HENRIQUE AJUZ HOLZMANN
JOÃO DALLAMUTA
(Organizadores)

ENGENHARIAS:

Criação e repasse de tecnologias

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APRESENTAÇÃO

Na sociedade atual, onde cada vez mais se necessita de informações rápidas e eficientes, o repasse de tecnologias é uma das formas mais eficazes de se obter novas tendências mundiais. Neste cenário destaca-se as engenharias, as quais são um dos principais pilares para o setor empresarial. Analisar os campos de atuação, bem como pontos de inserção e melhoria dessa desta área é de grande importância, buscando desenvolver novos métodos e ferramentas para melhoria continua de processos.

Estudar temas relacionados a engenharia é de grande importância, pois desta maneira pode-se aprimorar os conceitos e aplicar os mesmos de maneira mais eficaz. O aumento no interesse se dá principalmente pela escassez de matérias primas, a necessidade de novos materiais que possuam melhores características físicas e químicas e a necessidade de reaproveitamento dos resíduos em geral. Além disso a busca pela otimização no desenvolvimento de projetos, leva cada vez mais a simulação de processos, buscando uma redução de custos e de tempo.

Neste livro são apresentados trabalho teóricos e práticos, relacionados a área de engenharia, dando um panorama dos assuntos em pesquisa atualmente. De abordagem objetiva, a obra se mostra de grande relevância para graduandos, alunos de pós-graduação, docentes e profissionais, apresentando temáticas e metodologias diversificadas, em situações reais. Sendo hoje que utilizar dos conhecimentos científicos de uma maneira eficaz e eficiente é um dos desafios dos novos engenheiros.

Boa leitura.

Henrique Ajuz Holzmann
João Dallamuta

SUMÁRIO

CAPÍTULO 11

DYNAMIC FUZZY COGNITIVE MAPS DEVELOPTMENT TECHNIQUE INSPIRED IN ANT COLONY OPTMIZATIONS, SWARM ROBOTICS, AND SUBSUNCTION ARCHITECTURE

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Márcio Mendonça
Universidade Tecnológica Federal do Paraná
Programa de Pós-Graduação em Engenharia Mecânica (PPGEM)
Cornélio Procópio – PR
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Wagner Fontes Godoy
Universidade Tecnológica Federal do Paraná
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Marco Antônio Ferreira Finocchio
Universidade Tecnológica Federal do Paraná
Departamento Acadêmico de Engenharia Elétrica
Cornélio Procópio – PR
http://lattes.cnpq.br/8619727190271505

Carlos Renato Alves de Oliveira
Universidade Tecnológica Federal do Paraná
Departamento de Engenharia Mecânica
Cornélio Procópio – PR
http://lattes.cnpq.br/6825913217364076

Mario Suzuki Junior
Universidade Tecnológica Federal do Paraná
Estudante de Engenharia Elétrica
Cornélio Procópio – PR
http://lattes.cnpq.br/1190228107571752

Ricardo Breganon
Universidade Tecnológica Federal do Paraná
Programa de Pós-Graduação em Engenharia Mecânica (UTFPR)
Cornélio Procópio – PR
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Francisco de Assis Scannavino Junior
Universidade Tecnológica Federal do Paraná
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Londrina - Pr
http://lattes.cnpq/4411484670091641

Vicente de Lima Góngora
Faculdade da Indústria SENAI Londrina
Londrina – PR

ABSTRACT: This work presents a cooperative architecture for autonomous agents based on Dynamic Fuzzy Cognitive Maps (D-FCM), an

evolution of Fuzzy Cognitive Maps (FCM), emphasizing that FCM is an evolution of Cognitive Maps. This architecture develops an autonomous navigation system for mobile terrestrial robots, including learning capability, self-adaptation skills, and behavior management. The navigation system developed adopts a multi-agent approach, based on Rodney Brooks' subsumption architecture, which allows for hierarchical decision-making, with actions and parallel processing. Reinforcement learning is used to automatically tune the system, allowing the D-FCM to be self-adaptive. A bioinspired strategy inspired by the behavior of ants is used for indirect communication between agents and simulated in a virtual environment, comparing it with another cooperation method based on navigation data. This work ends with a discussion of the results. Furthermore, it finally concludes and addresses future work.
KEYWORDS: Dynamic Cognitive Maps, Cooperative Autonomous Agents, Subsumption Architecture, Swarm Robotics, Multi- agent systems.

