An Approach for Virtual Organisations' Dissolution

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Abstract. Current research on virtual organisations focuses mainly on their formation and operation phases, devoting only little attention to the dissolution phase. These passages typically suggest that dissolution should occur when the organisation has fulfilled all its objectives or when it is no longer needed. This last definition is quite vague and hard to define, as the need for an organisation is not always easy to measure.

We believe that, besides fulfilment of objectives, more causes should be considered for the dissolution of a virtual organisation, since an organisation is not always capable of achieving its goals or continuing operations. Organisations can change during their operation, as might the environment in which they operate, and these changes may affect their performance to the point that they should not continue operating. In addition, the causes that could lead to dissolution could affect the formation of future organisations. Considering the correspondence between virtual organisations and real-life organisations, some portions of real-world commercial law related to dissolution can be applied to the virtual world.

In this paper we introduce the different causes that should be considered for virtual organisation dissolution, and a case study focused on one of these causes is presented as a way to emphasise the significance of the dissolution process.

1 Introduction

Generally speaking, virtual organisations (VOs) are composed of a number of autonomous agents with their own capabilities and resources for problem-solving, task execution and performance. Being autonomous, agents usually pursue individual goals, but in some cases, these goals can be achieved with better performance or higher benefits inside a cooperative environment with other agents, where the resulting organisation can even offer new services through the combination of complementary abilities. For example, in an economic environment,

agents may represent different units or enterprises that come together in response to new market opportunities that require a combination of resources that no partner alone can fulfil [1]. These cooperative organisations have been researched mainly from the point of view of their formation and operation. However, their lifecycle has been outlined as having an additional phase and therefore is comprised of *formation*, *operation* and *dissolution*.

Although the automation of the dissolution process has been mentioned as a research and development challenge in the study of VOs [2], there is not much work addressing dissolution. This phase is often overlooked by deeper research, yet, in economic terms, if an organisation's dissolution is not properly managed, it can generate tremendous costs [3]. The timeliness of dissolution is dictated by the existing agents and resource availability. If a VO is underperforming without a chance for reconfiguring itself (or if the possible reconfiguration is not sufficient to improve performance), then it should dissolve in order to free assigned resources and members.

Under normal circumstances, the dissolution should happen after the VO has fulfilled its objectives [4]. Some researchers also mention that such partnerships should dissolve when they are no longer sustainable [5] or the VO is no longer needed. The main topic of this paper is the clarification of these terms, through an identification of the causes that should be considered for the dissolution of a VO.

The paper is organised as follows: Section 2 briefly describes some real-life organisations and the normative environment that provides the context for the dissolution process of virtual organisations. Section 3 describes the normative framework used for supporting the dissolution process. Section 4 explains the dissolution process, describing the steps needed for dissolution and the causes that should lead to a VOs dissolution. Section 5 presents a case study focused on one of the causes for dissolution presented. Finally, in section 6, the conclusions of the current work are presented.

2   Real-World Organisations

In virtual environments, agent societies enable interactions between agents and are therefore the virtual counterpart of real-life societies and organisations [6]. As such, when seeking to support VO dissolution, issues related to the dissolution of real-life organisations should be considered.

The most common type of regulated social organisation is the commercial organisation, such as a limited or public limited company. These organisations are regulated by law, and therefore they exist inside a normative environment enforced by its respective legal institution. Every country has its own laws, but there are several common key features among Western countries that can be used for reference. We shall use Spanish Commercial Law ([7], [8]) as a starting point, specifically those laws concerning the dissolution of this type of commercial organisation.

The dissolution of a commercial organisation is divided into two phases. First, there is the identification of a *dissolution cause*. In some cases, the agreement of

the organisation's members is also needed to move forward to the next phase. The second phase is *liquidation*, wherein, once a dissolution cause is identified, the organisation moves forward to perform the tasks needed to enact its end, producing a dissolution report that summarises the organisation's activity.

From the text above, the dissolution causes can be classified into two different groups:

- Causes that, when identified, dissolve the organisation automatically without needing of the members' (or the boards) agreement.
- Causes that, when identified, need an agreement from the members (or the board) before going on to the next step, the *liquidation*.

These causes depend on, besides the law itself, the contents of the organisations articles of association, their statutes (where, for example, the duration of the organisation is specified, in case the partners decide to have a fixed duration) or the organisation's assets. The law may also include slightly different legislation on some aspects depending on the organisation's scope.

