COGNITIVE TASK IN NATURAL LANGUAGE FOR THE FIRST 10 LEVELS OF THE SOKOBAN GAME IN THE METACOGNITIVE ARCHITECTURE CARINA

Juan F. Tuirán Jiménez
jtuiranjimenez66@correo.unicordoba.edu.co

Adán A. Gómez Salgado
aagomez@correo.unicordoba.edu.co

SUMMARY

The purpose of this article is to describe the natural language made for the creation a Cognitive Model for the first 10 levels of the Sokoban game in the metacognitive architecture CARINA. A Cognitive Model is the theoretical foundation and empirical specification of mental representations and processes that intervene in cognitive functions or processes. SOKOBAN is a game, which its main objective is simple, the player must transport one or more boxes to sites called storage spaces. The methodology used for this work is a cognitive modeling, which consists of seven steps.

Keywords: Natural Language, SOKOBAN, Cognitive Model.

I. INTRODUCTION

Cognitive Modeling (MC) is a cognitive science research methodology that produces theories that can be expressed as computer programs [1]. The Cognitive Modeling have seven steps: i) selection of the cognitive task; ii) obtaining information to describe the cognitive task; iii) description of the cognitive task in natural language; iv) description of the cognitive task in GOMS; v) codification of the cognitive model from goms to the language M++; vi) execution of Runnable Cognitive Model in Carina; vii) testing and maintenance of cognitive model [2]. The cognitive task stage in Natural Language is: specify the necessary requirements to solve the problem in expressions of the human language [2].

The cognitive Modeling produces computational models of cognitive processes usually dominated as Cognitive Models [1] A cognitive model should converter in format JSON and be exported to metacognitive architecture to be executed [2]. A Cognitive Architecture consist a general-purpose control system, which is inspired by scientific theories that was developed to explain cognition in animals and humans [3]. A Metacognitive Architecture provides a concrete framework for the process of modeling mechanisms that an intelligent agent develops on itself for high-level reasoning [4]. The main difference between metacognitive architecture and cognitive architecture is that, the first have two levels, meta-level and object-level [2] and the Cognitive Architecture only have one level of reasoning. CARINA is a metacognitive architecture designed for artificial intelligent agents. This architecture is derived from the MISM Metacognitive Metamodel [5].

SOKOBAN is a game, which each level represents a warehouse, where the boxes are placed randomly. A storer in charge will have to take these boxes and push them through the whole warehouse, this in order to bring them all to their target, which in this case would be the storage spaces [6] According to [7], SOKOBAN has several characteristics of which the player should be very attentive, to be able to solve the problems that arise while advancing in level: i) those within the grid may not be in a dead center, for example: the box may be in the corner, however, the position is not the destination; ii) the player will only be able to move one box at a time, he cannot move two or more boxes simultaneously; iii) if the player wishes to move a box down, it must be a path that reaches the top of the box and there must be a space at the bottom of the box; iv) the final score is related to the steps the player performs, for example: the more steps the player

moves, the higher the cost and, therefore, the lower the score; vi) Each step carries 1 cost. Problem Therefore, different ways may lead to objectives, but differ in scores. The purpose of this article is to present cognitive task in natural language for the first 15 levels of the Sokoban game in the metacognitive architecture CARINA.

II. SOKOBAN

SOKOBAN is a logic video game, which was created by Hiroyuki Imabayashi in 1980. SOKOBAN is commonly known for the degree of complexity that is acquiring, as the game is advancing in level, however, is simple, is to transport one or more boxes to certain sites called storage spaces, the player can only move in the main directions (up, down, left and right), also can only push one box at a time [8].

