Journal of Universal Computer Science, vol. 20, no. 6 (2014), 859-884
submitted: 1/7/13, accepted: 14/2/14, appeared: 1/6/14 © J.UCS

A Taxonomy for Virtual Enterprises

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Abstract: The purpose of this paper is to present a taxonomy able to contribute to building a framework within the domain of Virtual Enterprises (VE), to facilitate the sharing of knowledge and contributions to knowledge, as well as for trust building among VE stakeholders. A VE taxonomy currently does not exist, and this lack is felt in the ambiguous way that some concepts are addressed, leading to a fragment understanding that hinders the development of the science of VE integration and management. The structure of the taxonomy developed is based on the view of the system as a 5-tuple consisting of Input, Control, Output, Mechanism, and Process, which is the underlying system-view in the well-know IDEF0 diagramming technique. In particular, this taxonomy addresses the VE extended lifecycle that implies the use of a meta-organization called Market of Resources, as an original contribution to the VE theory and practice. The taxonomy presented does not repeat what the literature already includes, or the commonplaces, and it is constructed in a way to be easily complemented with other VE partial taxonomies that may be found in literature. Some suggestions for extensions to other interrelated domains (as evolution leaves taxonomies in an open or incompleteness state) are given in the text.

Keywords: Virtual enterprise, taxonomy, Market of Resources
Categories: M.4, L.1.3

1 Introduction

The purpose of this paper is to present a taxonomy able to contribute to building a framework within the domain of Virtual Enterprise (VE), to facilitate the sharing of knowledge and contributions to scientific knowledge, as well as to support negotiation, dialogue, trust building and sharing of tacit and explicit knowledge among VE stakeholders. Currently, such a taxonomy defining VE concepts or definitions, management, integration, reconfiguration and operation processes, tools and mechanisms, and underlying theories and approaches, does not exist, and this can be felt through the several dispersedly developed taxonomies that can be found in the literature. Although very rich, these taxonomies were specifically developed to cover aspects such as e-Commerce [Hsu, 08] [Lee, 09], electronic negotiation [Lomuscio, 03], [Ströbel, 03], [Hudert, 09], electronic contractualization [Grosof, 04], [Milosevic, 04], collaboration in virtual enterprises [Camarinha-Matos, 06], workflow support [Grefen, 06], supply chain networks strategies [Moller, 06], just to mention a few, and

although somehow related to the VE domain, naturally have not lead to unifying definitions and clear concepts, as this was not their underlying purpose.

Humans have always searched for order in the world and, implicitly, a reliable and valid classification of entities, and this is such more important in the scientific domain [Dunn, 82]. The noun "taxonomy" has a Greek origin and is defined at Merriam-Webster online [Taxonomy, 10b] as "(1) the study of the general principles of scientific classification; (2) classification; especially: orderly classification of plants and animals according to their presumed natural relationships". The Merriam-Webster's Learners' Dictionary [Taxonomy, 10a] adds the meaning "the process or system of describing the way in which different living things are related by putting them in groups". According to [Cheung, 05], unstructured knowledge makes difficult the process of knowledge acquisition, organizing and sharing.

Many researchers [Lethbridge, 01], [Meyer, 93] [Rasmussen, 07] have identified the proliferation of complex and sometimes duplicated, overlapping (which does not mean contradictory) terminology, addressed from different dimensions, leading to fragmented understanding and hindering the development of the science of VE integration and management.

It can be verified that authors in general use some definitions and concepts interchangeably and ambiguously, so that in particular the understanding of VE integration, operation and management can be fragmented and hindered (as developed later in section 3).

Virtual Enterprises, Agile/Virtual Enterprises, Virtual Organizations, Smart Organizations, Networked Enterprises, Star Aliances, BM_Virtual Enterprises, to name just some, are designations of similar, complementary and overlapping models and concepts; in front of this, how can a manager, a policy maker, a researcher, a student, capture the correct sense of them all? What are their associated enabling technologies? And other similar questions related to the ambiguity of diverse definitions within the VE theory arise.

