Creating Virtual Communities by Means of Swarm Intelligence

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Abstract

During centuries, observing the behavior of wild species has always been fascinating and full of mysteries. Modeling human interactions based on those revealed on the wilderness conducts to innovative solutions, but also poses unexpected issues. In this article, we describe our approach of creating communities of virtual entities by means of swarm intelligence. We discuss the algorithm of creating the virtual communities along with the issues that arise when modeling business entities as individuals of the swarm.

Keywords: swarm intelligence, virtual communities, virtual enterprise, business dependencies, Virtual Swarm Creation Algorithm

1. Introduction

In a complex and dynamic environment, as it is the business one, the fight for long-term survival is crucial. Business companies try to adapt their strategies according to market changes, but have difficulties to overcome these changes when the dimension of the company is small and its resources (both human and financial) limited. In this turbulent context, forming virtual business communities would certainly be a solution; as such communities can share their resources and thus contribute to the welfare of the whole community.

In this article, we present a technique for constructing virtual communities by considering each member of the community as a member of a swarm. Modeling the business environment with the aid of swarm behavior poses several interesting issues that we discuss later on a distinct section. By creating virtual communities of business entities, we aim to improve the survival of the companies on the medium and long term, as, by sharing resources, virtual members would help themselves to survive in the extremely dynamic (and sometimes hostile) business environment.

The paper is organized as follows. In the next section we provide a brief introduction on the terminology of swarm behavior, swarm intelligence and its applications to the business environment. The second section presents how we can model the creation of virtual business communities by means of swarms. Later, we introduce the swarm creation algorithm and discuss the issues that we encounter in its design. We conclude the paper with setting future research directions.

2. Swarm Intelligence

During the last decades, scientists have increased their efforts in understanding the nature and applying the knowledge extracted from the animal world to solve complex problems. In [6], the authors present a thorough survey on the scientific literature regarding swarm intelligence. They start by defining the term *swarm behavior* the aggregate motion performed by groups of individuals from various species (for examples, a school of fish that swims, turns, flees together [7], cited in [6]).

A *swarm* is defined in [6] as a set of *N* agents that are cooperating to achieve some purposeful behavior and achieve some goal. The agents use simple local rules to govern their actions and via the interactions of the entire group, the swarm achieves its objectives [6].

Swarm intelligence, according to [6], is the emergent collective intelligence of groups of simple autonomous agents. An *autonomous agent* is a subsystem that interacts with its environment, which probably consists of other agents, but acts relatively independently from all other agents. The autonomous agent is *self-organized*, i.e. it does not follow commands from a leader, or some global plan ([2], cited in [6]).

In [1] the authors introduce several applications of swarm intelligence principles to the business environment. While social insects have been so successful because of three characteristics: *flexibility* (the colony can adapt to a changing environment), *robustness* (even when one or more individuals fail, the group can still perform its tasks) and *self-organization* (activities are neither centrally controlled nor locally supervised), business executives mostly relate on the first two attributes and avoid the one regarding the self-organization.

According to the swarm intelligence principles, even if individuals follow simple rules (like certain species of ants which are able to find the shortest path to a food source merely by laying and following chemical trails [1]), the resulting group behavior can be surprisingly complex and remarkably effective, which conducts to the fact that, to a large extent, flexibility and robustness result from self-organization [1].

An interesting comparison between the insects' ecosystem and the business environment is depicted in [1]. The authors point out the ties between a company's spin-off and a honeybee colony. When a honeybee colony becomes too large - that is, when it reaches a point of diminishing returns - the nest splits into two, behavior which can be used by large corporations in determining when to spin off some of their operations. In the authors' opinion, no social-insect equivalent exists in the case of mergers [1], in contrast with the spin-offs case. Despite the fact that there would not be any equivalent to the mergers case, in the next section of the paper we shall explore the creation of a virtual community formed by more business entities which would act as a swarm.

3. Creating Virtual Communities

In our past research, we have investigated several methods of suggesting mergers between two business entities based on the analysis of each one of the two candidates' last financial statement [4, 5]. Our models developed so far considered only the case in which two companies tend to combine, therefore we should have provided an answer of the type: *Company **A** buys company **B*** (or vice versa), *company **A** merges with company **B*** (when the two companies are almost equal when considering their position on the market), *the two companies **A** and **B** create a virtual enterprise* (thus continuing to exist independently, but joining forces to meet a common goal, such as a joint project - a thorough discussion on the issues regarding the Virtual Enterprise can be found in [3]) or *the two companies remain independent of each other and act independently*.