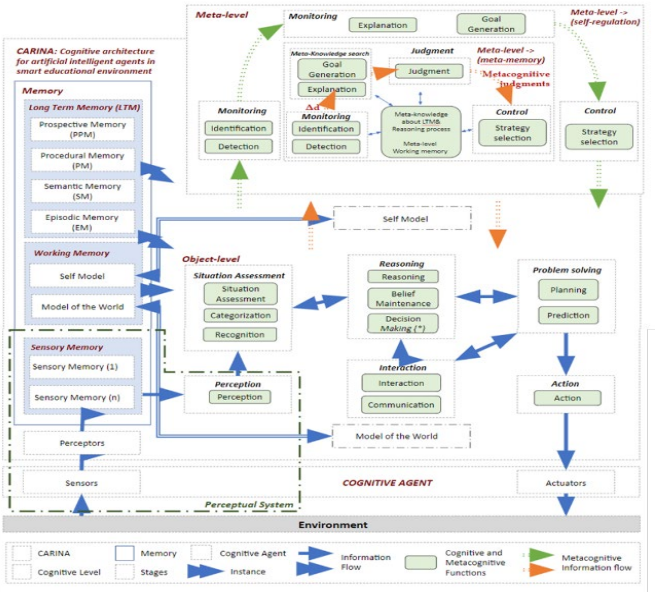
According to [9] in this research was performed a deep analysis to find the optimal solution to any map in the game SOKOBAN. For this, first study the complexity of each of the problems when solving a level and then implement that data in an artificial intelligence to perform the necessary actions to meet the main objective, this bearing in mind that the intelligence must be based on the research already done.

[8] in their research they implement different algorithms in the game SOKOBAN in an artificial intelligence which they call as (CNN) Convolutional Neural Network the algorithms were as follows: Depth First Search (DFS), Breadth First Search (BFS), Uniform Cost Search (UCS) and algorithm A*. After the application, obtained results such as, that there are similar movements when playing in the game, however, differ in the amount of time they last to execute them.
[10] in this research they train a neural network against a classical solver. This in order to develop a neural network capable of generating possible states with an accuracy of 99%, also to propose their approach as a method to develop neural networks that are able to replace human experts and classical AI to generate new solutions for games like SOKOBAN.

III. CARINA Metacognitive Architecture

CARINA is a metacognitive architecture designed for artificial intelligent agents. This architecture is derived from the MISM Metacognitive Metamodel, with this CARINA can integrate self-regulation and metamemory using introspective monitoring and meta-level control, also assuming a functional approach to the philosophy of the mind [11].

CARINA is divided into two cognitive levels: the object level and the meta-level. The object level is that which encompasses the model that has an artificial intelligent agent in order to reason about the world and solve problems. On the other hand, the meta-level encompasses a dynamic model of the object level [4].



"Fig 1. Structural view of CARINA"

IV. Cognitive Modeling in CARINA

The steps of Cognitive Modeling in CARINA are described below:

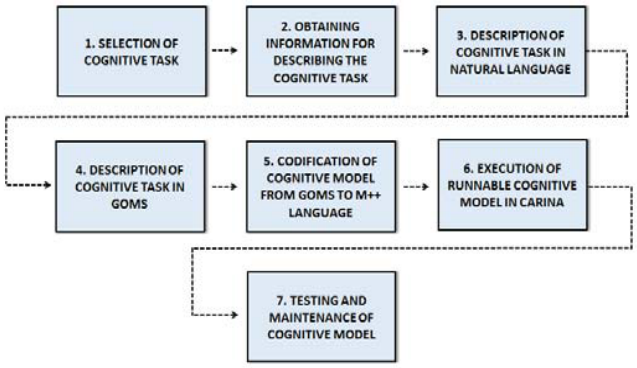


Fig 2. Cognitive Modeling Process in the Metacognitive Architecture CARINA

1. Cognitive Task Selected:

The problem is established as a cognitive task using natural language

2. Information Obtained to detail the Cognitive Task:

At this stage, the sources of information (obtained from experts, users or documentary sources) are selected in order to be able to describe the cognitive task.

3. Description of Cognitive Task in Natural Language:

This stage allow to specify the necessary requirements to solve the problem in expressions of the human language.

Below is the development of the phases:

Cognitive Task Selected

The cognitive task to be modeled cognitive task in natural language for the first 10 levels of the SOKOBAN game in the metacognitive architecture CARINA

Information Obtained to detail the Cognitive Task

The information that describes the cognitive task was obtained through two experts and from some documentary sources.