DINÂMICA FUZZY COGNITIVA DE MAPAS TECNICA DE DESENVOLVIMENTO INSPIRADO NA OTIMIZAÇÃO DA COLÔNIA DE FORMIGA, ROBÓTICA DE ENXAME E ARQUITETURA SUBSUNÇÃO

RESUMO: Este trabalho apresenta uma arquitetura cooperativa para agentes autônomos baseada em mapas cognitivos difusos dinâmicos (D-FCM), uma evolução dos mapas cognitivos difusos (FCM), enfatizando que FCM é uma evolução dos Mapas Cognitivos. Esta arquitetura desenvolve um sistema de navegação autônomo para robôs terrestres móveis, incluindo capacidade de aprendizagem, habilidades de auto adaptação e gerenciamento de comportamento. O sistema de navegação desenvolvido adota uma abordagem multiagente, baseada na arquitetura de subsunção de Rodney Brooks, que permite hierarquicamente a tomada de decisões, com ações e processamento paralelo. O aprendizado por reforço é usado para sintonizar automaticamente o sistema, permitindo que o D-FCM seja auto adaptativo. Uma estratégia bioinspirada inspirada no comportamento de formigas é utilizada para comunicação indireta entre agentes e simulada em um ambiente virtual, comparando-a com outro método de cooperação baseado em dados de navegação. Este trabalho termina com uma discussão dos resultados. Além disso, finalmente conclui e endereça trabalhos futuros.
PALAVRAS-CHAVE: Mapas Cognitivos Dinâmicos, Agentes de Navegação Cooperativos, Arquitetura de Subsunção, Robótica de enxame, Sistema Multiagentes.

1 | INTRODUCTION

Research in autonomous robotics, particularly collective robotics using biologically inspired systems by social insects (collective intelligence), is known in the literature. For example, works on swarm robotics using a group of robots inspired by insect colony behavior can be found in (Mohan and Ponnambalam, 2009).

The term "Swarm Intelligence" refers to sophisticated collective behavior that can emerge from the combination of many simple individuals, each operating autonomously (Sharkey, 2006). Thus, Swarm intelligence is "a property of systems of non-intelligent robots exhibiting collectively intelligent behavior".

In this work, mobile robots with exploration abilities share the information with other mobile robots, and the method used to share the information is inspired by the behavior of ants, implementing concepts of artificial pheromone.

Generally, Artificial Intelligence (AI) has application in various areas of knowledge such as neuro-biological, mathematics, and computer science. The research area of an intelligent system is aimed at developing computational methods that try to imitate or approximate the capacity of humans being to solve problems. These new methods attempt to emulate the ability of humans to cope with very complex processes based on inaccurate or approximate information. However, this information can be obtained from the specialist knowledge and / or operational data or behavior of an industrial system (Passino and Yurkovich, 1997).

There are studies in the literature that uses heuristic knowledge for modeling decision making in autonomous navigation through fuzzy systems; for example: Astudillo et al., 2006; Min et al., 2006; Mendonça, 2011).