After a literature review on VE, the authors concluded that the literature provides a wide range of definitions, characteristics, models, typologies for VE, most of them overlapping and duplicated, and sometimes using different terms for the same dimensions. However, some of these works are superficial or incomplete, very focused and covering a narrow view, such as defining communication flows or defining typologies and coordination among VE members. Some of the contributions referred are not precisely taxonomies, but characterization efforts, sets of properties or characteristics of a given aspect/view of a VE.

But developing foundational taxonomies is not simple at all. The authors describe a set of key elements/ assumptions, focusing on a "system view" based taxonomy. The structure of the taxonomy developed is based on the view of the system as a 5-tuple consisting of Input, Control, Output, Mechanism, and Process, which is the underlying system-view in the well-know IDEF0 diagramming technique. In particular, this taxonomy addresses the VE extended lifecycle (proposed in [Cunha, 05b]) which besides the traditional VE life cycle phases (VE creation /integration, operation and reconfiguration along time and finally its dissolution), implies the use of a meta-organization called Market of Resources, as an original contribution to the VE theory and practice.

This structure was intentionally used to facilitate the transposition and the relationship with other VE models already developed using IDEF0 representation, as well as to facilitate the use of IDEF0 and similar techniques in the conception and development of new models.

The taxonomy presented in the paper is expected to facilitate the sharing of knowledge in the domains of VE concepts or definitions, management, integration, reconfiguration and operation processes, tools and mechanisms, and underlying theories and approaches.

The taxonomy presented does not represent a merge of existing or already published partial taxonomies, that is, the taxonomy presented does not repeat what the literature already includes, as well as repeating the commonplaces, but it is constructed in a way to be easily complemented with other VE partial taxonomies that may be found in literature, in a form of new "branches" of the taxonomy "tree" that can be added ("grafted").

In this context, some suggestions for extensions to other interrelated domains (as evolution leaves taxonomies in an open or incompleteness state) are given in the text. In other words, although a taxonomy is always incomplete, the taxonomy herein introduced is broader in coverage than the existing ones, which can be seen as branches of it, and deeper (in detail). It is not possible to completely define a subject, objective and exhaustively, "it is only possible to classify our knowledge of it" [Gershenson, 99].

The paper is organized as follows: section two introduces basic concepts related to taxonomy definition and representation, as well as presents a literature review on VE taxonomies. Section three introduces concepts related with the VE model, namely definitions, requirements, enabling structures and section four states the building blocks for the introduction of the "system-based view" taxonomy, introducing the meta-enterprise called Market of Resources as an enabler of the VE model. Section five presents the taxonomy and finally section six highlights some limitations of this work, suggests a few extensions to other interrelated domains and draws conclusions of the undertaken research.

2 Background

This section makes a brief introduction to the basic concepts to be developed in the paper and presents a literature review on VE related taxonomies

2.1 Definition of taxonomy

"The fact that others might introduce old words with new meanings into previously relatively stable domains of discourse should make us think." [Gilchrist, 03]. Hence, Gilchrist explained the need to organize knowledge in taxonomies, and identified several triggers for this. Carolus Linnaeus (1707-1778) is recognised as the father of modern taxonomy, and developed the *Linnaean* taxonomy, a method of classifying living things, and arranging them in a hierarchical structure. However, in the year 300 b.C. Aristotle was one of the first to use this term to name hierarchical schemes oriented to the classification of scientific objects.

A taxonomy is defined as the practice or principle of classification. According to biological terms, it is defined as the science of classifying plants, animals, and micro-organisms into increasingly broader categories based on shared features. In biology, taxonomy, classifies all living organisms from single celled organism, insects, birds, mammals, and humans in a hierarchical order. In short, classification is the arrangement of things according to likeness and unlikeness, in terms of belonging to set and subsets.