We now pose a more complex problem: giving a set of companies:

$A_1, A_2, ..., A_N$

can we construct a virtual cluster of companies (or virtual Business Community) from these companies so as to join forces and create more added value than in the cases of a single company acting independently or the case of creating pairs of virtual entities from two companies?

For instance, the *wheat producer* decides to join forces with a *flour* producer in order to reduce costs. Furthermore, it would be interesting that the two companies would virtualize with a *bread producer*, which, later on, would join forces with a *commodities transportation company*. Thus, in the end, the virtual company formed from the wheat, grain and bread producers and the commodities transportation company could create an integrated value chain with the purpose of reducing the bread's final cost of production.

But does such an entity suffice to act according to the principles of swarm intelligence that we have point out in the previous section? The Virtual group is *self-organized*, each one of the companies can act independently without supervision (or, as stated in [1], the group needs relatively little supervision or top-down control). Also, the Virtual Community is *flexible*: each member of the group can easily adapt to changing environments (for instance, an increase in electricity price would not stop the flour producer to stop its processes).

In addition, we ask ourselves: is this Virtual community *robust* (i.e. when one or more individuals fail, the virtual group will still be able to perform its tasks)? By considering each company *an individual* of the virtual community (and not each company's employee an individual), we believe it cannot (the wheat producer does not have the capabilities to directly produce the bread without the flour producer), thus our virtual community requiring further adjustments.

The solution to the *robustness issue* would be to allow more individuals (distinct companies) specialized in producing flour to join the virtualized community. Generally, a *robust virtual community* would need at least two companies from the same business sector (i.e. competitors) to join the virtual community. The later competitor would help the virtual community survive even in the case that the former flour producer (or another member of the community) could not meet its goals. By allowing more competitors to join the virtual community, the robustness increases, thus reducing the risk that the community would not meet its final goal.

4. The Virtual Swarm Creation Algorithm

In this section, we present the algorithm for creating a Virtual Community (or Swarm) based on the dimension of the swarm and the starting entity as inputs (see the next algorithm).

```
Algorithm VirSwarmCreation(N, E, out S);
In:
      N – dimension of the Swarm
      E – starting entity
Out:
      S – the Virtual Community
Begin_algorithm
      S = S ∪ Backups(E);
      If (n > 1)
      {
            V = GetVirtualization(E, S);
            S = S ∪ V;
            S = VirSwarmCreation(N-1, V);
      }
end_algorithm

Function Backups(E)
In:
      E – starting entity
Out:
      L – list of Backups Entities
Begin_function
foreach (company B in CompaniesList)
      if (ActivityCode(B) == ActivityCode(E) and
          MAVOC(B,E) == Virtualization)
            If (SizeOf(L) < RecommendedSize(ActivityCode(E))
                  L = L ∪ B;
            Else
                  break; /* The required size of L has been reached*/
      return L;
end_function

Function GetVirtualization(E, S)
In:
      E – starting entity
      S – the previously-chosen community (Swarm)
Out:
      V – Virtualization Candidate
Begin_function
foreach (company V in CompaniesList)
      if (ActivityCode(V) <> ActivityCode(E) and
            MAVOC(V,E) == Virtualization and
            ActivityCode(V) ∉ ActivityCodes(S))
                  return V; /* The virtualization candidate*/
end_function
```

The `Backups` function returns one or more business entities that have the same sector of activity with the initial company *E*. The backup entities will have the role of minimizing the risks of not accomplishing the company's tasks that could arise in a complex business environment. The number of entities returned by the function depends on the business class of the entity and also on the economic conditions. The companies that are backups of the entity E are considered from the virtualization candidates of the company E, i.e. the MAVOC score function [5] between *E* and each of the backups is *Virtualization*. We further discuss on the robustness issue on the subsequent section of the paper.

We recall that the MAVOC score [5] takes as input the financial statements of two companies ***A*** and ***B***, then it computes a strategic suggestion of type ***A*** *buys* ***B***, ***B*** *buys* ***A***, ***A*** *and* ***B*** *merge*}, **A** *and* ***B*** *create a virtual Enterprise* or ***A*** *and* ***B*** *conserve their status*.

The `GetVirtualization` function returns a virtualization candidate not-previously chosen for *E* (for which the MAVOC score function [5] between *E* and *the candidate* is *Virtualization*) that has a different business sector than the one of *E*. The condition that the virtualization candidate had a different business sector than *E* assures that the virtual business community has diverse members. Allowing only the companies from the same sector of E to enter the virtual community (as in the case of company's backups) would significantly limit the community's capacities, which also limits its survival possibilities in the future.

