

## TER REPORT

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# Study and research work

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## Contents

<b>1</b>	<b>Introduction</b>	<b>2</b>
1.1	Presentation of the group . . . . .	2
1.2	Subject presentation . . . . .	2
1.3	Rules presentation . . . . .	2
<b>2</b>	<b>Secure AI</b>	<b>3</b>
2.1	Initial idea . . . . .	3
2.2	Realization . . . . .	3
2.3	Performance and rating system . . . . .	5
2.4	Strengths and weaknesses . . . . .	6
<b>3</b>	<b>Ambitious AI</b>	<b>6</b>
3.1	Initial idea . . . . .	6
3.2	Realization . . . . .	7
3.3	Performance and rating system . . . . .	8
3.4	Strengths and weaknesses . . . . .	9
<b>4</b>	<b>Showdown</b>	<b>10</b>
<b>5</b>	<b>Epilogue</b>	<b>10</b>

# 1 Introduction

## 1.1 Presentation of the group

- Ralph EL CHALFOUN was in charge of the making and improvement of the IA. He made statistics to analyse the performance of the AI he also managed the logbook.
- Jérémy HIRTH was also in charge of the making of the AI, he held the tests up to date and optimized the code.
- Rémi YACOUN realized some tests and renamed some classes
- Nabil YABOUB, wrote the ReadMe, and also did some tests.

## 1.2 Subject presentation

Our team has coded a numerical version of the “Seven Wonders” game, we have implemented all the constituent and all of the game board rules (except for one, cf:1.3) on its 2020 version. We have a server where we send the games data, and where we calculate the statistics depending on several factor: number of games, players, type of AI, ... It is also possible to display or not, the game and the statistics in full color.

For the TER part we have developed two advanced AI each one executes a different strategy. First, the Secure AI will make choices depending on the Wonder given in the start. Then the Ambitious AI will make choices depending on the other players and the state of the game.

## 1.3 Rules presentation

The 7 Wonders game can host 3 to 7 players (our version does not handle the 2 players rules). The game takes place in 3 ages, where each age has 6 rounds. At each start of age, 7 cards are hand out to the players. At the start of the game, players receive a Wonder which they will keep the entire game and which provides them a resource.

During a round every players choose a card of their hand and then three choices are available to them :

- Build this card (if they have enough resources).
- Build a level (floor) of their wonder (if they have enough resources).
- Discard and obtain 3 coins.

They are different type of cards: resources, scientific, civil, trader, military, guild.

The resources cards are only available on the first and second state the resources earn with those can be traded to buy other type of cards. The scientific cards grant bonuses that will be convert in victory points at the end of the game. civil cards grant victory points. Trader cards give coins and discount to buy resources to the adjacent opponent. Military cards allow to reinforce the military defense (useful for wars). And the guild cards give a lot of points depending on either the players inventory or the close neighbors ones ,but are only available on the last age.

Some of the resources card are multi-choices, which means that they can give a resource or another but not both at the same time. Unfortunately your version of the game does not support this rule, but it does not have a significant influence on the course of a game.

When the round is over, each player will give their cards to their neighbor. At the end of each age, a war is announced, this means that every player will compare his military defense with his two neighbors and win victory or defeat points.

At the end of the last war players will count the points gained through their cards and Wonders. The player with the most points wins the game. In the event of a draw, the player with the most coins wins.

## 2 Secure AI

### 2.1 Initial idea

During our Project Development and Software Engineering phase we had developed several little advanced AIs. The game is called Seven Wonders, and since wonders give powerful and unique bonuses in most cases, we started with an AI who tries hard to build all floors of its wonder.

And then we realized that the majority of points are obtained thanks to the buildings and not necessarily from the Wonders. So creating an AI for each card color seemed like a good idea to determine which color is the most profitable.

Finally, in general, wonders give more useful bonuses to a certain card category. And that's when we finally got the idea of our Secure AI. Why not ally the strategy of building your wonder, and depending on it, choose a color of card to play. For example the BABYLON wonder gives a multi-choice bonus on scientific resources, this is one of the best bonus for a scientist strategy.

Our secure AI will therefore "plug in" to other AIs depending on the wonder received at the start of the game, in our code you will find it under the name of "Composite".

### 2.2 Realization

For the realization we started by randomly assigning the AIs among the wonders. We analyzed the scores and then we shuffled again. Very quickly we understood that the monetary/coin AI (which targets the yellow cards) was not a good strategy, the mechanics of 3 coins for 1 point will not compete with civil or scientific strategies. Likewise the military AI which is very restricted, during the game it will gain a maximum of  $2 \times 1 + 2 \times 3 + 2 \times 5 = 18$  Victory points and will cause the adjacent opponents to lose 3 points, i.e. a difference of 21 points, which is very easily recoverable with other types of cards.