Institutions regulate interactions between the members of a society, defining the "rules of the game", what is permitted and what is forbidden and in what conditions [9]. Similarly, a VO needs to operate within a normative environment, enforced in this case by an electronic institution (EI), which is the electronic counterpart of real-life institutions.

3 Normative Framework

Commercial organisations are restricted externally by the legal context in which they operate and internally by the statutes or articles of association created during the organisation's formation. There are, then, different normative layers related to the organisations' activities. First, a common set of norms for every organisation exists in the form of the law; specific norms for each one of them consist of the statutes or articles of association. An institutional normative framework should therefore include a hierarchical organisation of norms. Borrowing from [11], we consider norms to be organised into three levels (see Figure 1).

The EI aims to support agent interaction as a framework of coordination and provides a level of trust by offering an enforceable normative environment. This means that the EI will facilitate both the creation and the enforcement of contracts among agents [12]:

- Institutional norms, at the higher level, influence the formation of VO constitutional and operational contracts; they set up the normative background upon which cooperative commitments can be established. Regulations on general contracting activities and the behaviour of every agent in the EI are included on this level.
- Constitutional norms represent the core of the cooperative agreement between the agents. The agreement is represented by norms that regulate the created coalition, which usually exists for a specified period of time. Norms at this level only affect the agents that participate in the VO.
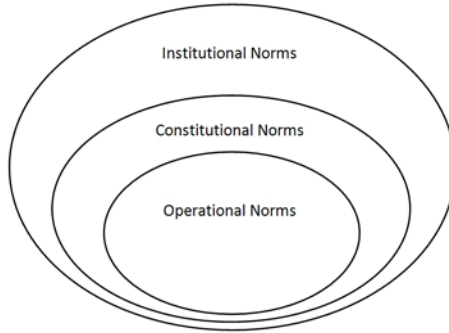
Fig. 1. Normative Framework

– Operational norms indicate the actions to be performed by contractual agents by specifying operational contracts, which may be established among a subset of the VO's agents.

Drawing a parallel between the real-life organisations (like commercial organisations) and the EI framework, institutional norms map commercial law, constitutional norms correspond to the organisation's articles of association or statutes, and the operational norms represent the individual task commitments inside the organisation (table 1).

Table 1. Parallel between societies and EI

Real-Life Societies	Electronic Institution Framework
The Law	Institutional Norms
Statutes	Constitutional Norms
Task Commitments	Operational Norms

The VOs activity is therefore governed by norms established for different layers in the institutional normative framework. When we focus on the dissolution phase of a VO lifecycle, we posit that there should be some norms related to the identification of when a VO has to be dissolved, thus helping to identify the causes of dissolution.

4   Dissolution Process

Inspired by commercial law, in this work we suggest a two-step dissolution process. First is the dissolution activation (which will be called *activation*), consisting of the identification of a cause of dissolution for the VO, and then the execution of the dissolution process follows, where the needed tasks for the dissolution will be run (this step will be called *liquidation*).

4.1   Activation

In the current literature, the causes for VO dissolution are mainly the successful achievement of all its goals or a decision by the involved partners to stop the operation [10]. But if the partners decide to stop the operation of the VO, they should somehow specify the cause of the decision; if the organisation is ending its activities before fulfilling its goals, this could be considered an unsuccessful venture. This information should be used for future organisation formation and partner selection.

Before dissolving, VOs can attempt to adapt themselves to environmental changes or perform a reorganisation in order to maintain or improve performance, depending on different causes. This means that it is not always the right choice to move forward to the dissolution, yet in some cases, it may be better to dissolve instead of trying to reorganise a VO.

We suggest then distinguishing two type of causes of dissolution: first, the causes that need the decision of the involved members for moving on to the dissolution, which will be called *Necessary Causes*, as they are necessary for the dissolution but not sufficient, as they need the members agreement.

Additionally, there are some causes that should automatically dissolve the organisation without needing the partners' decision. These causes are the *Sufficient Causes*.

During the VO operation, *necessary* or *sufficient* causes could be identified, which could lead the VO to different dissolution sub-states (figure 2). If a *sufficient cause* is identified, the VO goes directly to *liquidation*, the mandatory step before the complete dissolution, where the organisation enters into an *on-liquidation* sub-state until it finishes related tasks. But if a *necessary cause* is identified, the VO goes to a *pending dissolution* sub-state, where the VO waits for the partners' confirmation for the dissolution, or for the VO modifications (the adaptation or evolution of the VO) that will avoid the dissolution and make the VO return to the operation phase. If no measures are taken for returning to the operation phase after a period of time defined by the EI, the VO dissolves, going to the *on-liquidation* sub-state.