Researches in autonomous robotics, in particular collective robotics using biological systems inspired by social insects (collective intelligence) are known in the literature (Bayindir and Sahin, 2007). Works about collective robots “Swarm Robotics” are listed as follows. Parker (2008) uses robots groups inspired by insect colony behavior to manage agents at their function’s execution exploration in environment. The application of techniques and/or concepts of collective robots are related to autonomous system and multi-agent systems. The theory of multi-agent systems is usually required to solve problems in dynamic and unpredictable environments. In such circumstances, a capacity to learn is particularly important for environment with rapid change (Wooldridge and Jennings, 1995). From autonomous agents’ theory, particularly cooperative autonomous agents, it should be emphasized the ability of autonomy of the agent, alone and/or in a group, i.e., the success in different settings without human intervention (Russel and Norvig, 1995).

A multiple agent’s control architecture for swarm robotics was developed in Vasile, Pavel and Buiu (2011), where a “man-swarm” interface was proposed. This architecture allows an operator to monitor and guide a swarm of robots to complete certain tasks through an agent by a GUI (graphical user interface). The robots are divided into local and social agents, where the local agents have the function to move, avoid obstacles and location. The control algorithm is implemented in the social agent based on an adapted version of PSO technique, a method developed by Kennedy, Eberhart and Shi (2001) to simulate behaviors of swarm, insect colonies and flocks of birds. The work of Mendonça et al. (2013) uses a DCN (Dynamic Cognitive Networks) for navigation and sharing memory path in unknown scenarios with explorer robots.

This paper discusses problems with sequential decisions in partially or totally unknown environment with multiple objectives. At this level of complexity, the proposed architecture presents learning, tuning and adaptation capacity, action management, and

finally, at the highest level of the D-FCM (Dynamic-Fuzzy Cognitive Maps) architecture.

Finally, a concept explored in this work is collective intelligence, in which the architecture uses the agent capacity of evolution. Evolution is conceptually different from learning because an agent can only evolve if it inherits knowledge from another agent, while learning the agent only needs himself (De Castro, 2007).

This paper is organized as follow: Section 2 presents a brief discussion of Fuzzy Cognitive Maps. Section 3 describes briefly the architecture of the D-FCM. Section 4 presents the simulated initial results. Section 5 shows the conclusions and finish the paper.

2 | FUZZY COGNITIVE MAPS

Cognitive maps were first presented by Axelrod (1976) in order to express the cause-effect relationships of the elements of an environment in binary values. Fuzzy cognitive maps have enjoyed a visible position in fuzzy modeling as graph-oriented models describing relationships among concepts (Pedrycs; Homenda, 2013). Fuzzy cognitive maps are fuzzy signed digraphs with feedbacks, and they can model the events, values, goals as a collection of concepts by forging a causal link between these concepts (Kosko, 1986).

As mentioned in (Papageorgiou and Salmeron, 2013), there is an enormous interest in FCMs and this interest on the part of researchers and industry is increasing, especially in the areas of control (Stylios and Groumpos, 1998; Stylios and Groumpos, 2004; Papageorgiou, Stylios and Groumpos, 2006), business (Lee and Ahn, 2009; Glykas, 2013), medicine (Papageorgiou, Roo and Huszka, 2012; Papageorgiou and Froelich, 2012; Douali et al., 2011), robotics (Motlagh et al., 2012a, 2012b), environmental science (Kok, 2009; Ramsey et al., 2012; Acampora and Loia, 2011) and information technology (Buyukozkan and Vardaloglu, 2012; Lee and Lee, 2012).

In this work the D-FCM, one of the proposed evolutions of the FCM, is developed directly by experts' knowledge. In other words, the concepts and relationships between them are modeled by heuristic or empirical knowledge of experts.

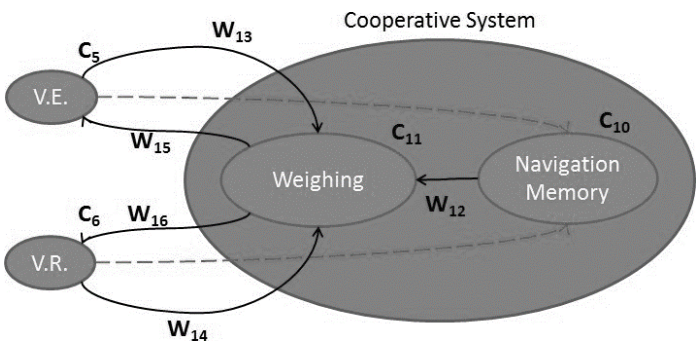

Figure 1 – Simplified D-FCM model for data processing in trajectory sharing strategy.

