Use of Theory of Mind to perform SWOT Analysis and thereby, Test the Efficiency of Theory of Mind in a Partially Competitive Environment

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Abstract

SWOT analysis is a strategic planning technique used by organisations to evaluate an idea, where one identifies the Strengths, Weaknesses, Opportunities and Threats. It is implemented by people, as a group, by analysing the data and discussing different scenarios. In this paper, we implemented a Multi-Agent System to perform the SWOT analysis using the concept of Theory of Mind. We also assessed if possessing a higher-order Theory of Mind is beneficial in a partially competitive environment; the results provided evidence that it is beneficial only to a certain extent, and beyond that, the advantages plateau.

1 Introduction

In this paper, we are collaborating on two entirely different concepts that are different in their field and usage. The first concept is the concept of SWOT analysis. SWOT analysis is an evaluation technique to identify Strengths, Weaknesses, Opportunities and Threats (SWOT) for any given idea. The process usually is done by an appointed group in any company, where each individual of the group identifies the Strengths, Weaknesses, Opportunities and Threats for the idea that is to be implemented. Once a member of the group identifies a strength, or weakness, or opportunity, or threat, other members of the team can support the proposal or deny its validity by proposing a valid counter statement. If the proposal is accepted, then it is considered to be a final list of SWOTs. In the final list of SWOTs, if the Strengths and Opportunities outnumber the Weaknesses and Threats, the idea will be implemented. If the Weaknesses and Threats outnumber the Strengths and Opportunities, the idea is dismissed and will not be implemented. The process of performing a SWOT analysis is time-consuming and is not affordable for small organisations such as start-ups. This difficulty faced by small organisations appeals for a better system that is affordable and time-efficient.

A Multi-Agent System is a group of individual computing elements interacting with each other to achieve a goal. "Each agent is capable of autonomous action - of deciding for themselves what they need to do to satisfy their design objectives." [Woo09], and they are capable of interacting with other agents of the group. The interactions can be in the form of cooperation, coordination, negotiation, and others. In Multi-Agent Systems, there are numerous concepts that the agents can use, depending on the purpose. One of the concepts is the Theory of Mind.

The second concept that we use is the Theory of Mind, which we use to implement the SWOT analysis mentioned earlier. Theory of Mind is a theory in the field of Psychology and was first coined

by Premack D. and Woodruff G. [PW78], in which they refer to the Theory of Mind as an ability to attribute mental states — beliefs, intents, desires, emotions, and knowledge — to ourselves and others. Over the years, the concept of the Theory of Mind has gained traction, especially in the field of Artificial Intelligence. After many experiments and studies, one important conclusion that was reached, among many, is that possessing Theory of Mind provides an advantage in a competitive environment [WVV13].

In this paper, we implemented a Multi-Agent System that uses Theory of Mind to perform a SWOT Analysis. The implementation of SWOT Analysis requires the system to be partially competitive. The environment is described as partially competitive because the nature of SWOT Analysis is that, in a group, one either supports an idea or discourages it. Supporting an idea is not a competitive act but discouraging an idea is, as discouraging an idea requires argumentation against the supporting idea. This influence of the Theory of Mind in a partially competitive environment is unexplored. Through this project, we found out that it is beneficial till a particular higher-order, after which the level of advantage remains the same.

1.1 Problem

Despite the importance of SWOT analysis, small organisations such as startups struggle to implement it. This struggle could be for any number of reasons, including but not limited to inconveniences such as lack of experience or the implementation team being too small. To eliminate this struggle, a system independent of people is necessary. The proposed system eliminates this difficulty that small organisations face. The system we propose is independent of people, quick in a way that it is non-time-consuming, and to implement it, no prior experience or knowledge is required.

1.2 State of the art

There has not been a lot of research concerning SWOT Analysis. From the latest research concerning SWOT Analysis [HLV99], SWOT Analysis is performed using a program based on conventional programming techniques. The process involves manually collecting the data from the experts who implement the system and using that data to modify the model to the specificity of the need. The system is too complex and requires significant processing power. The authors of the [HLV99] declare that Artificial Intelligence research methods can't be used as the task is too complex and it requires a much greater computational power. It was due to the limited computational power of the hardware. With the exponential rise in computational power and the increasing ease of access, we should be able to use methods of Artificial Intelligence in performing SWOT Analysis.

