Mobile cooperative robotics through humanoid agent imitation

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Abstract

This article presents a new development in cooperative robotics based on the imitation principle, in which a humanoid mobile agent acts as a master in the sequence of lateral displacement in order to move an objective load, coordinating other tree agents through zigbee communication, in a Token-ring network. The movement of every agent is determined by the gravity center (GC) and the movements reply of the master, in such a way that two of them acts by mirror imitation when confronting the master and the third one acts by direct imitation when standing on its side.

keywords: cooperative robotics, Bioloid, imitation, inter-robot communication.

Resumen

En este artículo se presenta un desarrollo en robótica cooperativa basados en el principio de imitación en la que un agente móvil tipo humanoide actúa como maestro en la secuencia de desplazamiento lateral para mover una carga objetivo, coordinando a otros tres agentes por medio de comunicación zigbee, en una red tipo Token-Ring. El movimiento de cada agente está determinado por el centro de gravedad (CoG) y la réplica de movimiento del maestro de forma tal que dos de ellos actúan por imitación espejo al encontrarse enfrentados a este y el tercero por imitación directa al encontrarse al lado.

Palabras clave: robótica cooperativa, Bioloid, imitación, comunicación entre robots.

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1. Introduction

Nowadays cooperative robotics is subject of study, given his application in several knowledge fields, including human activities support [1] [2]. One of the learning techniques created to achieve interaction between each of the robots (agents) is given by the imitation of an activity or sequence of movements [3] [4].

The tasks that several agents can do are defined by the interaction between these ones and the role performed by them. In order to achieve a common objective, it is necessary to establish movement strategies that define displacement trajectories for each agent [5], communication strategies in order to feed back the action realized by each agent and learning strategies [6] that allows achieving autonomous operation.

Within the sphere of robot development, the ROBOTICS INC [7] COMPANY offers a set of humanoid robots known as BIOLOID, which have been using in robotic control applications in the teaching field [8], mobile robotics investigations [9], and human behavior replication [10], among others. This kind of robots is suitable in uses within cooperative robotic applications, especially on human behavior imitation tasks [11].

In this article the development of an application in cooperative robotics between BIOLOID agents is presented, agents which use geometrical analysis technique (GAT) in order to establish the predefined movement sequence of the master robot, which via wireless communication transmits the orders to the other 3 agents. Each agent will replicate that movement in a direct or mirror way, with respect to the gravity center (GC), moving a load cooperatively.

The communication established between the agents, replicates the token Ring network topology, in which a permission transmission signal, allows to inform the master that such agent achieved his group movement task, only if it could generate the movement given his GC.

This article has the following structure: section 2 describes the movement technique GAT, section 3 describes the control system used in the cooperation between agents, in section 4 the result analysis is presented and finally section 5 describes the achieved conclusions.

2. Movement morphology

The lateral displacement movement analysis technique used in each of the Bioloid robot agent, consists in the geometrical analysis of the agent, which is described in detail in [10]; Such movements are initially programed in the master agent, which performs displacements to the right and the slave agents imitates exactly in the same direction (direct form) or in the opposite direction if these are in front of the master (mirror). Fig. 1 describes the geometrical analysis that derives in the lateral displacement of the agent towards right, where it starts from a rest position (A) and then it executes the movements within the equilibrium ranges, given the robot geometrical structure (steps B, C and D).

From the given angles the variability range of the gravity center adopted by the agent in the movement sequence, is established through the equation 1, in such a way that if friction or an obstacle causes the agent to exceed this range, it will return to the previous position and notifies the master. Fig. 2 shows the sequence applied over the agent.

$$y' = \frac{\sum_{j=1}^{F} \mu_{B'}(y_j) \cdot y_j}{\sum_{j=1}^{F} \mu_{B'}(y_j)} \quad (1)$$

For each one of the agents, lateral movements are implemented with four positions, each one of these including movements from one or more actuators, as shown in the flow diagrams of the Fig.3 for direct action and 4 for mirror action. Fig. 5 presents the angles induced over the humanoid legs for mirror actions regarding the master, derived from the geometrical analysis. The influence of these angles on the agent actions are presented at Figure 6.