Figure 1 shows a simplified version of this trajectory-sharing strategy. Where the concepts V.E. and V.R. are related to the outputs turn left and turn right, respectively. The variables W13~16 represent the causal relationships between concepts.

For this method, two new concepts were implemented to the D-FCM, the Navigation Memory (C10) and Weighting (C11). The concept C10 saves the navigation data and shares them. It is noteworthy that there is no causality between the concepts C5/C6 and C10, represented by the red dotted line, that only acquire the data to be saved in the memory. The concept C11 treats and weighs the information from the outputs C5 and C6 with C10. After this treatment is done, C5 and C6 receive new values.

The second strategy is inspired in ant´s colony communication for foraging, in which the ant releases a chemical (called pheromone) to demarcate the path traveled. Transmitting and receiving data implicitly on the path taken by the colony. In other words, the agent will travel through the environment and leave demarcations (pheromones) about his path taken in the environment, and other agent interpret that pheromone and use it to aid his decision making.

To implement this strategy, three new concepts were added to the D-FCM, the concept of Pheromone Release (C10), Weightings (C12) and Pheromone Detection (C11). In addition, two new concepts of selection are added, WS5 and WS6. The figure 2 shows a simplified model of this method. Where the concepts S.E., S.F. and S.D. are related to the left, frontal and right sensors, respectively. The black dotted lines imply in concept values that are used only to select the state of the D-FCM.

The C10 concept manages the pheromones to be released by the agent, if the selection criteria are met (WS5). The C11 concept is a new “input” variable for the D-FCM, similar to the input sensors, this concept detects the pheromones left by other agents. These pheromones are considered as secondary targets, not being necessary for the agent to capture it, however, helping in the decision-making process of the system, anticipating obstacle avoidance maneuvers or on capturing targets. A selection system between the concepts C11 and C12 will alter the causal relationship of W12, referring to its intensity, given by the selection rule WS6. The C12 concept is similar to the Weighting concept from the trajectory sharing strategy. This concept will weigh the information acquired by the outputs C5 and C6 and the information from the pheromone reading. C5 and C6 will receive new values after the treatment is done.

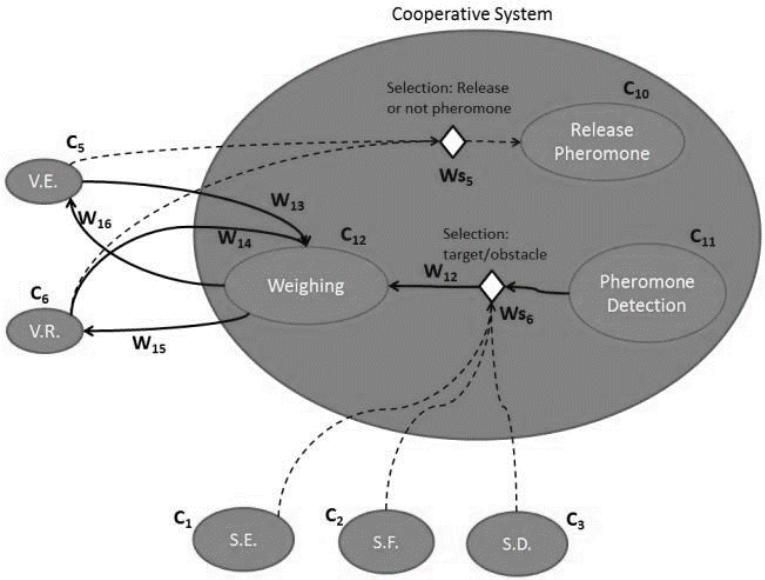

Figure 2 – Simplified D-FCM model for data processing in pheromone sharing strategy.