But this was all just observation and deduction, so we decided to do some stats specifically for our AI. So we have to calculate for each AI its win rate for each wonder when it obtains it. Not forgetting the fact that we also implemented Night Wonders, so there are 14 values for each AI. Let's take a look at our results.

	Civilian	Military	Scientist	Monetary	Wonders
Babylon J	32%	1%	48%	6%	15%
Babylon N	32%	3%	46%	5%	13%
Olympia J	35%	7%	48%	5%	9%
Olympia N	27%	6%	47%	5%	12%
Halikarnassos J	32%	5%	49%	5%	10%
Halikarnassos N	34%	3%	47%	4%	8%
Gizah J	29%	2%	45%	6%	10%
Gizah N	33%	3%	46%	7%	8%
Alexandria J	32%	2%	48%	4%	13%
Alexandria N	32%	3%	45%	6%	7%
Rhodos J	34%	4%	47%	14%	13%
Rhodos N	36%	8%	48%	15%	19%
Ephesos J	28%	3%	45%	4%	10%
Ephesos N	29%	2%	45%	5%	12%

Obviously, scientist AI is the most successful of our component AIs, with civilian taking second place. The other strategies do not give good enough results to be selected.

Now another factor to consider, that of the rivalry between these AIs and themselves. Even if the scientist strategy seems to be the best in all cases, is it really the case when it encounters the same strategy? Let's see the results of a 4-player game with 2 scientists AIs and 2 civilians AIs:

Score type	scientist	Civilian
Games won	41.72%	58.28%
Total average	40.37	43.66
Coins	4.11	2.00
Civil	3.25	28.66
Science	26.35	0.81
War victory	4.85	10.23
War defeat	3.10	1.52
Guild/Bonus	4.85	3.51

By averaging between identical strategies, we obtained this result. It is clear here that civilian AI is doing better in rivalry than scientist one. In this case we have decided to take mostly civilian AI but still keep scientist AI for wonders such as Babylon which offers a scientific advantage on stage 2 of the wonder.

Finally, here is the pattern that our composite AI will follow:

Wonder at day	Strategy	Wonder at night	Strategy
Babylon	Scientist	Babylon	Scientist
Olympia	Civilian	Olympia	Civilian
Halikarnassos	Civilian	Halikarnassos	Scientist
Gizah	Civilian	Gizah	Civilian
Alexandria	Civilian	Alexandria	Civilian
Rhodos	Civilian	Rhodos	Civilian
Ephesos	Civilian	Ephesos	Civilian

scientist and civil strategies are similar and function as follows:

- **CARD:** they each have a list of wanted cards for each age, this list is made up of the main cards for each of the strategies (green for scientific, blue for civil), it is designed to create chains of cards and thus not to have to pay for buildings in ages II and III.
- **RESOURCES:** they also have a list of wanted resources, this list is updated each turn in order to obtain an ideal resource inventory to buy the wanted cards. AIs will not be looking for excess resources, nor will they be looking to stock up for a card if they already have the previous chained card.
- **WAR:** If no wanted card or wanted resource is available in their hands, the AI will attempt to defend themselves by purchasing a Military Card if possible and necessary.

## 2.3 Performance and rating system

Now let's see what our Composite AI is worth, against first of all, two random AIs, here a 3-player game restarted 20,000 times:

Score type	Random	Composite	Random
Games won	00.42%	99.12%	00.46%
Total average	22.00	52.98	22.05
Coins	12.32	6.01	12.40
Civil	6.01	29.25	5.91
Science	0.95	8.63	0.95
War victory	3.75	8.89	3.79
War defeat	1.90	0.76	1.87
Guild/Bonus	0.86	0.96	0.89

We observe thanks to these scores, that indeed AI is more often civilian than scientist, it wins most of the time in wars and rarely loses, its average of points is very good and its economy also (this is due to the resources sought and chained cards which prevent it from doing too much trade).