1.3 New idea

The novelty of the proposed approach is the use of a Multi-Agent System that applies the concept of Theory of Mind to perform the SWOT analysis rather than conducting time-consuming interviews and lengthy processes. From the real-life scenario of performing SWOT Analysis, we draw inspiration in a manner that each agent of the proposed system will have different beliefs and perform classifications according to their beliefs. Since the system is partially competitive, we expect that possessing a higher-order Theory of Mind will be beneficial in a way that the prediction accuracy of higher-order agents is higher than that of lower-order agents.

2 Method

2.1 Simulation model

The current State of the Art for designing a system that performs SWOT Analysis is a long process and consists of the following steps. Before proceeding to the SWOT analysis, the strategy has some key concepts that have to be fulfilled. First, knowledge is acquired by applying interviewing techniques to experts in the field. The knowledge that was gathered from the experts is then refined to remove the unnecessary data. Based on this refined data, a standard model is modified and adapted to fit the desired field of implementation, using a structure diagram. The structure diagram shows the relationships between the data structures (called domains) and the involved reasoning processes called inferences. Each data structure has its own function in the decision process, called the domain role, by which it is named. In addition, each reasoning process has its own specific task in the decision process. The new model will output the result of SWOT Analysis with a certain accuracy.

A supervisor will check the output and isolate the output based on the arena of implementation. There are usually five different management areas:

- the market
- the finance
- the production
- the people
- the environment

There are a set of rules (specific functions) for each management area that affects the decision. The final decision is made by the supervisor and based on the decision, the organisation takes action. The current State of the Art is described briefly using a flow diagram in Figure 1.

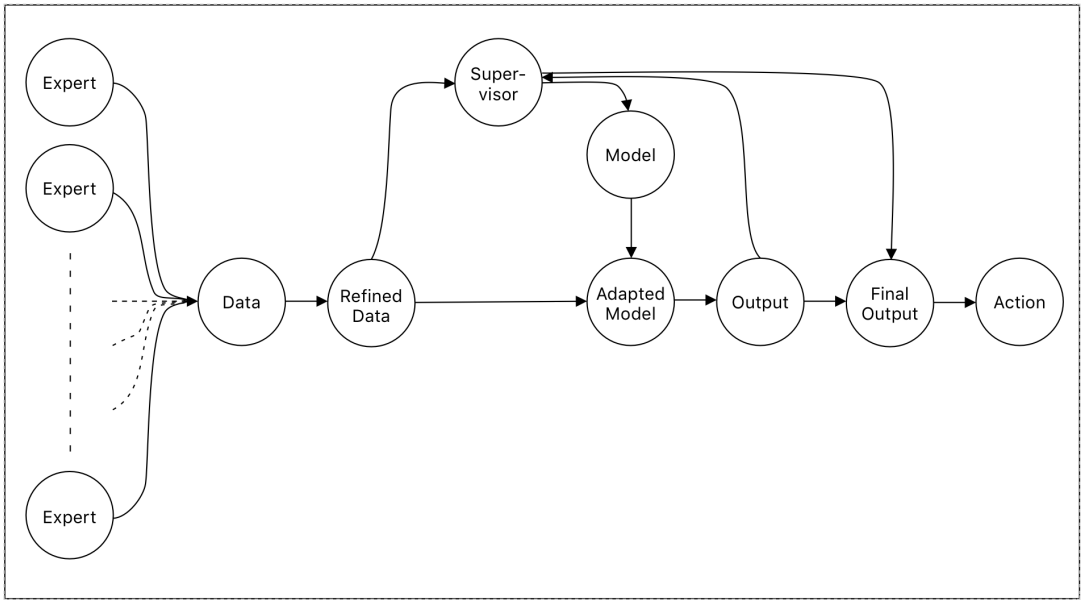

Figure 1: Flow Diagram of the current State of the Art

The model that we took inspiration from is efficient, but only under specific conditions. The proposed approach follows a different approach than the State of the Art, but the goal is the same. In

the new approach, we gather data from the experts once. If there is any new data at any point in time, it can be added to the existing data; unlike the current State of the Art, where the data is gathered again through repetitive interviews. The data obtained is then organised and trimmed into a dataset. Few sample data entries are presented in Table 1.