In short, during the dissolution, if a *sufficient cause* is detected, the organisation goes into *liquidation*. If a *necessary cause* is detected and no actions on the VO are taken to solve the issues related to the dissolution cause, the VO goes into *liquidation*.

Sufficient Causes. *Sufficient causes*, once identified, are sufficient for the automatic dissolution of the VO. The causes of this type that we have identified are as follows:

- *Deadline:* In the VO cooperation agreement, created during its formation, the duration of the organisation can be specified. During the operation of a VO, partners can modify their own normstheir cooperation agreementso they can extend the lifespan of the organisation, but once it is reached, the organisation should dissolve, as it was created to exist only for this duration.
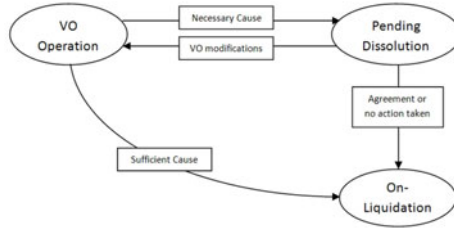
Fig. 2. Dissolution Sub-States

- *Reduction:* During the formation of a VO, the agents specify in the cooperation agreement the resources that they are willing to devote to the organisation. This is what defines the organisation's assets: the total amount of resources that the organisation has. The EI should establish the minimum required resources for a VO to be considered as such. If for some reason the VO suffers a reduction of its resources below the minimum, the VO dissolves. For example, on a football (soccer) team, the minimum amount of resources for a team is 7 players; below that number, one no longer has a team.
- *Agreement:* As we cannot disregard the case where VO partners arbitrarily decide to dissolve the organisation, the agreement for the dissolution should be considered too. For that, a minimum percentage (typically over 50%) of partners must decide to dissolve the organisation.

Necessary Causes. *Necessary causes* are necessary, but not sufficient. To be made sufficient, they need the agreement of the VO partners. Putting it another way, the partners have to take action to prevent the dissolution.

- *Fulfilment:* As mentioned before, the dissolution can be reached by the successful achievement of all the VO goals. During the formation of the VO, agents must define the organisation's goals in the cooperation agreement. Once they are fulfilled, the Institution can be dissolved. The reason that this is a *necessary cause* and not a *sufficient* one is that once the goals have been achieved, the agents can evaluate whether they want to set new ones based on the performance and continue operating.
- *Unfeasibility:* There are some cases when a VO cannot fulfil its goals. This could happen due to internal issues, such as the loss of key resources for achieving all the goals, or it could be brought about by external causes, such as changes in the environment that affect the organisation, such as the arrival of a new organisation that competes for the same goals. The VO can make changes to improve its performance, change its goals or add new resources, among other measures, to prevent the dissolution.
- *Inactivity:* For any reason, it could happen that the VO could show no activity during a period of time; after a specified period, the organisation could be considered as idle or dead, and after that, it could go on to the dissolution phase.

– *Loss:* This dissolution cause makes sense only when the benefits of the VO are measurable and in the same unit as the assets specified in the VO formation (see the *Reduction sufficient cause* above). In the cooperation agreement, the organisational assets are specified based on the resources that each member is willing to spend. If, during the operation of the VO, instead of benefits there are losses and these losses are over the half of the organisational assets, the VO can be dissolved as it can be considered unviable.

Some examples of possible action for the VO to take to avoid dissolution after a *necessary cause* are identified below:

– New goal definition or reallocation of resource and agent assignments for given tasks.
– Addition of new agents to the VO or replacing partners.
– Force the resumption of VO activities after a period of inactivity.
– Modify the VO assets by adding new resources or removing them.

In short, there are seven different dissolution causes, grouped by *sufficient causes* and *necessary causes* (table 2).