A counter is also inserted into WS5, specifically to assist when the state of release pheromone is triggered, giving it some periodicity. This counter will decrease in values that are directly related to the intensity of the outputs V.E. and V.R., in other words, the value subtracted from the counter will be higher when V.E. and V.R. are high, and lower when the V.E. and V.R. are low. For instance, some of the rules for the selection methods WS5 and WS6 are:

- (Ws5) **IF** (V.E. and V.R. are high **AND** counter is low) **OR** (counter is very low) **THEN** Pheromone Release is triggered.
- (Ws6) **IF** detected an obstacle **THEN** the weight W12 is medium.
- (Ws6) **IF** detected a target **THEN** the weight W12 is low.

Briefly, the cooperative system covers techniques or models for cooperative navigation. The strategy used for this work was inspired by Swarm Robotics. Therefore, the agent will use the experience from another agent as follow: the first agent passes and leaves a pheromone in the environment, or a data stored in a navigation memory, the next agents will use this “navigation experience” in their decision making.

In the test scenarios there are fixed, dynamic and unexpected (arise during the course) obstacles, as will be demonstrated in the next topic. Therefore, in a simplified form, the expectation of the Swarm Robotics concepts applied in the D-FCM architecture aims to increase the performance of a group of agents, performing tasks with higher level of complexity.

3 | RESULTS

A simulation environment with 2-D animation was developed to test and validate the proposed cooperation navigation system. In the simulation environment, the trail with three colors symbolizes the mobile robot. The light "+" signs represent the static and unexpected obstacles, the strong "*" sign represents the dynamic obstacle and the "." sign represent the pheromones left by the agent, they are represented by two colors, yellows for pheromones released by other agents and green for the ones release by the agent. The "Δ" represent the targets. In the simulation, a track or trail is used to show the trajectory of the dynamic obstacle.

The results are shown in the following figures. In these figures, the graph shows a scene in the plane XY with a starting point (15, 0) and end point (0, 205) of the robot trajectory. The graph also shows the dynamic path traversed by the agent. The flaws in the trajectory represent the speed ups, when the sensors don't detect any obstacles or targets, the robot accelerates. In all experiments was found that the robot reaches the destination point within a [-8, 8] range. Figure 3 shows the virtual environment used for the simulation.

In these experiments, an unexpected dynamic obstacle appears on the scenario when the robot is passing by the coordinates (6, 88), in this region there is a critical situation. The presence of dynamic obstacles increases the difficulty of the strategy employed by the controller Right after moving to divert the mobile obstacle, the agent faces a "wall" of obstacles created by the unexpected obstacles. Similarly, the mobile obstacle traverses a linear path between the points (-11, 86) and (3, 86), so that the mobile robot will need to decide on the action to be taken.

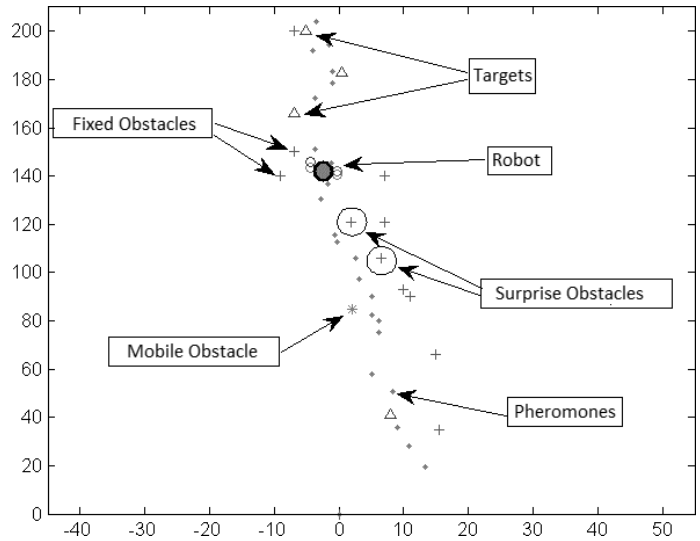

Figure 3 – Simulated Environment.