Experts	x
Knowledge Area	Cognitive computing
Number of experts	1 MSc. in Technology of Information Applied to Education 2 Lic. Computer science
Syntesis if cognitive task description	Develop of cognitive models for the solutions the levels of SOKOBAN'S game. This cognitive models looking for: (a) describe (b) predict, (c) and prescribe, the necessary actions for complete each level

Fig 3. Format to synthesize the cognitive task description when the *information source comes from experts*

Description of Cognitive Task in Natural Language

The following aspects constitute the cognitive model for the solutions the levels of SOKOBAN´S game: goals, Actions, Mental States and Production Rules. This cognitive model has as purpose main Goal show the process the boxes storage, this process is structured for several sub-goals that allow to achieve the construction of the solutions the levels of SOKOBAN´S game step by step. These Goals and sub-goals are presented below, considering the process of generating of solutions described described by [9]. The solution generation for the levels of SOKOBAN´S game is formed for two steps: Move and push a box. In Figure.4 is presented the goals and sub-goals that must be carried out for the construction of solutions the levels of SOKOBAN´S game.

Successful subject	Unsuccessful subject
Agent move to the right	Agent move to the right
Agent pushes the box 1 to the right	Agent pushes the box 1 to the right
Agent pushes the box 1 to the right	Agent pushes the box 1 to the right

"Fig 4. Description of the cognitive task in natural language."

Considering the above, the cognitive model for the solution of the SOKOBAN levels is

described below in natural language.

```
L.1
The agent is in its initial position
Step 1. The agent moves to the right.
Step 2. The agent move the box 1 to the right.
Step 3. The agent move the box 1 to the right.
```

"Fig 5. Description of the cognitive task in natural language for the level 1 in SOKOBAN."

```
L.2
The agent is in its initial position
Step 1. The agent moves to the right.
Step 2. The agent moves down.
Step 3. The agent moves down.
Step 4. The agent move the box 1 to the left.
Step 5. The agent moves to the right.
Step 6. The agent moves up.
Step 7. The agent moves up.
Step 8. The agent moves to the left.
Step 9. The agent move the box 2 down.
Step 10. The agent moves up.
Step 11. The agent moves up.
```

Fig 6. Description of the cognitive task in natural language for the level 2 in SOKOBAN."

```
Step 12. The agent moves to the left.
Step 13. The agent moves to the left.
Step 14. The agent moves down.
Step 15. The agent moves down.
Step 16. The agent move the box 2 to the right.
```

Fig 7. Description of the cognitive task in natural language for the level 2 in SOKOBAN."

```
L.3
The agent is in its initial position
Step 1. The agent move the box 1 down.
Step 2. The agent moves up.
Step 3. The agent move the box 2 to the left.
Step 4. The agent move the box 2 to the left
Step 5. The agent moves to the left.
Step 6. The agent move the box 3 up.
Step 7. The agent move the box 3 up.
Step 8. The agent moves down.
Step 9. The agent moves to the right.
Step 10. The agent moves to the right.
```

Fig 8. Description of the cognitive task in natural language for the level 3 in SOKOBAN."

```
L.4
The agent is in its initial position
Step 1. The agent moves down.
Step 2. The agent moves to the left.
Step 3. The agent moves to the left.
Step 4. The agent move the box 1 up
Step 5. The agent moves down.
Step 6. The agent moves to the right.
Step 7. The agent moves to the right.
Step 8. The agent moves up.
Step 9. The agent move the box 2 to the left.
Step 10. The agent move the box 2 to the left.
```

Fig 9. Description of the cognitive task in natural language for the level 4 in SOKOBAN."

```
L.5
The agent is in its initial position
Step 1. The agent moves down.
Step 2. The agent move the box 1 to the left.
Step 3. The agent move the box 2 up.
```

Fig 10. Description of the cognitive task in natural

language for the level 5 in SOKOBAN."

```
L.6   The agent is in its initial position
      Step 1. The agent move the box 1 up.
      Step 2. The agent move the box 1 up.
      Step 3. The agent moves to the right.
      Step 4. The agent moves up.
      Step 5. The agent moves up.
      Step 6. The agent moves to the left.
      Step 7. The agent move the box 1 down.
      Step 8. The agent move the box 1 down.
      Step 9. The agent move the box 1 down.
      Step 10. The agent move the box 1 down.
```