Let's see what happens when it is confronted with its component AIs. This time a 7 player game repeated 20,000 times:

Score type	Rand.	Composite	Wonders	Monetary	Military	Scientist	Civilian
Games won	0.01%	22.86%	6.77%	3.55%	2.77%	33.42%	30.60%
Total average	18.80	43.39	36.37	32.59	35.40	45.79	45.60
Coins	12.35	3.03	3.92	11.46	6.54	4.33	2.63
Civil	6.29	26.16	15.59	5.28	8.07	6.39	34.33
Science	0.87	7.10	5.90	1.18	2.67	31.84	1.67
War victory	1.86	7.15	8.19	7.91	15.90	4.09	7.38
War defeat	3.67	2.25	2.07	2.18	0.31	3.10	2.18
Guild/Bonus	1.09	2.21	4.85	8.94	2.53	2.24	1.78

Obviously this is not the configuration that will make our Composite AI shine, because here, no matter what wonder it obtains at the start of the game, it will choose either scientist or civilian strategy, and here, an opponent of each is present. Its scientist and civilian components obtain better scores because there will be, in each game, one of the two who will play alone on its own ground, unlike the other who will compete against the Composite AI.

## 2.4 Strengths and weaknesses

The strengths of this strategy:

- Composite, it can play on two different fronts depending on its wonder and therefore it is not easily predictable for a new opponent.
- Its modularity, we can easily change the research lists (cards and resources), and its component strategies.
- When it is the only one to play on its strategy, it achieves very high scores.

The weaknesses of this strategy:

- Non-scalable strategy, no game-to-game improvements against the same opponents.
- Despite the optimizations, it remains weak against an identical AI, finally having only two component AI, it will often have to share its strategy with the opponent.

# 3 Ambitious AI

## 3.1 Initial idea

The concept of our Ambitious AI is based on observation of the game, unlike Secure AI, it has a stronger ability to adapt, even if overall it will follow a thoughtful strategy. Basically we started with the idea of creating a Counter-Play AI, the principle was to analyze the opponents in order to counter them by determining their strategy during the game.



## 3.2 Realization

We started to realize our Counter-Play AI at the beginning of December 2020, we always had in mind to realize a Counter-Play AI but during our tests of the Secure AI, we realized that our vision of the new AI had to go through some changes.

First, let's analyze what would be the simplest strategy to counter our Secure AI. Even if it can follow two different strategies, it will not change strategy along the way, as a reminder it will be based either on the purchase of scientifics (Green) or civil (Blue) cards, so the best way to prevent it to win would be to buy either green or blue. However, this is also the best way to lose because, by the time our Counter-Play AI detects the strategy, it will lag behind the opposing strategy, and playing on someone else's field is not profitable in Seven Wonders. Also this technique can only counter a color strategy so a smaller number of opponents.

We therefore oriented ourselves differently, so that our AI can win a larger number of games, while countering a lot of strategies, we have developed these game mechanics, the strategy is carried out in two stages, Age I-II and Age III:

- Age I-II: we can consider these ages as the preparation phase, the resources are only available at this time, the buildings are not very expensive but do not bring in a lot of points either, and the same goes for the wars. This is why our AI will focus on purchasing resource buildings (Brown and Gray).
- Age III: this is the most decisive phase of our strategy, the cards at age III are the most important, for all strategies combined. The AI will choose the cards in its hand very thoughtfully, it will calculate for each card its rate of return in terms of points at the current state of the game and choose the most profitable. It may as well choose a civil, military, scientist, guild, or trader card. And that is the key point of our strategy.

Indeed the key point is at Age III, the accumulation of resources during the first ages will allow the AI to buy any card of age III, and in addition to that, given that the strategy is not based on a particular card color, it can buy any color.

Now why is our AI a CounterPlay?

- Money: during the game, our AI will almost never buy resources from the opponents because it will already have a lot of them, in addition to that it is the other players who will buy from it, thus making it gain a lot of coin. The AI is also more likely to win a tie, based on its coin amount.
- War: the AI will defend itself throughout the game by buying shields when they are useful and profitable, thus losing points to opponents, it will in principle not buy more shields than necessary.
- Age III: as explained previously, it will be able to buy any color of cards. The fact that it takes a lot of important cards at age III prevents other AIs from completing their strategy (such as guild cards or the "Palace" card for civilian AI).

### 3.3 Performance and rating system

As with our Secure AI, we will first be based on a 3-player game performed 20,000 times. Let's take a look at the results:

Score type	Random	Counter-Play	Random
Games won	00.11%	99.79%	00.10%
Total average	22.81	55.38	23.01
Coins	7.73	13.44	7.87
Civil	10.42	21.80	10.16
Science	1.79	2.98	1.84
War victory	3.86	12.40	4.00
War defeat	2.60	0.54	2.55
Guild/Bonus	1.60	5.37	1.70

Something interesting to note is the fact that the Counter-Play AI scores are mostly double that of Randoms, this is because the AI has no particular color strategy, all types of points can interest its, it all depends on the current state of the game, the inventory of its neighbors, what it has in its hand.