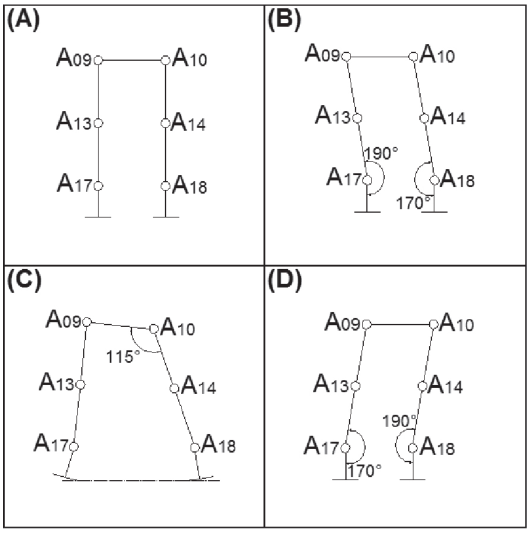

Figura 1: GAT of lateral movement towards right.

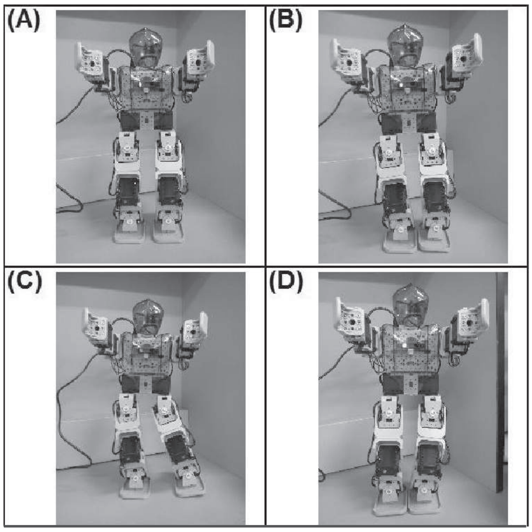

Figura 2: Lateral movement towards right.

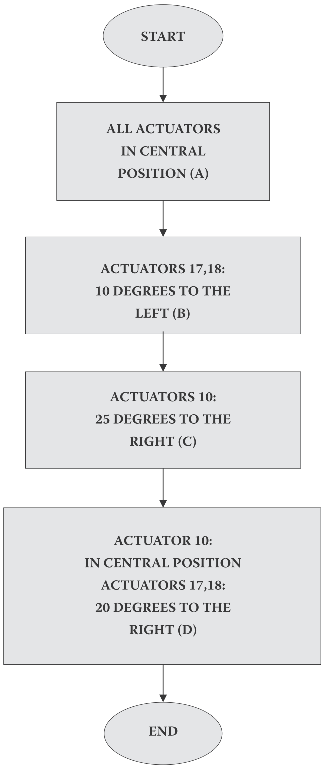

Figura 3: Lateral movement towards right diagram.

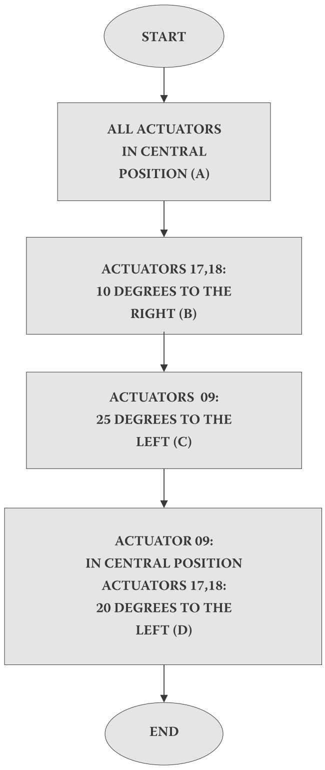

Figura 4: Lateral movement towards left diagram.