The algorithm functions as follows. Considering the example of wheat producer-flour producer-bread producer-transportation company, the algorithm starts with the *Wheat producer*, and the empty swarm:

```
S = ∅;
VirSwarmCreation(4, 14210118, S);
```

(`14210118` is the Registration ID of a Wheat Producer situated in the Dolj County)

it adds to the swarm a list of virtualization candidates from its sector of activity (considering the nowadays risky business environment, it would add more than one candidate as to cover increased business risks for its sector of activity).

Moreover, the algorithm extracts a virtualization candidate by inspecting the business sectors that depend on the wheat producer (here the Business Dependency Map introduced in [4] is used). Considering that the production of flour has a greater dependence on the wheat production than the bread production has on the wheat production, the production of flour would be selected, then emphasized the virtualization candidate which has the highest virtualization score with the company *E*, let us name it *V*.

After adding the candidate to the swarm, the algorithm continues with completing the swarm from the current candidate *V*, assuring that a candidate is chosen only once. The algorithm finishes when the construction of the Virtual Community is complete, i.e. we have reached the required dimension of the swarm.

We should point out that *N* (the dimension of the swarm) does not include the backups (companies that have the same sector of activity with the starting company), thus the whole dimension of the swarm would sum *N* with the number of backups of each one of the swarm's members.

5. Issues

In this section, we discuss several issues that we encountered when modeling the creation of virtual communities as swarms. We recall that in our previously developed model MAVOC [5] two companies tend to virtualize when they are relatively small companies and they are similar (or close) in terms of number of employees, turnover, market share.

Are Such Virtual Communities really robust?

In the previous section, we have stated that backup entities are needed in order to create robust virtual communities that tend to appear similar to swarms. But the question is how many backups are needed for a virtual community (i.e. companies that have the same sector of activity with one of the community's companies)? We believe the number of such *backup companies* rises along with the risks associated with the sector of activity of a company, but also with the economic climate. For instance, in a period of severe flooding, the wheat producer companies will tend to be exposed to higher risks, thus several companies from various regions (both national and international) would be needed to be part of the virtual community.

Is an entity autonomous?

In the business world, the entities are tied by various relationships of type *supplier-client*, which creates a dependence between the client and the supplier. In this context, can entities be modeled as autonomous? We can model them as autonomous, considering a free market with no dominant position on it. We recall that in [5] our model has suggested the creation of virtual entities from rather equal companies in terms of number of employees, turnover or market share.

Are the entities (individuals) equal?

In our model, we consider an *individual* of the swarm the business entity that is a member of the virtual community. For the same reasons that we stated above, the virtualized communities (or clusters) would consist of companies of small, but almost equal, size. Our previous studies have shown that during the last years a consistent number of companies had only one employee, which make them ideal candidates for a virtual community (by joining forces, they would increase their strength in terms of financial capital, human capital, market share). In this sense, it is suitable to consider these entities as equal.

Can we also model mergers this way?

Modeling mergers raises more complex problems than in the case of creation of virtual entities. Whereas the virtual entities appear and disappear along with the opportunities that exist in the market, the creation of a merger between two companies implies more time and intense effort for negotiation. For these reasons, we believe that mergers cannot be modeled as swarms, as mergers usually occur between large companies with different characteristics in terms of market share, profits, turnover. Despite this drawback, we believe modeling virtual communities is far more interesting than modeling a small number of mergers (we have previously shown in [5] that from a number of 61.944.015 pairs of companies, our model suggested a virtualization for 28.374.777 of them, i.e. 45,8%).

6. Conclusions

Modeling business activities as swarm behavior is fascinating, intriguing and promising. Such modeling is *fascinating* as the business world is frequently compared to the wilderness, when considering its intense preoccupation of surviving. It is also *intriguing* as many questions arise from such a modeling (some of them were discussed in a separate section of our article). It is as fascinating as *promising*, because it opens new paths to solving business problems: how can two or more companies cooperate in order to improve the outputs (taken as a single company's output).

As future research directions we plan to study the introduction of a fitness function of the swarm which would compute the likelihood that the swarm would survive in the business environment. Such a swarm would have to compete with other virtual communities in order to survive on the market. Thus, even more difficult questions arise: what will it weight more? The dimension of the virtual community? How fit its members are? How dependent they are according to the dependencies between the business classes?

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