Today the concept is applied in a wider sense and refers to the classification of things and to the principles underlying such a classification. Almost anything on earth may be classified according to some taxonomic scheme. The basic idea behind taxonomy is to provide a controlled vocabulary for metadata attributes, and to specify relationships between terms in the controlled vocabulary [Taxonomystrategies, 09].

The benefit of this approach is that it allows related terms to be grouped together and categorized in ways that make it easier to find the correct term to use whether for searching or to describe an object. So, a taxonomy describes the subjects being used for classification, but is not itself metadata; it can be used in metadata, however.

According to [Guarino, 00], [Welty, 01], taxonomies based on a partial-ordering relation commonly known as is-a, class inclusion or subsumption, are an important part of conceptual modeling, providing substantial structural information, and are typically the key elements in integration efforts; a well-formed taxonomy has significant implications for understanding, reuse, and integration of knowledge.

2.2 Representation of taxonomies

Taxonomies are a common and powerful tool to structure information. The efficient representation of taxonomies as free-structured sets of concepts is not a new concern. Taxonomies are special trees where each leaf node represents some object and all other nodes represent classifications of objects represented by its child nodes; a taxonomy could be presented as a two or three-dimensional grid or as a graph of interlinked nodes [Gambosi, 87]. Hierarchical order is just one way of representing a taxonomy, and is the one adopted in this paper.

The scope of a taxonomy is defined by its extent and granularity [Villa, 07]. Granularity deals with articulating something (hierarchically) according to certain criteria, where a lower level within a perspective contains knowledge or data that is more detailed than the adjacent higher level [Keet, 2006], [Villa, 07].

A taxonomy is a structure of knowledge representation simpler than the ontology, but that can be used as basis to the development of ontologies [Sugumaran, 02], [Corcho, 03], [Gilchrist, 03], [Kashyap, 05] [Hepp, 07]. Ontologies, taxonomies, and other semantic hierarchies are increasingly necessary for organizing large quantities of data [Kaiser, 08].

2.3 A review of literature on VE taxonomies and related

Literature has been offering VE classifications since the mid-nineties. This section presents a compilation of the main contributions towards the definition of VE related classifications, definitions and taxonomies, based on a literature review, in order to present our vision of a VE, based on the representation of a set of concepts identified within the VE subject domain, definitions and identified relationships.

In 1995 [Sarkar, 95] classified "intermediary" (cybermediary) functions in electronic commerce; in 1999 Bichler & Segev [Bichler, 99] described approaches to brokerage services in electronic commerce and later [Ávila, 02] identified and systematized brokerage functions in VE.

The firsts virtual organization taxonomies were developed in 1998 by Bultje [Bultje, 98], based on definitions, characteristics and typologies of inter-organizational co-operation, and in [Lethbridge, 01] it was introduced a taxonomy of virtual organization structures based on the cross-boundary information flow requirements of member organizations; this contribution defined the basic, elemental structures for a virtual organization and specified the relation among the member organizations and between the organization and the customer.

Bafoutsou [Bafoutsou, 02] presented a review of research on taxonomies in the area of creating collaborative applications for E-collaboration and collaborative systems; the inter-organizational application integration aspects, in-line with the needs of the networked organizations, were analyzed and characterized in [Themistocleous, 02] [Irani, 03], while later Choi *et al.* [Choi, 08] proposed a framework for VE collaboration. [Westphal, 10] defined typologies of cooperation in intensive collaborative interactions between the partners, with an approach that provides an information basis for the management of collaboration when companies work together in cooperation.

Gunasekaran [Gunasekaran, 02] proposed a framework as a basis for understanding the major strategies and relevant technologies of Agile Manufacturing (AM). Similarly to what happens with the VE concept, the term 'agile', coined in 1991 [Nagel, 92], leaves still some concerns that prevent companies from taking an entirely different direction from AM.

Lomuscio [Lomuscio, 03] presented a comprehensive definition of automated negotiation parameters in e-commerce settings, and [Ströbel, 03] characterized and compared a large variety of electronic negotiation designs and systems, ranging from auctions to bilateral bargaining systems. Hudert [Hudert, 09] made a review of literature on taxonomies originating in e-commerce research and economics; these taxonomies presented a set of parameters that allowed for detailed description of specific negotiation protocols, that their authors used to propose a Negotiation Framework.

