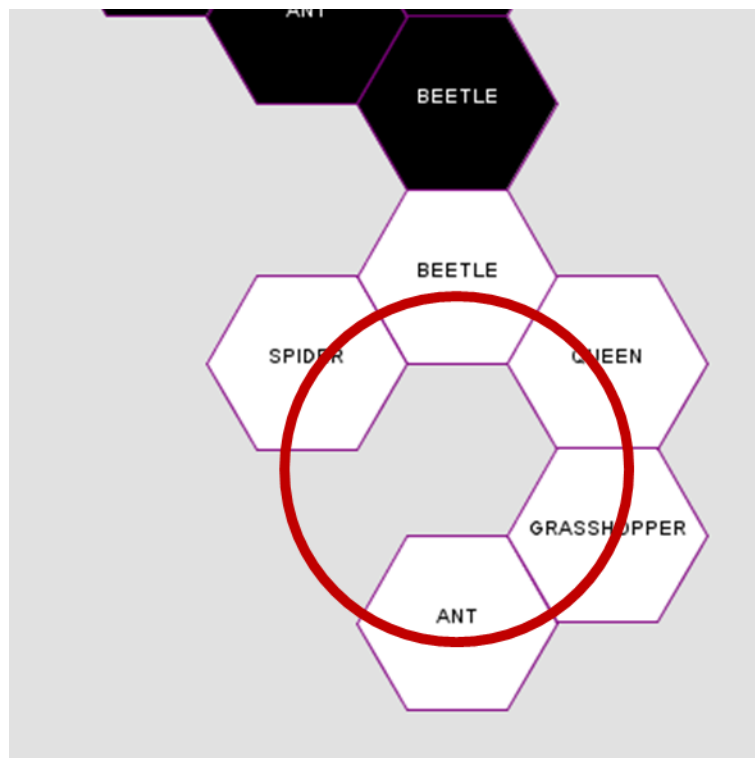


Figure 5.1. Creating a circle next to a Queen makes it difficult to surround.

5.4 Late game

It is hard to state a strict value to when the late game in Hive starts as it is almost interchangeable with mid game with next to no difference. One might consider that it starts when all the players pieces are on the board, but from a strategic view, there is no real difference from the mid game.

5.5 Defensive

As stated above a Beetle or Grasshopper early makes for a better defense than a Spider or an Ant. To achieve these moves, Beetles and Grasshoppers are given a higher value than usual during the first couple of turns. This way it makes it beneficial to place them early in the game, but later on Ants become the preferred pieces. Empty hexes next to the queen also increase the total value. After the early game, circling becomes a major goal in the defensive strategy. Circles and partial circles are created by looking at an empty hex next to the queen and counting the number of pieces around it. More points are given for each piece next to such an empty hex, this way an almost complete circle made of 5 out of 6 possible pieces will still give a massive defensive bonus, as only Beetles and Grasshoppers would be able to enter it. Only making defensive moves will not win the game, so in order to make offensive moves beneficial, even if playing defensively, a limit was put on how much defense would increase the total value. This means that at some point, the value given from defense is at its maximum, and a second circle will not increase the value any more. When defensive moves no longer are as beneficial, the best thing to do is to go on the offensive.

5.6 Offensive

The second implemented strategy was an offensive one. Opening with the sacrifice of a Spider and then placing the Queen. This is then followed by an early Ant for the possibility of pinning and then a Beetle. When mid game starts, additional points are given out mainly for each of the opponents pieces that are pinned and for having a Beetle on top of the enemy Queen. This makes the AI try to focus on aggressive pinning and locking down the opponent's pieces as well as try to get a Beetle into a position where it can drop pieces next to the opponent Queen. Each state in which the opponents Queen has more pieces next to it is also worth a lot more which makes the AI more prone to try and surround the opponents Queen. In order to prevent it from focusing entirely on being offensive it also has a decreasing factor of value for each state in which its own Queen is threatened to make it avoid them as much as possible.

Chapter 6

Results

6.1 Ties

Many of the games played by our AI resulted in ties. For a defensive player it was easy to keep an offensive player from winning by creating circles around their own Queen or moving it out of danger. These games often ended with both players repeating the same moves over and over, which according to the game rules is a draw. In this report, a tie has been recorded as soon as the AI starts cyclical repeating as well as if both Queens are surrounded on the same turn.

6.2 Defensive

The defensive strategies defense value is based on number of empty hexes next to the players Queen as well as complete or partly complete circles around the Queen. The offensive value is based on the players moveable pieces, the opponents pinned pieces as well as the number of occupied hexes next to the enemy Queen. By testing various values for how many points these things gave, the results shown in the tables below were acquired. The standard values were defined so that a single circle would almost be enough to reach the defense value limit. Standard value for a circle was set to 70, and value for empty hexes next to the players Queen was set to 5. With the defense limit at 100, a circle and a few empty hexes or a circle and a partial circle, would be enough to reach the limit and promote offensive moves.

