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Framework for development algorithmics swarm elligence to applications in supply warehouse

Marco de desarrollo algorítmico de inteligencia de enjambres aplicada en almacenes

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Abstract: Intelligence biological Swarms has had a high development in different fields of applied engineering, as in the case of collaborative robotics where, bio-inspired algorithms seek to mimic emergent behaviors that happen in developed nature, when members of a swarm interact locally to generate intelligence to solve a problem in a self-organized manner. Among the applications in fields of engineering is the development of automated processes in environments throughout the production chain of companies. That is why this article seeks to provide a framework in warehouse automation picking, applying artificial intelligence algorithms, specifically the technique of swarm intelligence, which enables the use of agents that interact collaboratively (zero collisions, handling objects, etc.) and competitive (lower energy expenditure for development activities), under a scheme of communication environment – agent – agent.

Keywords: Warehouse, swarm intelligence, stigmergy, artificial intelligence, agents.

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Resumen: La inteligencia de enjambres biológicos ha tenido un alto desarrollo en diferentes campos de la ingeniería aplicada, como es el caso de la robótica colaborativa en donde, a través de la bioinspiración, se desarrollan algoritmos que buscan imitar los comportamientos emergentes que suceden en la naturaleza cuando interactúan los integrantes de un enjambre de manera local, generando una inteligencia para resolver una problemática de manera auto-organizada. Dentro de las aplicaciones en campos de la ingeniera está el desarrollo de procesos automatizados en ambientes de toda la cadena productiva de las empresas. Es por ello que este articulo busca dar un marco de referencia en la automatización de almacenes de picking, aplicando algoritmos de inteligencia artificial, específicamente la técnica de inteligencia de enjambres, que posibilite el uso de agentes que interactúen de forma colaborativa (cero colisiones, manipulación de objetos, entre otras) y competitiva (menor gasto de energía para el desarrollo de actividades), bajo un esquema de comunicación ambiente – agente, agente.

Palabras clave: Sistema de almacenamiento, inteligencia de enjambres, estigmergia, inteligencia artificial, agentes.

1. Introduction

In collaborative robotics, various techniques have worked, given the degree of complexity [1] of the tasks, and objectives to fulfill and restrictions that exist. Some search algorithms [2] and explorations are inspired by behavior of organisms. This is the case of cellular autopoiesis, where the entity of the cell seeks and maintains an exchange with its environment to survive and remain in a stable state.

The case also colonies of ants and swarms of insects that interact with hierarchical architectures, where individuals are autonomous and tasks are distributed generating a group self-sufficiency, to develop a set goal, and as the interaction environment is changing, the ants are adapting to it. [3]

We also observed for collaborative robotics techniques from control systems and feedback. [4] Wherein the architecture can be hierarchical most of the time; as an individual or agent distributing tasks, or a program of set rules to follow to achieve the objective or establish certain amount of restrictions.

In the case of hierarchical architecture, systems begin to see individuals or more complex agents where they have some autonomy and restrictions, and when they interact with other agents or individuals, complex behaviors emerge.

Here we see that collaborative systems are complex and cannot be separated, because their components are interdependent.

These types of dynamic, collaborative individuals with hierarchical architectures will be based on their interactions and will describe their behavior over time.

Emerging behaviors in a system are global properties that arise from the interaction of individuals locally. [6]

If we explore this topic we see that emergent behavior is not present in individual functions or agents, if not manifested only when working collaboratively among agents. It is necessary, as we generate a collaborative system or are integrated by several individuals, for a system to describe desired emergent behavior, so that their interactions will help to meet the objectives, such as exploration, allocation, and fulfillment of tasks within a system.

This is where we come to the definition of self-organization, where it is desired that the system of agents or individuals reach a desired state.

That is why self-organization is used to talk of swarms, flocks of birds, traffic management, and many other systems, where local interactions of individuals result in an overall pattern or pattern of behavior. [7]

To interpret the self-organization in collaborative systems, we refer to the dynamics of the system to the desired configuration to comply with certain conditions under a certain amount of restrictions.

This is the case of Homeostasis, which describes the regulation of body functions. If we review classical control systems, we want the dynamics of a system kept within ranges of stability, even if environmental disturbances or noises alter the behavior of the system.

In this case, a living system will always try to stay in areas that maintain survival. We define homeostasis as the ability of an organism to remain in a stable state of operation for internal or external change.

