Stigmergy-based Software Toolkit for Virtual Enterprises

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Abstract: - This paper aims at illustrating how a stigmergic approach can easily improve the speed and the stability of a planning process in an agile production environment. Adapting the collective behaviour of ant colonies to a stigmergic cooperation mechanism, logistically improved by a communication agent and a realistic environment, translates into powering the manufacturing resources in solving the production process. In the framework described below every ant agent takes care of one piece of work/task. Following the pattern available for a product, the ant colony first plans the way between raw material to final product and then follows the execution, dealing with unexpected situations. By using the same environment in planning and in tracing the products, it is kept up to date and also is the planning.

Key-Words: - virtual enterprise, stigmergy, ant farms, agents, environment eave.

1 Introduction

The manufacturing enterprises are required to design and create new products efficiently in order to remain a viable competitor on the market. In order to reduce both the product launching time and the production time, manufacturing enterprises should be adaptable, flexible, and able to design and modify their own services and processes efficiently. Moreover, as the consumers are asking for customized products in small quantities, the virtual enterprises are becoming effective to a greater extent in this new kind of evolving markets where they only need to exist as long as the user requires it.

"A **Virtual enterprise** (VE) is a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities."[1]

In the light of a powerful service-orientated economy, products seam to "emerge" on the market, depending on the clients requests. Therefore the production process becomes less predictable and expert systems less useful.

Inspired from ant's communication and life style, stigmergy holds the key of resolving unexpected problems and dealing with unexpected resource and product changes with a rather simple approach: **pheromones**. In fact, **the environment is changing**, machines and people involved in the production process – the ones who produce – do the same job as before. We aim of constructing an environment fit to encapsulate local information that is then available for the entire **ant team** constructing the production process.

2 Problem formulation and approach

In regard to the virtual enterprise requirements and characteristics, we create a **flexible** and **on time** solution toolkit, using a stigmergic approach on an agent based framework.

The production process is logically split into 5 dimensions.

The first one is the **environment**, consisting in the resources of the virtual enterprise and the connection between them. It is less important if the resources are from one or from many factories, they are finally the real limits of a virtual enterprise. Of course, those limits can expand or they can shrink, according to the players' involvement and technical problems.

The second dimension is the real foundation of virtual enterprises: **client demands**. In fact, the knowledge about what resources are for can help in the developing of new or customizable products.

The thread dimension involves the **roadway between client demands and the product itself**. Using ant farms (one ant represents one fragment of a product) we are guiding the ants (therefore, the fragments of products) inside the environment from raw material to well designed products.

The fourth dimension is a **reality check**, which ensures that the planning process goes well in reality, allowing adjustments and re-planning. This dimension also allows adjustments to the environment, like equipment failure, cost changes and so on. As a future extension of the scientific model presented in this paper, reality check information can be introduced through mobile devices as pads or even through direct connection with the production devices.

The fifth dimension is very important because it is **a learning process**. Each time a resource is used it gains an amount of pheromone from the ant that is using it. The pheromone can then evaporate ore accumulates over time, making the resource a target for ants searching that type of service. In this way the stigmergic toolkit earns the intrinsic information of the system from the way the system evolves.

3 Dimension

The five-dimensional system representation relies on the idea that each dimension is an independent component and the result is a flexible flow from client demands to actual results.

The fifth dimension practically emerges from the planning process enriching the environment witch then has a certain (user chosen) impact on the planning process.

The independence of each dimension does not involve a non-communication status, in fact it distributes locally (in the environment) most of the information, making an ant driven planning possible.

For a better understanding of this structure see fig 4.1.