Table 2. Dissolution Causes

	Deadline
Sufficient Causes	Reduction
	Agreement
	Fulfilment
Necessary Causes	Unfeasibility
	Inactivity
	Loss

Activation within an Electronic Institution Framework. In the different layers of the EI normative framework (from section 3), we should have norms that support the VO dissolution at both the institutional and constitutional levels. Institutional norms should contain at least four values for dissolution support, which we will call *dissolution support elements*:

– Minimum Resources (R): The minimum resource requirements that a VO needs to have to be considered as such. The VO assets have to be greater than this value.
– Time of inactivity (Ti): The time that a VO has to be inactive before considering its dissolution.
– Maximum loss over assets (Ml): The maximum percentage of loss over the VO's initial assets before considering its dissolution.
– Minimum votes for the majority (V): The default value for the minimum percentage of the total number of participants needed to agree on the dissolution.

These values in the top level of the norms hierarchy (Institutional Norms) can be context-dependent. The grouping of predefined norms by appropriate contexts

mimics the real-world enactment of legislation applicable to specific activities [13]. So, depending on the type of organisation, it could have some different *dissolution support elements*.

The following is an abstraction of the concepts that should be included in a VO contract. Regarding the constitutional norms, the VO contract should include at least the VO duration D (or the starting and ending dates for the VO operation). The contract structure should contain the cooperation effort to which each agent has committed as a result of the negotiation process prior to the VO formation. For each agent A_i, with the assigned resources R_k, based on the cooperation effort structure specified in [11]:

$$CoopEff = \{\langle A_i, R_k, W \rangle\}$$
$$W = \langle MinQt, MaxQt, Freq, UnitPr \rangle$$

W represents the workload for each participant agent A_i specified between a minimum ($MinQt$) and a maximum value ($MaxQt$), with a frequency ($Freq$) during the lifetime of the organisation and the unit price ($UnitPr$) that the agent has assigned for performing the assigned workload.

The frequency depends on the unit used for measuring the VOs duration (i.e., days, weeks, computer cycles), which in turn depends on the VO's scope. For example, when the duration unit is *days*, if the workload is specified for each week then the frequency $Freq$ is 7 (every seven days).

The significance of the cooperation effort for the dissolution is that with it, the organisational asset Oa of the organisation can be calculated, given the total duration of the organisation D for each agent A_i in the VO:

$$Oa = \sum_{A_i} MaxQt * UnitPr * \frac{D}{Freq}$$

This organisational asset will be used to evaluate the *Reduction* and *Loss* dissolution causes.

Each one of the causes of dissolution depends on one normative level (table 3) except for *Reduction* and *Loss*, which depend on both institutional and constitutional norms, as they depend on the initial VO assets (and thus on the constitutional norms) and on a minimum value specified in the institutional norms in the case that the VO has not redefined this for itself.

Unfeasibility is a different case. Although it can be considered as a constitutional norms-dependent cause, the truth is that it is more complicated to identify than by observing the assigned resources for each VO goal. A VO could find itself in a situation where it cannot fulfil its objectives for causes beyond the control of the organisation itself. Sometimes for external causes, VO performance could decrease, and the organisation should adapt to the environment, making modifications by reconfiguring itself (some authors introduce a separate phase for adaptation, and others mention the adaptation as a part of the operation phase), or dissolve. Tools for monitoring the VO are needed for identifying cases such as *Unfeasibility*, which, once identified, can enable the VO to avoid a useless extension of operation time if the expected results are to be negative.

Table 3. Dependence between dissolution causes and normative framework levels

Normative Level	Dissolution Cause
Institutional Norms	Agreement Inactivity Reduction Loss
Constitutional Norms	Deadline Fulfilment Reduction Loss

4.2   Liquidation

Liquidation is the last step before the complete dissolution of the VO. Every running task must be stopped and the VO activity frozen for realising the *liquidation* step. The organisation goes into an *on-liquidation* sub-state inside the dissolution phase (see Figure 2).

During the organisation's operation, a profit and expenses log must be maintained, which will allow the VO to create the final balance during this step. Some of the other main aspects that should be supported [10] are:

– Definition of general liabilities upon the dissolution of the VO.
– Keeping track of the individual contributions to a product/service that is jointly delivered (in terms of the quality and product life cycle maintenance).
– Redefinition/discontinuing information access rights after ceasing the cooperation.
– Assessing the performance of partners and generating information to be used by partner selection tools in future VO creation.

This last item is especially relevant, as it not only supports the formation of future VOs but can also support the identification of dissolution causes based (such as *unfeasibility*) on past experiences. An organisation can use this information to identify whether it is possible to fulfil its objectives given its status at a specific time.