Figures 4, 5 and 6 show the navigation path using the first cooperation method, which the information stored in a memory about the path taken by previous agent. Figure 4 shows the simulation result of a first agent navigating through the unknown environment.

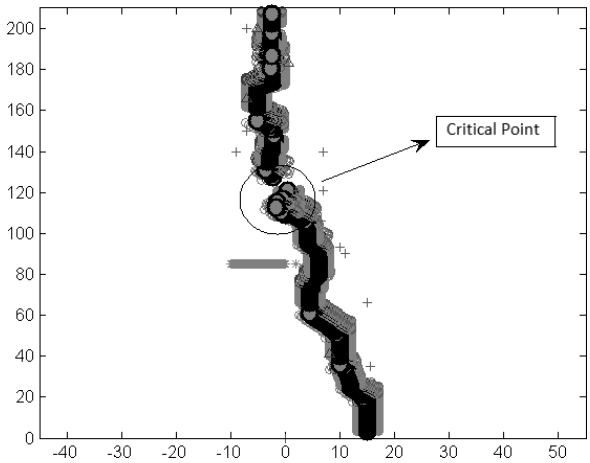

Figure 4 – First agent – D-FCM with trajectory sharing.

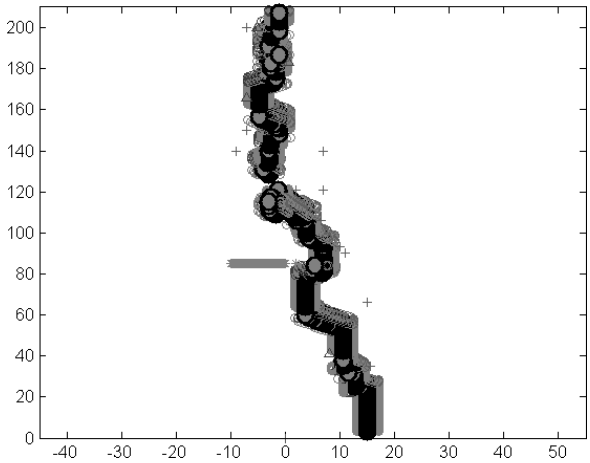

Figure 5 – Second agent – D-FCM with trajectory sharing.

There is a critical point near the point y=110, where the agent triggers the reverse state to divert the obstacle. The agent must also perform the reverse maneuver to divert the obstacle in figure 5 as well. Figure 6 shows the trajectory of the third agent. This agent is able to bypass the obstacles in the critical point (y=110) without triggering the reverse state, but he does not reach the first target. It is noticed also that the trajectory of the agents is smoothed comparing the first and the third agent trajectories.

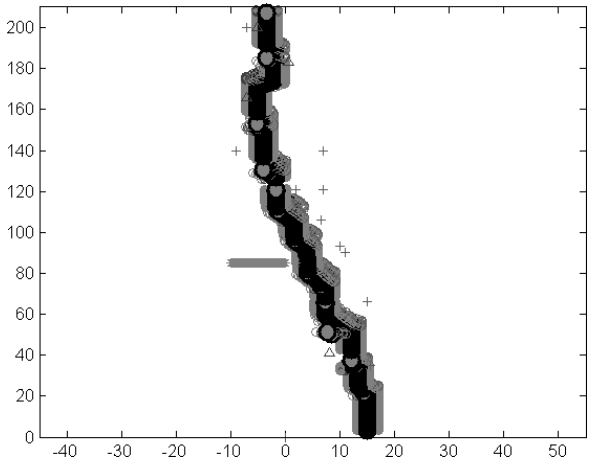

Figure 6 –Third agent – D-FCM with trajectory sharing.