Malucelli [Malucelli, 06] combined the use of ontologies and agent technologies to contribute in solving the heterogeneity problem in e-commerce negotiations; the authors developed a methodology that assesses lexical and semantic similarity among concepts represented in different ontologies, the Ontology-based Services. [Jagdev, 08] contributed to the design and implementation of a bid auction application for procurement automation within supply chains embedded in extended and virtual enterprises, using ontologies

[Jung, 07] proposed a framework to overcome the heterogeneity between taxonomies for describing resources, to enable inter-alignment between organizational taxonomies.

Efficient and secure knowledge sharing is critical to the success of a VE; Chen [Chen, 08] proposed a ontology-based knowledge sharing model and a multiple-layer knowledge representation framework for knowledge sharing in a VE.

Eschenbacher [Esch, 11] analysed collaboration intensities within networked enterprises relationships.

[Thoben, 01] proposed typologies for enterprise network based on attributes of the network, node-related attributes and product-related attributes. Typologies of enterprise networks, envisaging network performance assessment are also presented in [Cagnazzo, 10].

Chen [Chen, 08] refered the often overlapping approaches and the lack of explicit definitions in architectures for enterprise integration. Indeed, although a taxonomy is never complete, all of these contributions are limited to only a part of a model, to a set of functions or processes. These are parts of a whole.

The various complementary contributions found (and many more could be added) show that the paradigms are defined with more or less extension and granularity and hence classifiable by some set of characteristics, principles, strategies, practices, enabling features, dimensions, etc. As we demonstrated, there exist a virtually infinite number of contributions towards the classification and organization of VE related concepts.

3 The Virtual Enterprise Model

Concerning the question of the VE as a new organizational paradigm, and according to the authors' opinion, there are three fundamental features of the VE concept that make the fundamental difference between the VE and the "traditional" enterprise. These are:

- The dynamics of network reconfiguration,
- Virtuality, and
- External entities (meta- (virtual) enterprise structures) as environments for enabling, or supporting, the VE integration itself as well as to support reconfiguration dynamics.

The concept of Virtual Enterprise as an organizational model has emerged a couple of decades ago, after a number of truly advanced organizational (and management) concepts that marked the decades from the seventies to the nineties, but which did not manage to succeed in all required dimensions in the nowadays turbulent and unpredictable market [Putnik, 05].

The functional requirements for the new approach were recognized (and published) already in the eighties, e.g. see Miles & Snow [Miles, 84], [Miles, 86], while virtually the most known references have appeared in nineties, e.g. Drucker [Drucker, 90] and Iacocca Institute [Nagel, 92], (which had defined a virtual enterprise concept as a part of a wider concept called Agile Manufacturing, or Enterprise).

The term and the concept "Virtual Enterprise" emerged already in the beginning of nineties and could be seen as the further optimization and perfection of the basic ideas about dynamic networking. However, unfortunately or not, until today, there is not a universally accepted definition, or model, of the VE.

A selection of definitions, which explicitly use the term "Virtual Enterprise", is presented in Box 1 –Virtual Enterprise, where it is demonstrated precisely the

overlapping and incompleteness of the concepts in some cases, the complementarity in another.