For its Ashby [8] part, it is proposed that homeostasis involves an adaptive reaction to maintain essential variables within a range.

Thus a dynamic system has a high homeostatic capacity if it is able to maintain its dynamics at a desired state without the change have to do is damaged or ceases to exist, to adapt and regulate itself over time. This is a clear example of self-organization used in a system.

As described above, this research is to obtain an approximation to a heuristic model that can respond to synch, collaborative and autonomous movement of natural biological swarms, to generate networks of agents (robots) self-organized meeting a goal and an intelligent response; without tele-operation or a previous assignment of tasks..

Storage systems today are critical and complex by the variety and volume of products that must manage [9]. For this reason it is essential to have strategies, techniques and methodologies to ensure the efficiency of time, movement, and clearance of different product categories through its permanence in a storage system.

For this reason, it is necessary to start this research with the review of multi-agent architectures which show results of performance analysis, which is the best suited for the development of the research project review. Additionally, it is necessary to review the different architectures of intelligence of swarms or group to recognize which are the best in the search for optimal answers in the space of solutions, that whereas the solutions to stay away from local optima and to find the optimum global.

It is vital to ensure local interactions between agents, as types of assertive communication are like the case of stigmergy, quorum sensing, etc. These types of communications are biological communications through which agents - organisms communicate among themselves and in their biological environment. Additionally, you need to review types of wireless communications in order to review the costs associated with energy in communication between agents and comparing this type of artificial communication can offer improvements over biological communications.

The study is considered necessary to the working environment, as this lets us define the different performance measures that are to be obtained in the multi-agent system based on the objective pursued by the self-organized swarm.

In addition, it seeks to make a study of different algorithms in the literature to find optimal answers within the search space of solutions (solution Search width, depth solution Search, Heuristics, etc.)

Among the conclusions it is set to finalize describe the requirements and constraints of the problem own research and requires a multiple simulations algorithm to know its efficiency in solving research.

Considering the above need to develop an algorithm that allows the movement of resources in an environment storage system, using intelligent agents to make decisions autonomously and in a coordinated manner, giving priority to the objective required by the resource, or failing is observed the movement or movements coordinated collaborative work.

1.1. Point of View

Automated techniques have been implemented, ensuring real-time travel routes, monitoring and traceability of the products thereof [10]. But that does not necessarily offer the optimal response when you need to establish mechanisms for reasoning about the problems that arise in the administration of warehouses, as distribution of resources according to the needs of movement, time and product characteristics [11] and [12].

This is where part of this research, which by self-organizing strategies, generate responses learning agents with decisiveness to provide a collaborative response capable of distributing the amount needed to move, dispose, and store product types.

Application examples can be observed in systems with high flow of resources and where they must ensure the effectiveness of the objective to achieve. One of them can be seen in the articulated transport system located in the city of Bogotá (Transmilenio). This system generates a high degree of storage as well as a high degree of moving resources (people or users). In this way, we can see algorithms or collaborative strategies within the system that are not according to how it should move or self-organize within the system to enter and then leave the same without affecting other resources. For this, an algorithm of self-organization, responding to movements organized and group resources needed at a specific time. Additionally, intelligent answers behaviors of other agents or resources to be generated can be grouped or leave certain position to another, avoiding collision and immobility of other resources or people who need to leave the storage system [13].

This case is repeated in collapsing avenues that users transiting there do not maintain certain rules of movement, and sharing of resources [14].

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2. State of the Art

Swarms biological exploration in its search for solutions, they present several mechanisms, including communication. These mechanisms allow them to find solutions through local interactions generated by sharing information, leading to emergent behaviors that meet objectives such as food transportation, migration to other regions, optimization in joint or solitary exploration, and quantity movements , using more or less swarm members according to the tasks the same swarm, preservation of individual energy, etc.

This whole process of Bio-inspiration has generated in the scientific community the need to describe these behaviors within artificial intelligence with mathematical algorithms; the case of search algorithm differential (DS).

In nature, we find a particularity when the temperature begins to drop and food becomes scarce, species like birds, monarch butterflies, ants, bees and whales; instinctively know that winter is approaching and therefore must migrate to warmer places. This act is done in terms of survival. The algorithm (DS) allows them to make strategic scales, in addition to solving problems during the trip. Describing always remain swarms solving their problems collectively [15].