Here in this case, being surrounded by random AIs, it cannot get a lot of points from the guild cards (because the guild cards depend mostly on neighboring inventories), on the other hand it gains a lot of war victory points because it takes the top on the randoms, in the same way having no civilian adversary the blue cards are most of the time the best choice.

Can having an opponent following the same strategy damage our AI? Let's see this by swapping out a random for another Counter-Play AI:

Score type	Random	Counter-Play	Counter-Play
Games won	00.05%	52.99%	46.95%
Total average	19.43	47.60	46.90
Coins	5.04	5.50	6.04
Civil	12.20	20.27	17.71
Science	2.86	6.15	6.55
War victory	1.27	10.50	10.96
War defeat	4.44	1.21	1.13
Guild/Bonus	2.49	6.40	6.76

Here we can't play more than 20,000 games due to the lack of CPU power, but in theory both Counter-Play AIs should aim for the same scores. In addition we can already observe that even if they do not have the same scores in each category, they still have a total average very close to each other. The disadvantages of playing against itself in this strategy are the war and economy side. They will not buy a lot of resources between them and they will each know how to defend themselves by buying shields. The good thing is that they still manage to have a good average because they are versatile.

Now let's test the performance of our AI in a 7-player game with different AIs. We play the game 20,000 times and get the following results:

Score type	Rand.	Count.Play	Wonder	Monetary	Military	Scientist	Civilian
Games won	00.25%	<b>39.22%</b>	4.91%	2.24%	1.96%	27.55%	24.12%
Total average	18.56	<b>47.11</b>	35.55	31.28	34.84	44.93	44.56
Coins	<b>11.84</b>	6.60	3.60	10.99	6.02	3.78	2.26
Civil	6.76	18.89	16.11	5.39	8.70	7.01	<b>34.96</b>
Science	0.93	3.10	6.31	1.39	3.07	<b>31.68</b>	1.72
War victory	1.70	9.87	7.77	8.01	<b>15.31</b>	3.69	6.49
War defeat	3.79	1.54	2.21	2.21	<b>0.43</b>	3.26	2.44
Guild/Bonus	1.13	<b>10.19</b>	3.97	7.72	2.17	2.04	1.59

First of all, we can see that the Counter-Play AI wins overwhelmingly against all AIs. If we observe each category of score, it is placed almost all the time in first or second place.

From this, we can confirm the fact that the Counter-Play AI is versatile on all fronts.

### 3.4 Strengths and weaknesses

The strengths of this strategy:

- Its ability to be versatile in terms of card choice.
- Its economy, it manages its money and resources very well.
- Its adaptability, to its neighbors and their strategies during the game.
- Its high score against all types of opponents.
- Does not depend on its wonder.

The weaknesses of this strategy:

- Non-scalable strategy, no game-to-game improvements against the same adversaries.
- Do not exploit its wonder.

## 4 Showdown

In theory our Ambitious AI has all the tools to beat our Secure AI, now let's see in practice what this gives with other tests. A 3-player game, facing our two advanced AIs, as well as a random so as not to influence the statistics too much :

Score type	Random	Secure	Ambitious
Games won	00.05%	27.88%	72.07%
Total average	21.47	46.26	52.30
Coins	5.91	1.85	9.51
Civil	10.98	26.33	18.16
Science	2.47	11.06	4.44
War victory	2.83	7.44	11.60
War defeat	3.50	2.06	0.89
Guild/Bonus	2.78	1.63	9.48

The verdict is final, our Ambitious AI dethrones the Secure AI with a victory rate of over 72%. Let's analyze why the gap is so pronounced.

The Secure strategy more often follows a civilian strategy than a scientist one, which could be problematic for the Ambitious. However, the fact that the opponent is an advanced AI allows it to win in return thanks to the guild cards, which are very profitable when the opponents are good players. In addition, the Ambitious AI with its full resource inventory can buy the Palace card when it's in its hand, thus causing the other AI to lose the best civil card. Add to this the fact that the opponent spends all his coins on the Ambitious AI. Wars are much more won on the side of Ambitious AI. All of these factors make our best AI a formidable opponent for Secure AI.

## 5 Epilogue

In conclusion of this report, we are on the whole satisfied with the results, because even if they were not always what we expected, we discovered strategies techniques, we understood thanks to the statistics that at certain times we were not heading in the right direction, and especially during the creation of Ambitious AI, this allowed us to correct and evolve our strategies.

There are obviously endless possibilities for improvements such as managing the wonder for Ambitious AI, or adding other Secure AI components, etc. The report stops here, but the research has not no end.