"A **Virtual Enterprise** is an organization fundamentally customer-oriented which accomplish the customer needs in a particular way and which is extremely time and cost effective." [Davidow, 92]

"A **virtual corporation** is a temporary network of independent companies – suppliers, customers, even rivals – linked by information technology (IT) to share skills, costs and access to one another's markets. It will have neither central office nor organization chart. It will have no hierarchy, no vertical integration." [Cadle, 01]

"**'Virtual Enterprise'** with the key processes subcontracted to other suppliers" [SME, 1993]

"**Virtual corporates** are fluid, on-line partnerships comprised of the best practices from various companies that bring together their individual core competencies to create a new product or service during a market window of opportunity. Once the life cycle of the product or service ends, they will separate and go about their businesses." [Hormozi, 94]

"The **virtual organization**, or more accurately, an organization with a virtual organizational structure, is only one of many forms that cooperation, both among companies and within a single company, can take. … A virtual organizational structure is an opportunistic alliance of core competencies distributed among a number of distinct operating entities within a single large company or among a group of independent companies. … While the virtual organization is opportunistic, its objective is to create solution products with lifetimes as long as the marketplace will allow. These products are expected to evolve, and as they do, so will the virtual organization's resource requirements. Some participants will leave to join other groups because their competencies no longer add enough value to be most profitably used in the virtual organization. For precisely the same reasons, others will join, because they can add value as the product evolves in one direction rather than another. … The virtual organization is a dynamic organizational tool for agile competitors. It is at once neither temporary nor permanent" [Goldman, 95]

"A **Virtual Enterprise** 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, and whose cooperation is supported by computer networks" ESPRIT IV PRODNET, [Camarinha-Matos, 97]

A **virtual organization** is a network of independent, geographically dispersed organizations with a partial mission overlap. Within the network, all partners provide their own core competencies and the co-operation is based on semi-stable relations. [Bultje, 98].

"A **virtual enterprise** is not really different from a traditional enterprise other than the fact that it can append and shed processes quickly. There are more legal and regulatory issues than technical issues when removing barriers to virtual-enterprise operations." [Nell, 98]

[*] – minor adaptations introduced by the authors to the original text

Box 1: Virtual Enterprise (adapted from [Putnik, 05])

It can then be summarized stating that a successful company must acquire the capability to achieve and explore the competitive advantage in synergy [Yusuf, 99], i.e., using the best resources available to an organisation [Cunha, 00], which requires

a shift from "self-centred close-enterprises" [Browne, 99] to dynamically reconfigurable collaborative networked structures, corresponding to the recent approaches of the Extended Enterprise [Browne, 95], the Virtual Enterprise [Drucker, 90], [Byrne, 93], [Goldman, 95], the Agile Enterprise [Nagel, 92], the Virtual Value Chains [Benjamin, 95], the Agile/Virtual Enterprise [Cunha, 00], [Cunha, 02a] [Putnik, 00], the Intelligent Enterprise [Quinn, 90], the Smart Organisation [Filos, 01], the OPIM model (One Product Integrated Manufacturing) [Putnik, 95], [Putnik, 97] and other models, each with its characterising nuances. These models are generally addressed as Virtual Enterprise (VE) models.

Therefore, a VE taxonomy should reflect the definitions of Box 1 (among other) and their subsequent narrowed or specialized evolutions traduced in the above models, their elements and relationships.

4 A "System-based view" of a taxonomy for the VE Model

This section introduces the representation to be used in the taxonomy as well as presents and briefly explains the VE lifecycle based on a Market of Resources.

4.1 Structure and representation

A taxonomy can have several perspectives/ approaches/views or interpretations, which lead to different criteria for construction. In this section we introduce a system view based, following the view of the system as a 5-tuple consisting of Input, Control, Output, Mechanism, and Process, which is the underlying system-view in the well-know IDEF0 diagraming technique. In particular, the taxonomy presented follows an IDEF0-based representation of a Virtual Enterprise structure, as defined in [Cunha, 05b], [Cunha, 06a].

Computer graphic dynamic representations of taxonomies, in the form of a tree, are a useful tool to represent taxonomies with the dimension of the proposed one, as they accomplish the need to compressed / extended representation of branches as one traverse the tree. For large taxonomies, these images are not transposable to paper, so the authors' taxonomy is hierarchically represented as an "and/or tree", where the levels are numbered and deeper levels are indented for better understanding. The top-down (hierarchical) representation supposes the initial identification of a limited number of higher categories, and the grouping of the rest of categories in successive levels of subordination up to reaching the most specific levels of categories. A hierarchical numbering was applied to distinguish the hierarchical level of each item in the and/or tree model.