The algorithm (DS), describes how some species seek their food, protect their young, and find a place to live [16]. Undoubtedly, everyday problems and reactions of these biological groups surprise, and to analyze using mathematical behavior to solve problems and survive in their ecosystems.

To ensure that it can move all the groups, in nature we see behaviors that allow them to generate variables for the number of problems and possible solutions. The search algorithm or differential (DS), allows taking into account variables such as the number of agents to displace, distances, and of course the scales necessary to arrive quickly and with the fewest possible casualties.

One application of the algorithm can be seen through a simulation. In the simulation the agents are subjected to various problems and as the algorithm (DS) manages to reach a solution of a global optimum, preserving the swarm and fulfilling the goal, to get to the place inhabited by the next season. Compared to the evolutionary algorithm (DE) [17]; the results show that the algorithm (DS) optimizes processes, further simulation can be seen, the speed to solve a problem and the search space of solutions provides faster routes to the global optimum. Unlike the algorithm (DE) simulation showed that a deficiency in the number of correct answers to overcome an obstacle and the response time was longer than could actually be observed in nature.

Another application of the algorithm (DS), is in the rationalization of energy [18] resources. We can see this reflected in nature when species are about to enter a state of hibernation. In which the accumulation of resources and proper use of them, plus the search for a good shelter is a priority. Another example is how groups rationalize their resources for migration, as these fail to meet nutritional needs and save energy with the least possible effort.

From the point of view of civil society, the use of the algorithm (DS), contemplate the rationalization of natural resources, own for the survival of the community. Proper rationing of resources could save entire communities in times of shortages. If we consider the current situation of our planet, optimization algorithms (DS) would have control in the distribution of resources in a satisfactory manner for all inhabitants.

Following our review of the literature on swarm intelligence, is the algorithm magnetic Optimization (MOA) proposed by Tayarani in 2008 [19], it is an optimization algorithm inspired by the interaction between some magnetic particles with different masses. In this algorithm, possible solutions are some particles with different masses and magnetic fields. Based on the suitability of the particles, the mass and the magnetic field of each particle determines which is better. The particles in the population apply attractive forces between itself and therefore move in the search space. Since the best solutions have a greater mass and greater magnetic field, the lower particles tend to move towards the most appropriate solutions and therefore migrate to the area around the best local optimum, which then escapes to find the best overall solution. [19]

The algorithms based on collective intelligence form a new paradigm of distributed intelligence, as they are able to find good solutions in optimization problems with a reasonable computational cost. These algorithms have become a topic of interesting research for many scientists in the field of Artificial intelligence. He defines collective intelligence as a meta-heuristic technique of AI based on the study of collective behavior systems present in nature, usually decentralized and self-organizing.

Bonabeau together with other researchers focused mainly on insect societies, such as termites, bees, wasps, and various ant species. However, the term hive is used in a general way to refer to any collection of agents or individuals who work together and reciprocally. This allows the ants perform complex tasks despite their individual simplicity. The ACO (Ants Colony Optimization) are pursued precisely to exploit this reality through a set of simple individual agents (ants) working together (colony), it is to obtain solutions to complex optimization problems. Specifically, the ACO algorithms simulate the behavior of gathering food from a colony of ants. Because these insects have a developed view, their communication with the environment is carried out through pheromones, particularly in the case of collection, through a trail pheromone, marking the routes to be followed by individuals' nest to the food source. Experiments with Iridomyrmex species humilis, humile Linepithema and Lasius niger, show that there is indirect communication between individuals through pheromones. Ants on their way from the nest to the food source and vice versa, deposit pheromones on the floor of a trail, which are able to smell the other components of the colony. The greater the concentration on a route, the greater the probability that an ant will follow the route.