Fig 11. Description of the cognitive task in natural language for the level 6 in SOKOBAN."

```
L.7   The agent is in its initial position
      Step 1. The agent move the box 1 up.
      Step 2. The agent move the box 1 up.
      Step 3. The agent moves to the right.
      Step 4. The agent moves up
      Step 5. The agent moves up.
      Step 6. The agent moves to the left.
      Step 7. The agent move the box 1 down.
      Step 8. The agent move the box 1 down.
```

Fig 12. Description of the cognitive task in natural language for the level 7 in SOKOBAN."

```
L.8   The agent is in its initial position
      Step 1. The agent moves to the left.
      Step 2. The agent move the box 1 up.
      Step 3. The agent move the box 2 to the right.
      Step 4. The agent moves to the left.
      Step 5. The agent moves to the left.
      Step 6. The agent moves up.
      Step 7. The agent move the box 1 to the right.
```

Fig 13. Description of the cognitive task in natural language for the level 8 in SOKOBAN."

```
L.9   The agent is in its initial position
      Step 1. The agent move the box 1 to the right.
      Step 2. The agent moves down.
      Step 3. The agent moves to the right.
      Step 4. The agent moves to the right
      Step 5. The agent move the box 2 up.
      Step 6. The agent move the box 1 to the left.
```

Fig 14. Description of the cognitive task in natural language for the level 9 in SOKOBAN."

```
L.10  The agent is in its initial position
      Step 1. The agent moves to the right.
      Step 2. The agent move the box 1 down.
      Step 3. The agent move the box 2 to the left.
      Step 4. The agent moves down.
      Step 5. The agent move the box 1 to the right.
```

Fig 15. Description of the cognitive task in natural language for the level 10 in SOKOBAN."

V. CONCLUSIONS

In this paper, the cognitive process for the 10 first levels of the SOKOBAN game is described through a natural language.

On conclusion, with the development of this research, the modelling of the cognitive task in natural language for the 10 first levels of the SOKOBAN game.

VII. REFERENCES

[1] Fum, D., Del Missier, F., & Stocco, A. (2007). The cognitive modeling of human behavior: Why a model is (sometimes) better than 10,000 words. Elsevier.

[2] Olier, A. J., Gómez, A. A., & Caro, M. F. (2018). Cognitive Modeling Process in Metacognitive Architecture CARINA. In 2018 IEEE 17th International Conference on Cognitive Informatics & Cognitive Computing (ICCI* CC) (pp. 579–585).

[3] P. Langley, J. E. Laird, and S. Rogers, "Cognitive architectures: Research issues and challenges," Cogn. Syst. Res.

[4] Caro, M. F., Josvula, D. P., Gómez, A. A., & Kennedy, C. M. (2018). Introduction to the CARINA metacognitive architecture. In 2018 IEEE 17th International Conference on Cognitive Informatics & Cognitive Computing (ICCI* CC) (pp. 530–540).

[5] Espinosa López, Ana & Gomez, Adan & Cálao, Yina. (2019). NATURAL LANGUAGE FOR FACTOID-WH IN ENGLISH AS A FOREIGN LANGUAGE.

[6] Carmignani, Vittorio & Biasini, Mirko & Filianos, Panagiotis. (2019). Implementation of a Single and Multi Agent system for Goal-Box Problem.

[7] Gao, H., Huang, X., Liu, S., Wang, G., & Zhong, Z. A Sokoban Solver Using Multiple Search Algorithms and Q-learning.

[8] Venkatesan, A., Jain, A., & Grewal, R. (2018). AI in Game Playing: Sokoban Solver. arXiv preprint arXiv:1807.00049.

[9] Majadas Sanz, R. (2016). Resolución del juego Sokoban con técnicas de búsqueda (Bachelor's thesis).

[10] Suleman, Muhammad & Syed, Farrukh & Syed, Tahir & Arfeen, Saqib & Iqbal, Sadaf & Mirza, Behroz. (2017). Generation of Sokoban Stages using Recurrent Neural Networks. International Journal of Advanced Computer Science and Applications. 8. 10.14569/IJACSA.2017.080364.

[11] Caro, M. F., Josyula, D. P., Cox, M. T., & Jiménez, J. A. (2014). Design and validation of a metamodel for metacognition support in artificial intelligent systems. Biologically Inspired Cognitive Architectures, 9, 82–104. https://doi.org/10.1016/J.BICA.2014.07.002