The following connectors are used in the representation:

|	- disjunction	e.g. A | B
/	- conjunction	e.g. A / B
(|)	- alternative	e.g. A (| B)

4.2 The IDEF0 representation of the VE lifecycle based on a Market of Resources

There are five elements in the IDEF0 functional model: each process (or activity) of the system is represented by a box, where *inputs* are represented by the arrows flowing into the left hand side of an activity box and *outputs* are represented by arrows flowing out the right hand side. *Inputs* and *outputs* connect the process to other boxes (processes) – see Figure 1. The top of the box is reserved for *control* information or constraints on the activities and arrows in the base represent *mechanisms* that carry out the activity. The *input*, *output*, *control* and *mechanism* arrows are also defined as ICOMs.

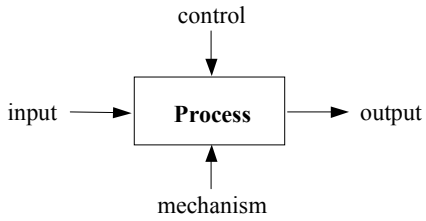

Figure 1: IDEF0 representation

The IDEF notation represents some of the systems' principles: inputs are transformed into outputs, control flows constraints or restricts the conditions in which the transformation occurs and mechanisms describe how the functions are executed. All inputs are converted, by influence of mechanism and control, into output.

The Market of Resources is the environment for enabling and management of efficient configuration, and assuring virtuality, at low transaction costs and reduced risk of knowledge leakage. It is one of the main tools conceived in the BM_Virtual Enterprise Reference Model (BM_VEARM) for managing, controlling and enabling networking and dynamics [Putnik, 00].

The Market of Resources is an institutionalised organisational framework and service assuring the accomplishment of the competitiveness requirements for VE dynamic integration and business alignment [Cunha, 02a], [Cunha, 02b], [Cunha, 05a], [Cunha, 05c]. The operational aspect of the Market of Resources consists of an Internet-based intermediation service, mediating offer and demand of resources to dynamically integrate in an VE, assuring low transaction costs (as demonstrated in [Cunha, 06b]) and the partners' knowledge preservation. Brokers act within the Market of Resources as intermediation agents for agility and virtuality.

In this "virtual" environment, offer corresponds to resources providers (individuals, enterprises) that make their resources (products, components, operations) available, as potential partners for VE integration, and demand corresponds to client, the VE owner, the entity looking for resources to create/integrate/reconfigure a VE to satisfy the Customer. Customer is the entity giving rise to a business opportunity and is considered outside the Market of Resources.

The overall functioning of the Market of Resources is represented by an IDEF0 diagram in Figure 2. It consists of the creation and management of the Market of Resources itself (Process A.1.), as the environment to support the design and

integration of the VE (Process A.2.) that, under the coordination of the environment, operates to produce a product to answer to a market opportunity (Process A.3.). The Market offers technical and procedural support for the activities of identifying potential partners, qualifying partners, and integrating the VE, as well as coordination and performance evaluation mechanisms.

Process A.2. (VE Design and Integration) is detailed in Figure 3. This operation is one of the most effort consuming for the user in its interface with the Market. The Request for VE Creation (or reconfiguration or dissolution), is composed by Request Negotiation, VE Design and Request Formalisation.