Word	Strength	Weakness	Opportunity	Threat	Tags
Loss	20	80	12	88	Franchise; Investment
Loss	15	85	27	73	Franchise
Loss	23	77	30	70	Investment

Table 1: Sample beliefs for the word *Loss*

Each value under the category name refers to how much an expert associates a particular word to that category. The tag column refers to the scenario when the word can be categorised into that particular category. For example, from Table 1, The first entry *Loss* has the value 20 under the category *Strength*; this conveys that the expert believes that the word *Loss* can be a strength with 20% belief. In the same first entry, under Tags, there are two words: *Franchise* and *Investment*; this conveys that when one is evaluating a word with the beliefs is valid when one is trying to establish a Franchise and trying to invest

The approach has two phases in its implementation. The first phase is the training phase, where each agent is trained on the same keywords but with different beliefs for categories of SWOT. Different beliefs refer to the values associated with each category for each word. An example of it has been provided in Table 1. Agent A0 is trained solely on the dataset, whereas agents A1 and A2 are not. Agent A1 is trained on the dataset and the output of agent A0. Similarly, agent A2 is trained on the dataset, the output of agent A0 and the output of agent A1.

Post-training, the system has three agents: A0, A1, A2 will possess zero-order Theory of Mind, first-order Theory of Mind, and second-order Theory of Mind, respectively. Each Agent is then tested on a test dataset. A0 possessing zero-order Theory of Mind is independent in its decision process i.e. it does not consider the other agents' outputs. Agent A1, possessing first-order Theory of Mind, not only takes the dataset, but also the output of agent A0 as input to make its decision. Agent A2 is also similar in a manner that it takes the dataset and output of agent A0 as input, but it differs by also using the output of agent A1 as input. The new idea is shown as a flow diagram in Figure 2

2.2 Implementation details

For the project, our choice was to use the programming language Python 3. We used libraries such as NumPy, pandas and Scikit-learn to handle the data importation, to create a Regression model, and to normalise data. The code for our project is split into two components: a folder for Datasets and a folder for agent models. The datasets folder has a total of four datasets, one for training each agent and one for testing. The folder of agent models has a python file that contains the code for all three agents.

2.3 Experiment design

Once the python file is executed, the agents are automatically trained on different beliefs using the different datasets. We tested the models using the test datasets. The results for the test dataset will be the output when the main file is executed. The code can also be modified so that it can take custom input.

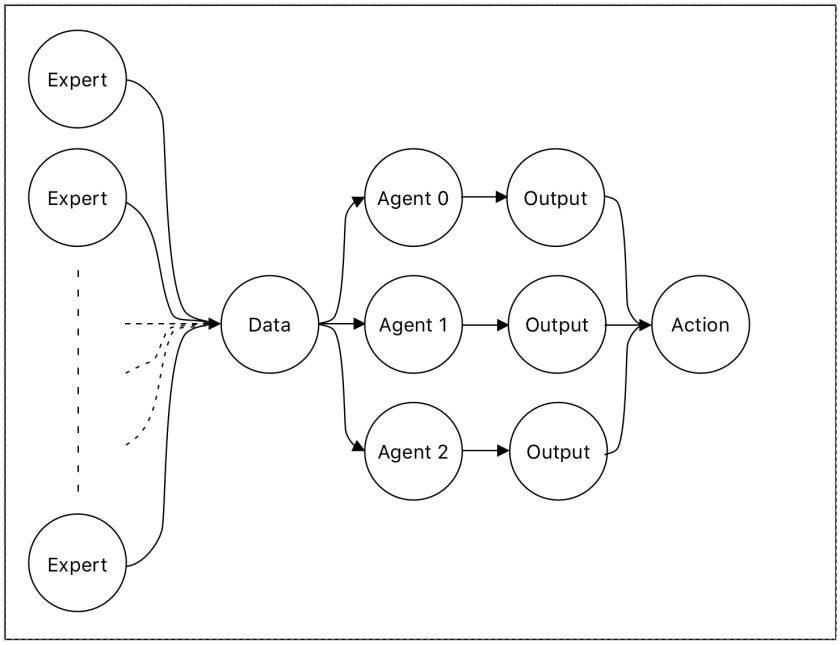

Figure 2: Flow Diagram of the Proposed model

3 Results

3.1 Experiment findings

The results from the modelled Multi-Agent System show that the models were able to perform the SWOT analysis. The accuracy for each agent in performing SWOT Analysis on multiple test datasets is presented in Table 2

Dataset	Agent 0 (ToM 0)	Agent 1 (ToM 1)	Agent 2 (ToM 2)
Test 1	75%	76%	76%
Test 2	72%	82%	74%
Test 3	88%	92%	89%