For evaluating the partners' performance, it is better not to make a single evaluation at dissolution time, but at several times during the organisation's lifespan in order to have a complete picture of the performance evolution. In the best case the evaluation should be made at every moment during the organisation's operation time, but as this is not always possible, at least three fixed times are recommended for evaluating the organisation: at the moment of its formation, at half of its expected lifespan and at the end, before dissolving [14]. Additionally, new evaluations should be made if key elements are changed within the VO, such as the cooperation agreement.

The evaluation of performance depends upon the VO's scope. A suggestion for the evaluation elements is:

$$Ev = \langle Time, CA, Ben, Exp, Wf, Wr \rangle$$

Where:

- $Time$: The time when the evaluation has been made.
- CA: The VO cooperation agreements.
- Ben, Exp: A balance of the VO's benefits and expenses.
- Wf: The workload (in time or price unit) used for the fulfilled tasks.
- Wr: The expected workload needed for fulfilling the remaining tasks.

The output of the *liquidation* process should be a dissolution report (DR), which will contain all the evaluations made during the organisation's lifespan Evs, together with the dissolution cause DC. Additionally, it can contain an assessment Sc (a score between 0 and 1) from each agent A_i evaluating the VO's performance based on the fulfilment of the agents individual goals. We suggest the following for the content of the dissolution report DR:

$$DR = \langle Evs, DC, Vals \rangle$$
$$Evs = \{Ev_1, Ev_2, ..., Ev_n\}$$
$$Vals = \{Val_1, Val_2, ..., Val_n\}$$
$$Val_i = \langle A_i, Sc \rangle$$
$$DC \in \{Deadline, Reduction, Agreement,$$
$$Fulfilment, Unfeasibility, Inactivity, Loss\}$$

This dissolution report, stored in a knowledge base, will facilitate future VO formation and partner selection, giving information about the performance (from the benefits and expenses) and evaluation of each agent, and it also provides information for the reasons why the VO has not fulfilled its objectives, when that is the case.

5   Unfeasibility Case Study

We developed a simple digital environment for simulating the creation of agent organisations and for testing a way to identify the *unfeasibility* dissolution cause. In this environment, agents form organisations (as the idea is to focus only on the dissolution, the organisation formation process is done automatically) with a fixed duration (in time steps), after which the organisation dissolves.

The mechanism is simple: agents move and interact asynchronously through a grid space (which represents the environment), and when they find another agent in their neighbourhood (nearer than two cells), they send a message proposing the creation of an organisation. In the next time step, agents reply with whether they accept or not. Every agent in the system offers a single (not unique) service, where the advantage of forming an organisation lies in that two agents together can offer their own service plus their service combination, expanding their own markets.

The idea is to demonstrate the utility of supportive tools to automate the identification of dissolution causes, as well as to demonstrate how the dissolution can affect the overall system performance, comparing the results with cases

without the *unfeasibility* cause. Additionally, agents have a transitional step between *dissolution activation* and *liquidation* for deciding whether to proceed or not, based on the evaluation results of the organisation's performance.

At the moment of their dissolution, each organisation will generate a *dissolution report* containing evaluations of the organisation at different time periods. Each evaluation will contain only the benefits since the last evaluation (or the benefits so far if it is the first evaluation), the diversity of the offered services and the time steps passed from the last evaluation. These evaluations will be generated at three time periods of the VO's lifespan: at the first third of its expected lifespan, at the second third, and at the moment of its dissolution, when the *dissolution report* containing the evaluations is created (thus, if a VO has a fixed lifespan of 30 steps, the report will contain evaluations of the VO's benefits at steps 10, 20 and 30). If an organisation decides to extend its lifespan, new evaluations will be added to the report.

A knowledge base with previous cases will be used to identify cases in which the agents' expectations will probably not be fulfilled. At first, this knowledge base will be empty, and it will be filled with the *dissolution reports* that each dissolved organisation generates.

For the simulation, the following assumptions related to the agents have been made:

1. Each agent offers a single service.
2. Agents who coalesce are more likely to reap benefits, to the extreme that, in this case, single agents receive no benefits.
3. When agents coalesce, there are three options related to the organisation's lifespan: a) set a fixed lifespan, b) do not fix a lifespan and c) set an initial lifespan that can be changed.
4. In the specific negotiation scenario, at least two agents coalesce; one agent who makes an offer for creating an organisation and one or more who receive the offer. Each offer has a 50% chance of being accepted. This is to simplify the negotiation process while still having the chance to offer refusals.