Most Combinatorial Optimization Problems of scientific and practical interest are included in the NP-complete class, because there are no exact algorithms with polynomial complexity to solve them. Because they are untreatable, they are designed to use a lot of approximate methods, which are good solutions in reasonable times. One of these methods is the heuristic goal by Ant Colony Optimization (ACO); which it has its inspiration in the behavior of real ants, minimizing the path between their colony and any source of supply, based primarily on the pheromone trails left behind. ACO meta-heuristics have been proposed various algorithms, which since inception have proven their broad applicability and efficiency in solving problems by Combinatorial Optimization. The existence of a large num-

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ber and variety of Combinatorial Optimization Problems included in the NP-complete class need to be resolved efficiently, promoting the development of procedures to find good solutions, although they were not optimal. These methods, in which the speed of the process is as important as the quality of the solution obtained are called heuristic or approximation. A heuristic method is a procedure for solving an optimization problem well defined through an intuitive approach, in which the problem structure is used intelligently to get a good solution. Then, in order to obtain better results than those achieved by traditional heuristic arise called meta-heuristic procedures. Meta heuristic procedures are a class of approximate methods that are designed to solve difficult combinatorial optimization problems, where classical heuristics are not effective.

The meta-heuristics provide a general framework to create new hybrid algorithms combining different concepts derived from artificial intelligence, biological evolution and statistical mechanisms.

Estimating traffic flows can implement good development strategies, while helping in the decision-making process when keys are controlled and distributed resources such as mass transit. The distribution of traffic can be modeled as a problem of Minimum Cost Flow for Multiple Real. For its solution, the Ant Colony Optimization provides a framework promising work. In this research, two new algorithms based on Ant Colony are presented, they are applied to real instances of flow estimation problem in any city. The achieved results are compared with those provided by classical algorithms, showing the effectiveness of the proposed method.

It is possible to simulate the behavior of a system through optimization a model accurately predicted; such simulation allows analysis of system responses to various events and decisions. In this study, we are concerned with the prediction of traffic flow distribution in the city. As a result of the optimization of a flow problem, it will be possible to simulate different strategies for decision-making scenarios such as the optimal distribution and synchronization of traffic lights, efficient selection of public transportation routes, or infrastructure development.

In recent years, meta-heuristics have demonstrated their ability to solve such complex real-world problems. In particular, the (ACO) meta-heuristic has proven especially equipped to deal with the kind of dynamism that exists in similar problems, such as traffic shaping and routing data.

We see the example of research view [20], two new ACO algorithms are presented to solve the problem MCMNF. Both algorithms use a data structure specially designed graphic construction as ants.

Various network problems or transport can be modeled as multi-commodity flow, therefore, a vast collection of algorithms can be found in the literature on this topic. If the flow values can be real numbers, then the algorithms based on classical mathematics, such as feasible direction, cutting planes and sub-gradient methods can be used.

Another practical approach is to approximate the linear objective function or a piecewise linear function. A combination of heuristics goal with mathematical programming has also been successfully applied to the problem MCMNF [21].

Moreover, if the flow values are integers, then the MCMNF becomes NP-hard problem. In this case, the Ant Colony Optimization (ACO) provides an appropriate framework for dealing with this type of optimization problem in real life.

Recent studies also show that the use of ACO may be effective in reducing response time and increasing sustainability in supply chain transport systems [22].

The new ACO algorithm called "Redundant Link", improves the results provided by the methodology of multi-path routing based ACO.

The solutions provided sufficient to deal with problems such as the explosion of network overload and merging traffic. An ant colony algorithm is built on the basis of a multi-target in order to find optimal solutions approach. The aim of these solutions is to increase sustainability without sacrificing economic goals [23].

The first attempt to develop an algorithm for the problem MCMNF formulation was applied to the arc-node, ie, the algorithm was executed directly on the network graph. In this algorithm, a number of ants were sent simultaneously on each source node with a respective receiving node as a destination, each ant representing a group of vehicles that have the same origin and destination. However, this approach was not effective; the main reason was the inability of ants to find short paths between zones.

The rules that determine the movements of ants were similar to the algorithm update ACS and trace [24]. This approach better reflects what happens in real life when a driver faces the task of determining a route [24].

From the algorithmic point of view, the formulation avoids the ants making a wrong decision that could lead to unnecessary long journeys, while allowing the use of a pheromone trail as a mechanism for distributing the flow through different paths. This approach leads to better computational results, but restricts the space of the original solution and the ants' capacity to adapt to the environment.