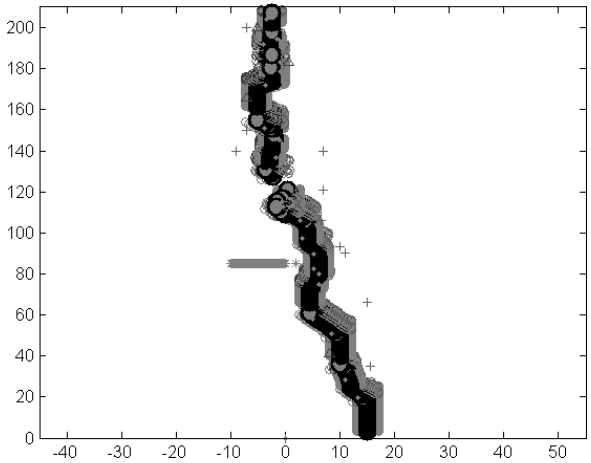

Figure 7 – First agent – D-FCM with Pheromone sharing.

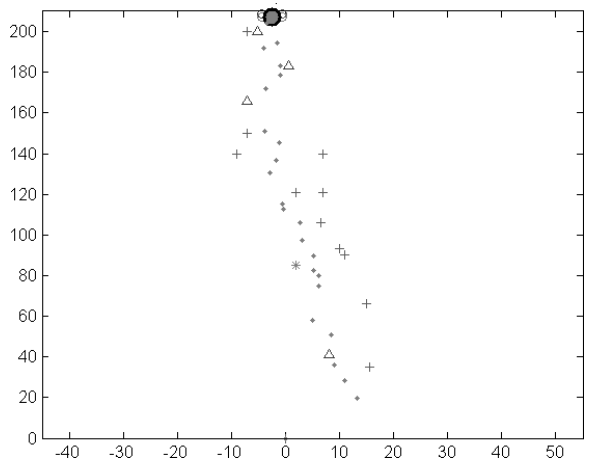

Figure 8 – First agent – D-FCM with Pheromone sharing - Trail of pheromone.

Figures 7, 9 and 11 show the results obtained by the cooperation method using pheromones. Figures 8, 10 and 12 shows the trail of pheromones left by the agent. The agents in the figure 4 and 7, being a first navigation, both agents don't have any shared information, so their trajectories are the same.

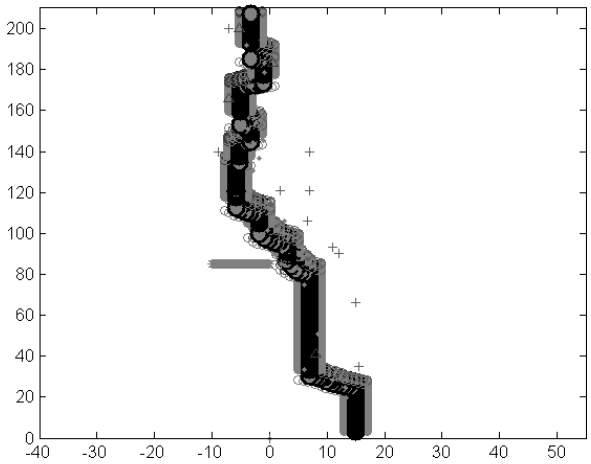

Figure 9 – Second agent – D-FCM with Pheromone sharing.