As for the calculated benefits and organisation services, it is assumed that:

1. Two or more agents offering the same service can't be part of the same organisation.
2. Benefits are calculated based on the services an organisation offers and the demand for these services.
3. The organisations will offer the individual services of each member agent, as well the combination of these services. For example, if an organisation is composed of two agents, which respectively offer the services A and B, the organisation will offer the services A, B and A+B (figure 3)
4. Every service has the same base demand, as do the combined services.
5. The demand of a service depends on the competition within this service (how many organisations offer the same service). For example, if an organisation offers the services A, B and A+B, and another active organisation offers the services A, C and A+C, there will be two competitors for the service A.
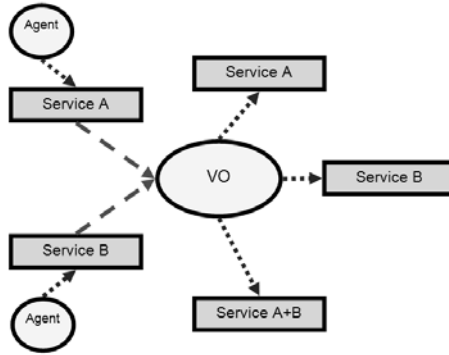
Fig. 3. Services of an organisation

Benefits for each time step are calculated by the following equation:

$$E = \sum_i (\frac{B}{C_i} + N)$$

Where:

- E are the total earnings or benefits of the organisation at each step.
- B is the base earnings for each service i.
- C_i is the number of organisations that offer the same service i (including the organisation whose earnings are being calculated).
- N is a random number from a normal distribution with average 0 and variance (B/2).

This implies that the greater the diversity in the services that an organisation offers, the lower competition and the higher benefits it will likely experience.

The organisation's goal is to receive at each time step a minimum "acceptable" benefit E above B/5; if it identifies that the goal is not achievable, an *unfeasibility* cause is detected. On the other hand, if the organisation estimates that its expected benefits can be over B/2, it considers whether to extend its lifetime, as the expected benefits are good.

To support the identification of the dissolution cause, a knowledge base with previous cases will be used. In this experiment, we will use a case-based algorithm (which from now on will be referred as *the algorithm*) to identify those cases in which it is better to dissolve the organisation if the goal cannot be fulfilled, which means that it finds itself in an *unfeasibility* case. The same algorithm will be used when the organisation's lifespan is about to reach its end, identifying whether it is better to extend it rather than to proceed to *liquidation*, as the benefit expectancies are good.

As said before, during the organisation's *dissolution*, a *dissolution report* will be created and stored in the knowledge base with different evaluation cases containing the VO's benefits, service diversity and the time step when the evaluation was made.

The algorithm, in its retrieving step, will identify pairs of consecutive evaluations similar to the current and last evaluations. Once a similar case is found, the algorithm will try to predict the following state based on the past case and to evaluate, reusing the past similar case, which is the best action for the organisation to take: whether it is better to continue operating by extending its lifespan or to dissolve.

The similarity for the algorithm is calculated by:

$$Sim = (Div_k * w_1 + Ben_k * W_2) + (Div_{k-1} * w_1 + Ben_{k-1} * W_2)$$

Where:

- Div is the diversity similarity at a time k and a time $k - 1$. This value is calculated by the percentage difference of the amount of different agent types (identified by the service they offer) that are members of organisations. For example, having in one case 4 different agents in an organisation, and in another 5, the diversity similarity will be $4/5 = 0, 8$.
- Ben are the benefits similarity per time step at a time k and a time $k - 1$. This is calculated by the same method as above, but using the benefits per step instead of the number of different agents.
- w_n are the respective weights for the similarity values. For this case, the weight will be equal for every similarity value.

In the knowledge base, there must be an evaluation at a time $k + 1$ in order to estimate the future benefits given the current state.

To distinguish positive cases (when it seems the that goal can be fulfilled for the next time step) from negative ones (when the goal cannot be fulfilled), the algorithm will compare earning expectations with the benefits found in similar past cases from the knowledge base, reusing values from past cases.

5.1   Setup

The simulation environment has been developed in RePast[1]. RePast is an open source agent modelling toolkit developed in Java that provides different tools for tracking and displaying agent and environment values. The tests were done in a grid of 50x50 cells, with 500 different agents who can each offer one of the ten different services. The base earning for each service was fixed at 1, and the default duration time of an organisation was 15 time steps. It was tested over 10,000 time steps through three different experiments:

Experiment 1: Organisations start with a defined lifespan, which can be extended or reduced, with support from the algorithm.