Based on the contextualization of bio-inspired algorithms in the nature described above, the need to explore ways of communication between intelligent agents [25]. As noted in the case of the use of pheromones of ants, maintains communication with the atmosphere and through which a memory is saved. The researcher, Pierre-Paul Grasse is the first Frenchman who introduced this term as mentioned in Article [26], which shows how Grassé explains the mechanism of pheromones. Given the fact that the swarm does not need a hierarchical control or a specific agent to delegate tasks to other agents. The researcher observed as biological swarms, like termites know where to make a contribution to the construction, or as soon as ants find food, they increase the flow of ants to the same point to collaborate and bring the food back to the nest. Investigations [27] concluded as ants instinctively increase the flow of a chemical which Grassé christened as pheromones. This mechanism is activated once the food source is found, which automatically allows the ants to understand that if they follow that path they will find food, and therefore should go to help bring food.

Reviewing the literature of communications within biological swarms is stigmergy word, which is the use of the environment as a means of communication and memory so that swarms can communicate incorporating chemicals that generate different reactions in organisms and facilitate decision decisions for jobs and tasks within the swarm.

Now the idea in environments of agents and multi-agents, with functions of self-organization, aims to create "artificial pheromones" that lead to generate local interactions between agents arising emergent behaviors, leading to global solutions and the fulfillment of its objectives. This mechanism would allow self-regulation and everyone working for the same goal. It also allows troubleshooting to give optimum results.

We can see in [28] swarms benefit when using the stigmergy, since agents only need to know their present work, regardless of the outcome or the next action or work. These agents need only focus on the work being done at that time. Studies show that focusing on a single task becomes a super-efficient agent, concluding that will allow you to perform more tasks if the agent unlike perform more than one task at the same time [28].

The interesting use of the environment as memory, ensures that the agent need not remember his activity, since this information is found in the environment and once contact with the same remind him.

Communication between agents is not necessary, only where local when performing a job needs, allowing independence between agents to do their jobs without knowing if more agents working around or with the need to seek company.

The agent is available to perform its task that is without time or cycle established but bearing in mind the importance that should give a result for the welfare of the whole swarm.

As can be seen, the stigmergy has many advantages and provides an overview of cooperation and coexistence that seems utopian given the current situation, but we have the ability to implement it to see consequences in human society productive self an organizing [29] behaviors and, as are the swarms of ants or bees..

3. Methodology

The methodology used initially consists of a literature review to identify the state of the art and thus contrasts with current theories and proposed ideas. After posing the problem adequately, it proceeds to develop the algorithm. The next step is the validation of the algorithm by implementing cases identified application and merit figures found in the literature. Finally, after testing the algorithm with the applications, we proceed to draw conclusions about the results.

The literature review will be done considering the present application as its relevance and impact are achieved. Publications specialized groups such as those formed by the IEEE (The Institute of Electrical and Electronics Engineers) and ACM (Association for Computing Machinery) and Journals as Applied Soft Computing, Engineering Applications of Artificial Elsevier and Swarm Intelligence and Data Mining, Stigmergic will be sought Optimization of Springer.

To achieve good performance, the algorithm is expected to develop an analysis of the different scenarios that may be self-organization applied to the distribution of resources in different industrial environments as agents: transportation, manufacturing, production and logistics.

Proposals on new concepts to develop will be formulated based on results and experience obtained prior to the final validation test cases. This step is considered as an iterative process of pre-validation before having a final formulation.

After having identified the different application scenarios it seeks to create a virtual scenario where we can generalize the application of the proposed algorithm to different cases. With this virtual scenario the respective simulations of the proposed solution are shown so that you can see the performance of the proposal from a qualitative perspective through simulations in real time and quantitative time by measurements given by performance indices which are analyzed statistically.

Finally, conclusions will be made observing the results of each application performing an analysis to indicate the effectiveness of the proposal. You can also identify new alternatives for exploration or correction of the proposal.

The research design will have a simulated experiment using simulation software and a computer. The idea is to work a multi-enajambre system under a scenario of multiple tasks or orders.

The first thing established is the search for the state of the art concerning the terms of the first specific objective. And then describe a strategy of swarm intelligence and multiagent architecture.

4 Conclusions

A self-organized coupled swarm intelligence process can be guided by manipulating the environment of each agent or individual in the swarm, so when an agent or individual manipulates an environment they belong to other individuals, these take actions through preset rules preset to manipulate their environment to achieve change according to their knowledge of the target. They must maintain established goals concrete for individuals belonging to the self-organized system to change states and generate a driving force that produces natural and emergently changing activities according to communication placing on the environment manipulated by one or more individuals.

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