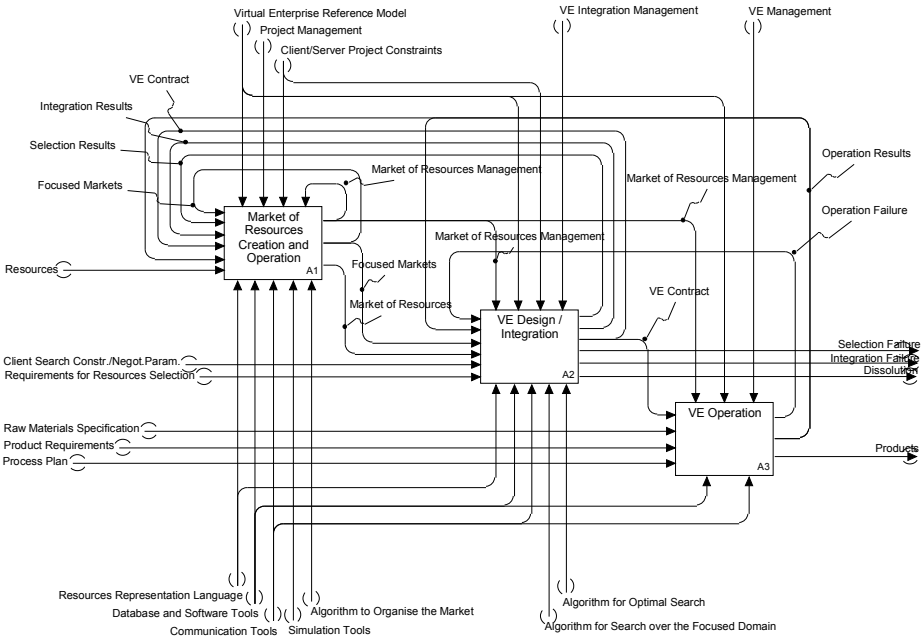

Figure 2: IDEF0 representation of the global process for the Market of Resources and for A/V E Design, Integration and Operation [Cunha, 06a]

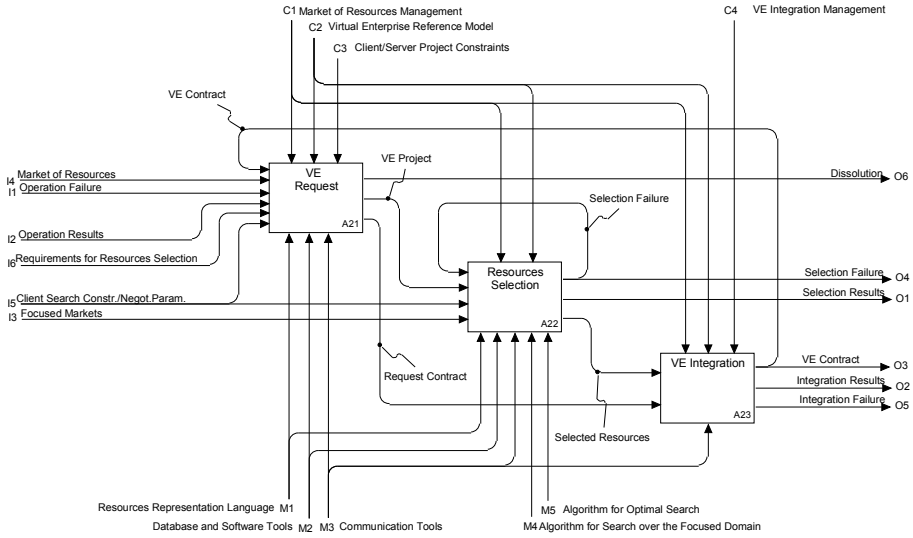

Figure 3: IDEF0 representation of Process A.2. – VE Design and Integration [Cunha, 06a]

5 A Virtual Enterprise taxonomy

The VE taxonomy following the "system"-based view is presented in this section. A special focus was given to the approached of using the meta-institution Market of Resources as a tool for VE integration, operation and reconfiguration (section 1.1.5.1.1.1.). Other approaches are expected to be developed in a near future.

```
Virtual Enterprise
1. Concepts ( | Approach )
/
2. Requirements ( | Input )
/
3. Processes ( | Activity )
/
4. Output ( | Result )
/
5. Tools ( | Mechanisms | Resources )
/
6. Management ( | Control | Constraints )
```

To simplify the presentation, the above six entries are detailed in six different subsections, and the detail of some deeper levels of the taxonomy are included as annexes.