Table 6.1. Results of tweaking points gained from circles on defensive white strategy

Points for circle	25	40	55	70	85	100
Outcome	Tie	Tie	Tie	Tie	Tie	Tie
Turns	54	54	54	58	58	58

Table 6.2. Results of tweaking points gained from empty hexes next to the player's Queen on defensive white strategy

Points for empty next to queen	0	3	5	8	10	15
Outcome	Tie	Tie	Tie	Tie	Tie	Tie
Turns	53	58	58	58	58	54

Table 6.3. Results of tweaking points gained from circles on defensive black strategy

Points for circle	25	40	55	70	85	100
Outcome	Tie	Tie	Tie	Tie	Win	Win
Turns	70	60	28	42	38	38

Table 6.4. Results of tweaking points gained from empty hexes next to the player's Queen on defensive black strategy

Points for empty next to queen	0	3	5	8	10	15
Outcome	Win	Win	Tie	Tie	Tie	Tie
Turns	38	38	42	42	68	50

6.3 Offensive

The offensive strategys total value is based on how many of the opponents pieces are pinned and how many pieces there are next to the opponents Queen. The standard value for a pinned piece is five times the value of the piece that was pinned, and 50 points for each piece next to the opponents Queen. These values were chosen to make the AI a lot more offensive than defensive. Changes to these values were tested and the results are shown in the tables below. The values chosen below were picked around the standard values. An extreme value was also tested to see if it would have more noticeable effect.

Table 6.5. Results of tweaking points gained from pinning on offensive white strategy

Points for pin	5	6	7	10	15	50
Outcome	Tie	Tie	Tie	Tie	Tie	Tie
Turns	42	42	42	42	42	42

Table 6.6. Results of tweaking points gained from having pieces next to the opponent's Queen on offensive white strategy

Points for piece next to queen	50	75	100	200	500	1000
Outcome	Tie	Tie	Tie	Tie	Tie	Win
Turns	42	42	42	42	37	35

Table 6.7. Results of tweaking points gained from pinning on offensive black strategy

Points for circle	5	6	7	10	15	50
Outcome	Tie	Tie	Tie	Tie	Tie	Tie
Turns	60	42	42	42	42	30

Table 6.8. Results of tweaking points gained from pieces next to the opponent's Queen on offensive black strategy

Points for empty next to queen	50	75	100	200	500	1000
Outcome	Tie	Tie	Tie	Tie	Tie	Tie
Turns	60	60	50	50	50	56

Chapter 7

Conclusion

The high number of draws was not entirely unexpected. In fact, it is one of the biggest problems in competitive Hive games.¹⁰ It was even more common when players could place their Queens on their first turn. Ever since that move was made illegal, the number of draws has slightly declined but are still not uncommon.¹¹ It has been openly discussed on forums that the rules should be tightened even more in order to further avoid ties.¹² All the tests with changes within the defensive strategy when playing as white resulted in deadlock ties, wherein both AI controlled players started to repeat their actions cyclically. When the defensive strategy was tested as black on the other hand, it performed better with four recorded wins. The first two wins was the result of the defensive AI almost entirely neglecting how surrounded its Queen was and focused only on circling as defence and then spending the rest of its time trying to surround the opponents Queen. The other two were the results of the defensive AIs extensive use of circling which made the offensive opponent try to pin too many pieces which spread out the playing field extensively and left an opening for the defensive strategy to move in on the offensives' Queen. When the offensive AI was put to the test, it only managed one victory against 23 ties. All ties were results of deadlocks since the offensive AI was unable to compute enough moves into the future to find a set of moves that would lead to victory. Why the one win did appear is probably because of its obscene high value given for pieces next to the opponents Queen making it focus everything on getting more pieces into those positions and neglecting everything else. From these results we can conclude that the defensive strategy most likely is more efficient. Every draw showed that the offensive strategy was unable to break the defence of the defensive one. It is quite possible that the offensive strategy could have defeated the defensive strategy if it evaluated more possible future moves. This would have allowed it to plan its attack

¹⁰Admin, The Draw Problem, BoardGameGeek.com, <http://www.boardspace.net/BB/viewtopic.php?t=190&sid=224a4ebf2091677f69d92d84944364db>, retrieved April 11, 2013.

¹¹BoardSpace, Boardspace Games Analysis, http://www.boardspace.net/cgi-bin/player_analysis.cgi, retrieved April 11, 2013.

¹²F. Juhnke, Long draws, BoardGameGeek.com, <http://boardgamegeek.com/thread/518951/long-draws>, retrieved April 11, 2013.

better by seeing further into the game and by doing so breaking the circle defence. To be able to break it, at least two moves would be needed with a Grasshopper or three with a Beetle should the piece not already be in a favourable position. One to move or place the Grasshopper or Beetle next to the circle, then one more turn for the Grasshopper to jump into the hole or two for the Beetle to climb on top of the circle and then ascend into the middle of it. This is in most cases more moves than the AI created for this report was capable of handling and thus resulted in the circle defence being far more effective than it otherwise should have been. When tested against human opponents it should still be an effective defence, just not as effective as versus the offensive AI.

Chapter 8

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Chapter 9

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