Table 2: Accuracy of agents of the system in performing SWOT Analysis

The accuracy of each agent for each test dataset might seem like it varies by a great value, but we would like to draw attention to the fact that the datasets used are custom datasets and are insignificantly small when compared to the data that can be obtained by actually seeking experts. Regardless, the average accuracy of Agent 0 with zero-order Theory of Mind, Agent 1 with first-order Theory of Mind, Agent 2 with second-order Theory of Mind is 78.3%, 83.3% and 79.6%, respectively. The results graph is visualised in Figure 3

In every test, Agent 1 performed better than the others. So, we consider that Agent 1, which has first-order Theory of Mind, as the best agent, and if implemented in real life, the output of Agent 1 can be trusted 83.3% of the time.

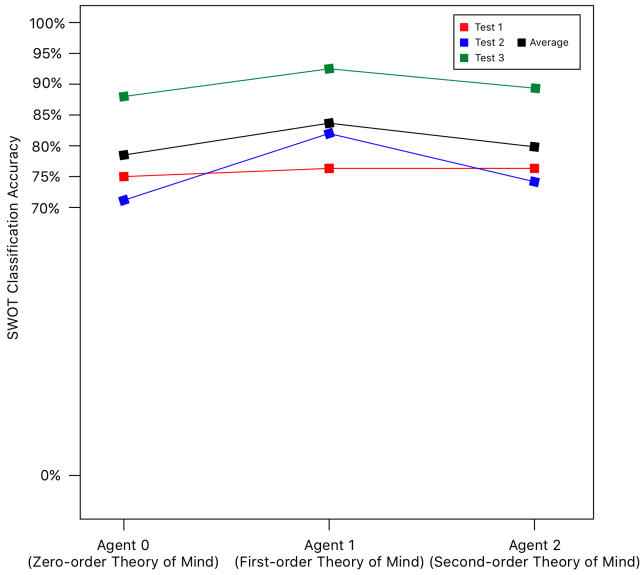

Figure 3: SWOT Classification Accuracy Graph

3.2 Interpretation of findings

From the results, we can infer that the implementation of SWOT analysis was successful. The performance of each agent differed because of the inherent beliefs they held. The performance of Agent 0 was the poorest among the three agents, and we can attribute that to the zero-order Theory of Mind it owns. Agent 1's performance was slightly better compared to the performance of Agent 0. The reason the performance of Agent 1 was better was that it has first-order Theory of Mind, and it considers Agent 0's output as part of its evaluation process. The performance of Agent 2 was different and not as anticipated. We expected that Agent 2 would perform even better than Agent 1, as Agent 2 has a higher-order Theory of Mind compared to Agent 1. However, the results suggest that the performance of Agent 2 was better than that of Agent 0, but not when compared to the performance of Agent 1; the performance slightly declined.

We believe that the decline in the performance of Agent 2 was due to the size of the dataset that we used, which is insignificantly small compared to the data that can be obtained from interviewing experts. We believe that when the actual dataset is used, the performance of Agent 2 will be similar to that of Agent 1, providing proof that there is no added advantage in possessing second-order Theory of Mind.

We can summarise the results by stating that having a Theory of Mind provides an advantage in a partially competitive environment, but there is no added advantage when the order of Theory of Mind progresses higher.

4 Conclusion

4.1 Discussion

In this project, we implemented a minimal system of agents that can perform SWOT Analysis. From the results, we provide evidence that the system of agents is reliable with a minimum accuracy of 76%, from the agent owning first-order Theory of Mind. We also explored if having a Theory of Mind provides an advantage in a partially competitive environment. The results suggest that it is beneficial,

but only up to a certain order Theory of Mind (in our project, up to first-order Theory of Mind), and beyond which there is no additional advantage.

4.2 Relevance

There are a few areas that we haven't traversed in this project and for future work, we would like to investigate that. One of them is: Since our datasets were small, results might be biased; so we would like to implement with actual data. Exploring this will provide us with real results and help us refine the model.

Another area which we would like to explore is the implementation model; we used a Regression model in this project, but we would like to implement it using Reinforcement Learning.

We believe that the model implemented in this project does not have a lot of potential compared to the Reinforcement Learning model which has real potential to be used by companies.

4.3 Team Work

From the beginning, all the team members met three to four times per week to work on the Project. The workload in implementing the project and writing the report was split equally among the four members.

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