Experiment 2: Organisations have an unlimited lifespan, so new organisations can never be dissolved. Since agents only get benefits when they are part of an organisation (from hypothesis 2), this could be a reasonable strategy to guarantee benefits for each agent at each time step once the agents have formed an

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[1] http://repast.sourceforge.net

organisation, as opposed to the other experiments where, due the organisations dissolution, there will more often be agents without organisations wandering in the grid without getting benefits.

Experiment 3: Organisations have a fixed lifespan that cannot be modified, so they always dissolve when the expected deadline is reached.

5.2   Results

After ten runs of 10,000 steps for each experiment, the results for the average benefits at each step can be seen on Figure 4. After step 8,600 the benefits per step seem to stabilise and reach the 98% of the steady value, so for the conclusions and the results calculation, we will consider the average benefits from step 8,600 onward. The average benefits per step are in Table 4.
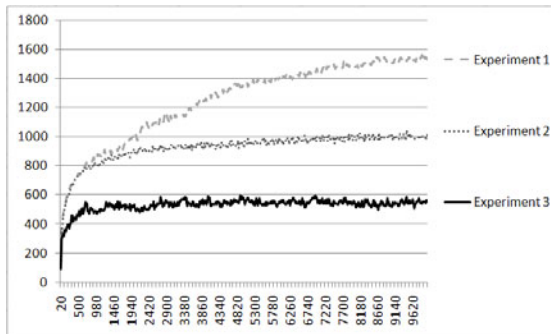

Fig. 4. Average organisation's benefits per step, 3 experiments, 10 runs, 10,000 steps each

Table 4. Average benefits per time step from the step 8600 onward

	Average Benefits	Std. Deviation
Experiment 1	1,530.04	12.69
Experiment 2	997.21	13.35
Experiment 3	543.77	16.26

There is a significant improvement when the algorithm enables identification of the unfeasibility dissolution cause for an organisation and when the organisation is allowed to modify its own lifespan (experiment 1). In Experiment 2, there are not many agents outside of an organisation, so most of them are getting benefits, but this does not guarantee that they are in the best possible organisation. They may do better to leave their organisationand not reap benefitsto search for new ones, instead of remaining part of a badly performing organisation. In this case, the unfeasibility dissolution cause not only helps to prevent organisations from operating when goals cannot be achieved, but it also helps to improve overall performance if goals are related to benefits.

6   Conclusions

VOs have been approached from different perspectives, but most of these approaches are focused mainly on the first phases of their lifecycle, (*formation* and *operation*), leaving the *dissolution* phase as an unresolved issue pending future work. The current paper makes an approach to this phase, presenting it as a two-step phase of (*activation* and *liquidation*), with two sub-states, (*pending dissolution* and *liquidation*).

One of the main contributions of this work is in the description of the causes of dissolution, besides VO goal fulfilment or the partners decision to dissolve. We also use elements from the dissolution process for supporting future VO formation, recording the resulting dissolution report from the *liquidation* step. This could be significant for future partner selection and for future identification of dissolution causes such as the unfeasibility cause, which can be identified by experience from past similar cases (see section 5).

Dissolution prevents the operation of badly performing or unnecessary organisations, and it can improve overall performance by correctly identifying those cases when an organisation should no longer operate.

Not all the dissolution causes are mandatory for dissolving the VO; some of them need the partners' approval for going on to the dissolution, as they could be also a cause for VO reconfiguration. The VO formation phase should consider new issues during the negotiation process, related to the norms for the *dissolution* phase.

Finally, the basis for the dissolution process was inspired by real-world organisations' dissolution; because of this, a normative framework is needed for supporting the dissolution process with a structure similar to that of real-life norms (the law at a higher level, and the organisations' statutes below). Although commercial law is used as an inspiration, this approach is not restricted to economically based organisations; assets, costs and benefits are not restricted to economical approaches, as they can be identified within the amount of workload inside a VO.

The *dissolution* phase is not trivial, so we offer an approach to it. Hopefully this work will fulfil the goal of emphasising its significance and provide a good reference for contributing to the formalisation of VO process. Future work will be focused on completing the formalisation of the dissolution phase and extend the work to other types of organisations.

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