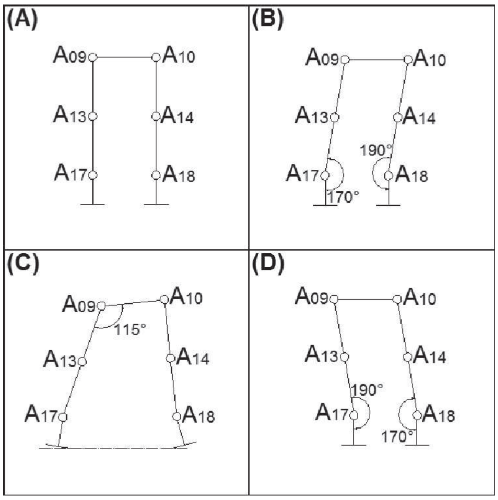

Figura 5: GAT of lateral movement toward left.

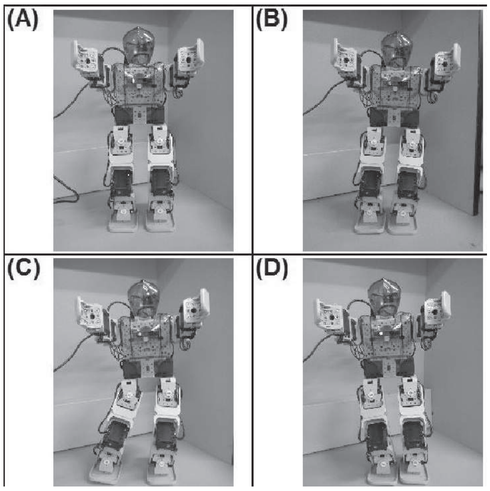

Figura 6: Pictures from lateral movement towards right.

3. Control system

The coordination system of the cooperative work between agents, it's determined by a communications system based on the zigbee protocol, in which the master robot initially guides the sequence of movements of the slave agents, identify them by an ID and send them the respective movement sequence, either direct or mirror, as shown in the flow diagram of the Figura 7.

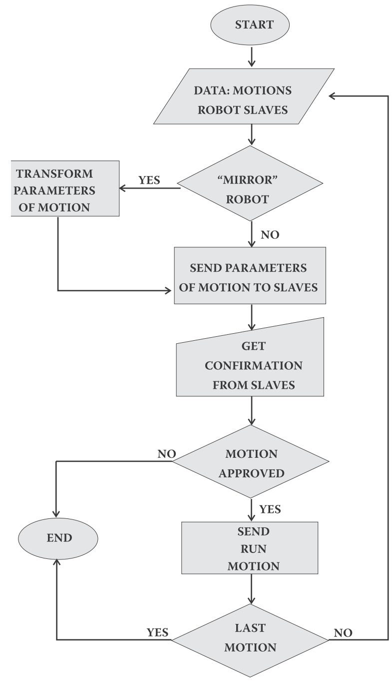

Figure 7: Master robot internal operation diagram.

Each one of the slave agents stores the received sequence imitating in either direct or reflected way, the movements of the master, if the same sequence appears for more than five times (reinforcement learning), each agent sends a learning code to the master, who in turn executes the listening mode, this means that the master sends only one code (Token) so that every agent takes it and if this agent has anything to send this can transmit, else this agent sends the token to the next one, until it returns to the master (Ring), as shown in Figure 8.

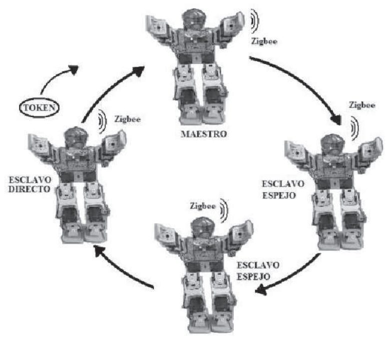

Figura 8: Cooperative network scheme.

Fig.9 shows how each agent operates. The sequence is interrupted if the movement of any of the agents it is no possible due to some obstacle or by the loss of the gravity center. When the master receives an incoming data from the slaves, it sends an interruption request in order to stop the movement sequence.