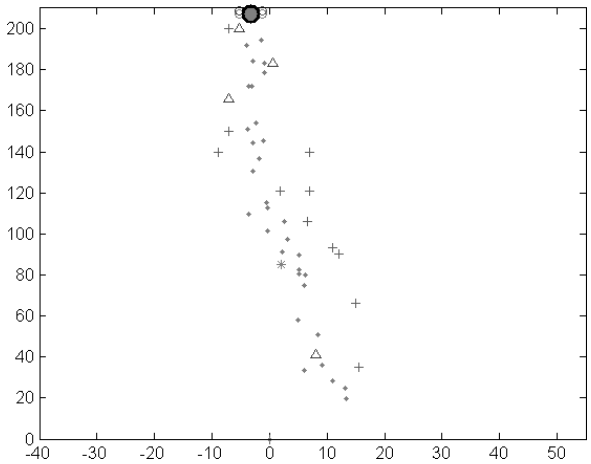

Figure 10 – Second agent – D-FCM with Pheromone sharing - Trail of pheromone.

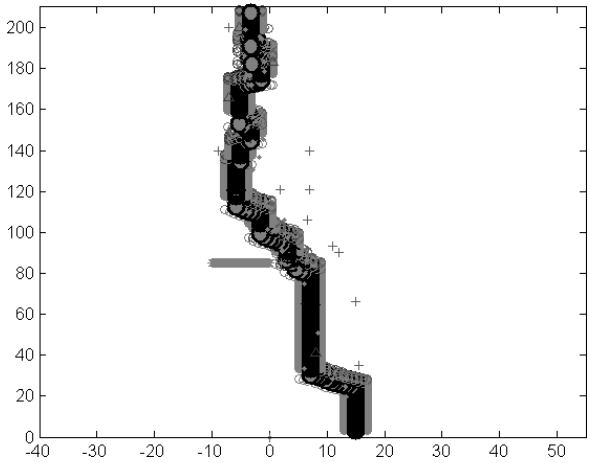

Figure 11 – Third – D-FCM with Pheromone sharing.

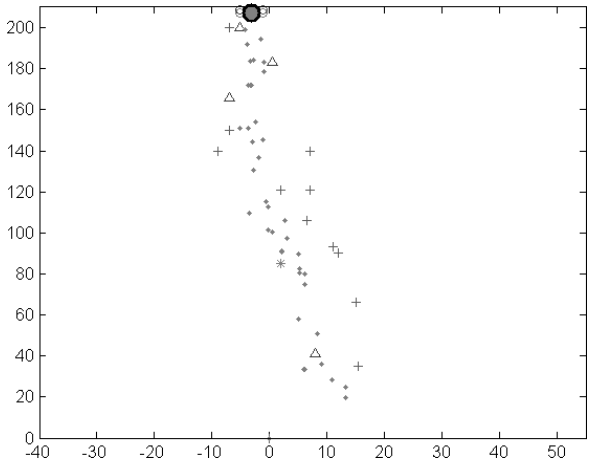

Figure 12 – Third agent – D-FCM with Pheromone sharing - Trail of pheromone.

4 I CONCLUSION

This paper presents an architecture for cooperative autonomous agents based on dynamic-fuzzy cognitive maps and inspired by concepts of Swarm Robotics. The subsumption architecture proposed allows decision-making in a dynamic environment, three different mapping layers that model different types of knowledge. These layers work together to contribute to the successful implementation of the strategy. Moreover, training methods are used for the calibration of offline models and experience sharing among agents. Finally, a reinforcement learning algorithm is also used for model tuning.

The results presented indicate that the D-FCM model demonstrated a capacity for learning, adaptation, and cooperation, allowing the agent to be rational, i.e., during the navigation, the inferences of specific sequences of actions allowed the agent to achieve its

goals (explore the environment, avoid obstacles and capture targets) with good performance.

Moreover, the capacity of the exploration group tends to be increased when there is a collaboration between team members. The purpose of this study was achieved by exploring an unknown environment only with sensor detection distance between objects without the use of a camera.

Further studies aim to improve the cooperative system, to allow the coexistence of multiple agents performing tasks in groups. New features should also be added, such as power management.

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