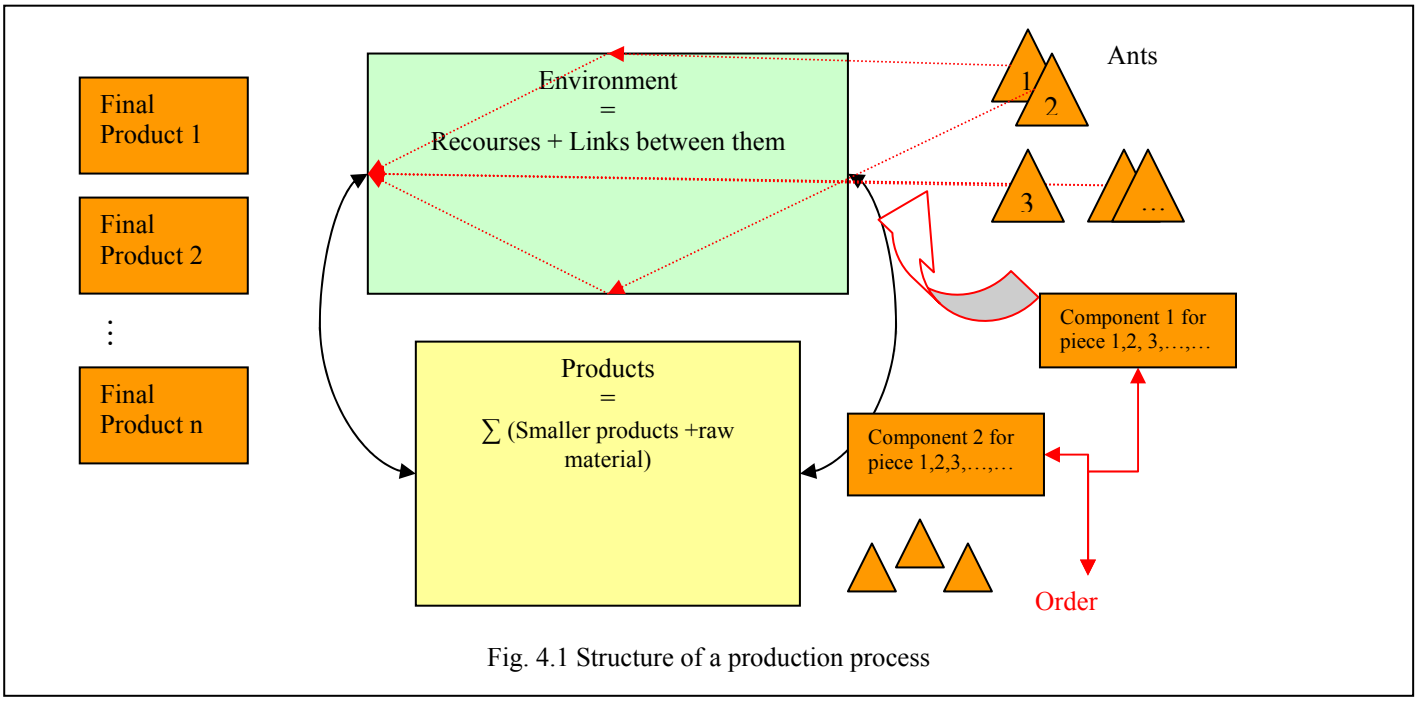

Fig. 4.1 Structure of a production process

4 Construction plans

Constructing a platform for the stigmergic toolkit involves creating agents and communication channels for them. There are four species of agents in this framework: order agent, production agent, planning agent and resource agent.

The order agent takes the order, picks the production pattern and demands the execution of the specified pattern to the production agent. When the production agent receives the ordered pattern, he divides it into component parts (indivisible ensembles or/and subensembles). Then, the production agent demands the planning of the intermediary part to the planning agent.

The planning agent (using ant farms) receives the task, interrogates the resource agents about the cost for executing the task and decides who will execute it. After deciding the best resource fit to execution the task, he demands.

The resource agent has two roles. The first is to evaluate the cost and the second is to execute the task. Executing a task may increase the cost of a future evaluation, because it will be available later. In evaluating the cost of a certain task, the resources taken into account are the amount of pheromone for the particular task (stored within it) and the physic cost (reflected by money, time or both) in various weights depending of the enterprise purpose. Each resource has a list of tasks. Each task is executed with a physic factory resource represented by the agent.

5 Communication structure and environment design

To ease the communication between agents we created an agent manager, who facilitates the transmission of messages within the framework. Another role of the manager is to ensure the startup of the agents and the

shutdown of the platform.

The vital part for ant orientation and success is the environment. In our framework the environment is composed of two parts: resources and product patterns.

The resources represent each machine or human working in the virtual factory. Each of these resources is able to execute one or more types of operations.

A product pattern is the sequence of operations needed for manufacturing a certain product. Operations in a pattern can be executed simultaneous or in a predefined order established by the pattern maker.

Operations are regarded as steps to obtain a product. An operation is the elementary action defined in the framework; therefore products are viewed as groups of operations. If a product is divided in subcomponents then merging the components is also considered an operation.

The planning agent is in fact an ant. When he demands the resources the cost of planning an operation he receives an answer from each resource that is able to fulfil that operation. Hence, the responses of the resource agents are constructing a graph. Every step of the planning process constructs a graph formed by all the possible ways of planning the product. The important part here is that the graph is not build entirely at the beginning; it is constructed step by step in the planning process. The advantage of this solution is a smaller amount of time needed and the option to change the assumptions, of dealing with the unknown in the form of excluding or including the resources in the planning process. The information of each planning is stored as a pheromone trace in the resource agents.

The purpose of this paper is to present a planning mechanism using stigmergy as a way of achieving an intelligent and self improving system. Thus the initial information stored in the resources can be the base point of a real time watcher of the production flow. In this case, the ants are the products and the road from raw material to well defined products is, in the best case, the one following the pheromone trace. Considering special events, like mechanical malfunctions, the ants will try to find an alternative way, and finally resume to the initial path when the obstacles are surmounted (because of the pheromone trace).

The two kinds of ants are related and use the same pheromone so they can be bourn on the same farm/environment. The problem of different ant species influencing each other is not harmful; moreover, it is a faster way to succeed. Due to signalized dead ends by the watcher ant, the planning ant will not involve the specified resources in the planning.

6 Conclusions and further work

The greatest challenge of using ant farms is the fact that they are not fully predictable.

As major advantage of ant farms we may consider the ability to resolve continually changing problems, like planning the production and watching it in the context of a changing environment.

When implementing certain behavior to the ant, the result is an army of small and not so smart artificial beings having one goal. The overall activity of those ants is almost unidirectional, if we are talking of a single planning process.

Understanding the history and the components of a manufacturing enterprise and extending the knowledge in the virtual enterprise context gives an overview of the production process.

Understanding that the ants follow a path signalized by pheromones and scaling that path with the factory infrastructure and products lied's to constructing an environment.

Beginning from those premises the planning process based on the environment and ant farms can generally solve the production process and when there are many resources, products, and greater failure risks the framework is a valuable choice.

A better control over the resources can be obtained using mobile devices. Implementing smart interfaces and studding the possibility of resource-environment direct interaction, is a subject concerning the future work for this project.

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