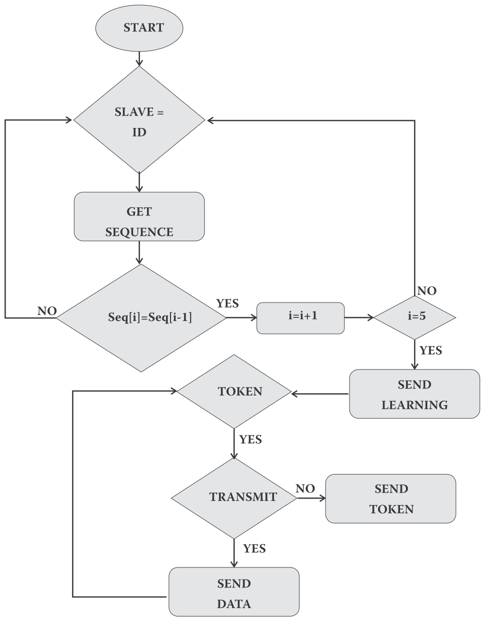

Figure 9: Internal operation diagram of the slave agent communication process.

4. Results analysis

The developed algorithm was initially tested with the coordination between two agents, the movements sequence appears in Figure 10.

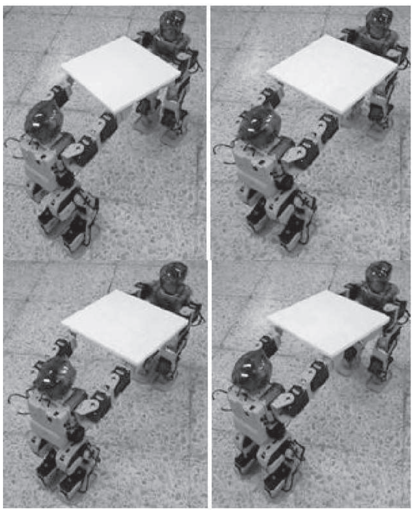

Figure 10: Movement sequence with two agents.

The response times of the communication process allows to maintain coordination between both agents, being the friction with the floor the only factor for synchronism loss, this cause an angular restriction of the programed movement, which in turn creates a perpendicular displacement of each agent, making them to move away from each other, although in the same direction as shown in Figure 11.

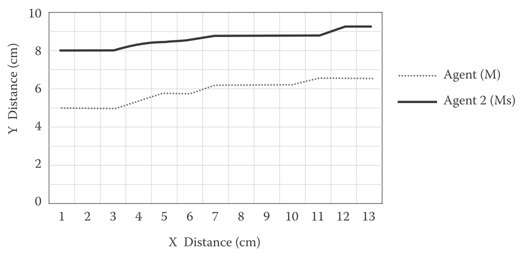

Figure 11: 2 agents movement Registry.

Agent 1 corresponds to the master (M) and agent 2 to the slave operating as a mirror (Ms). In this figure it is clear that the displacement doesn't describe a straight line and that friction and reaction effects of each agent, makes them to describe a movement in the same direction but no uniformly. Figure12 shows the results when the algorithm is applied on 4 agents: the Master (M), the slave operating in direct mode located to the left side (Ds) and the two agents that operate as mirror slaves of the master (Ms) while the reinforcement learning task is present.

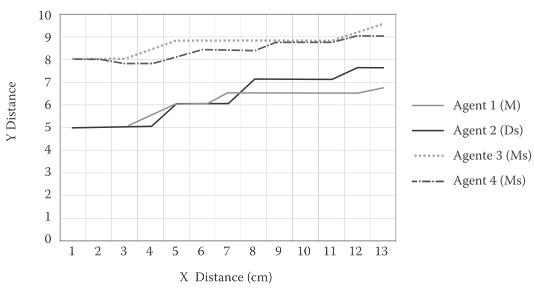

Figure 12: 4 agents movement Registry.

The effect is exactly the same respect to the displacement, although, different for each agent, given the characteristics of the object which will be carried by the agents over their arms, still allows the cooperative displacement of such object, due to the coordinated movement of each agent in the same direction.

5. Conclusions

Through the use of geometric analysis technique of the Bioloid Robot, it is possible to define the movements ranges that allows the displacement, but maintaining a gravity center that provides displacement stability.

Applying the basic concepts of Token Ring networks, an efficient interaction method between agents was established, given the reinforcement learning, the communication time decrease considerably, which will probably allow an interaction with a greater number of agents.

When analyzing the displacement of each agent, it becomes evident the need of additional sensors, that allow course correction for each agent and gives uniformity to the displacement between every other agents.

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