5.1 VE concepts or approaches

```
Virtual Enterprise
1. Concepts ( | Approach )
   1.1. Supply chain
   1.2. Extended Enterprise
```

```
   1.3. Agile Enterprise
   1.4. Smart organizations
   1.5. Virtual Enterprise
   1.6. Collaborative Networked Organization
   1.7. Agile/Virtual Enterprise
   1.8. BM_Virtual Enterprise
      1.8.1. BM_Agile/Virtual Enterprise
      1.8.2. BM_Virtual Enterprise
         1.8.2.1. Business centered
         1.8.2.2. Resource centered ( | Server/Client centered | Service
                  centered )
   1.9. Ubiquitous Enterprise
      1.9.1. BM_ VEARM based Ubiquitous Enterprise
      1.9.2. Other
   1.10. Virtual Organization
   1.11. OPIM (One Product Integrated Manufacturing)
   1.12. Other
```

5.2 VE requirements or inputs

```
2. Requirements ( | Input )
   2.1. Objectives
      2.1.1. I*PROMS objectives
         2.1.1.1. Identification of the VE State-of-the-art
         2.1.1.2. Identification of VE enabling factors and technologies
         2.1.1.3. Identification of VE ontologies
         2.1.1.4. Identification of a VE Road-map
         2.1.1.5. VE Research Integration
      2.1.2. Other objectives
      2.1.3. Identification of the VE State-of-the-art
      2.1.4. Identification of VE enabling factors and technologies
      2.1.5. Identification of VE ontologies
      2.1.6. Identification of a VE Road-map
      2.1.7. VE Integration
      2.1.8. Information discovery and integration
      2.1.9. Resources taxonomy
   2.2.
   /
   2.3. Attributes and Functionalities
      2.3.1.  Integrability ( | Interoperability )
      2.3.2.  Distributivity
      2.3.3.  Agility ( | Dynamics )
      2.3.4.  Virtuality
      2.3.5.  Partnership coordination
      2.3.6.  Partner relationship
      2.3.7.  Responsiveness
      2.3.8.  Flexibility
      2.3.9.  Utilization of ICT
      2.3.10. Communication
      2.3.11. Price
      2.3.12. Cost
      2.3.13. Quality
      2.3.14. Profit
      2.3.15. Quick response
      2.3.16. Lead time
      2.3.17. Customer satisfaction
      2.3.18. Quick (pro-)action
      2.3.19. Other
   /
```

```
2.4. Domain
   2.4.1. Manufacturing
      2.4.1.1. I*PROMS (Innovative Production Machines and Systems)
         2.4.1.1.1. Production Organization and Management (POM)
         2.4.1.1.2. Innovative Design Technology (IDT)
         2.4.1.1.3. Advanced Production Machines (APM)
         2.4.1.1.4. Production Automation and Control (PAC)
      2.4.1.2. Others
   2.4.2. Others
```

5.3 VE processes or activities

```
3. Processes ( | Activity )
   3.1. Model 3 - BM_VEARM
      3.1.1. Identification of the Opportunity
      /
      3.1.2. Contractualisation with the Market of Resources
      /
      3.1.3. Design and Integration ( | Reconfiguration )
      /
      3.1.4. Operation
      /
      3.1.5. Dissolution (a special case of Reconfiguration).
   3.2. Model 1 - PRODNET
      3.2.1. Creation
      /
      3.2.2. Operation
      /
      3.2.3. Modification
      /
      3.2.4. Dissolution
   3.3. Model 2 - VERAM
      3.3.1. Preliminary design
      /
      3.3.2. Identification
      /
      3.3.3. Concept
      /
      3.3.4. Requirements
      /
      3.3.5. Detailed design
      /
      3.3.6. Implementation
      /
      3.3.7. Operation
      /
      3.3.8. Decommission
   3.4. Other
   /
   3.5. Integration
      3.5.1. Transaction based
         3.5.1.1. Direct
         3.5.1.2. "Federated"
         3.5.1.3. Open
         3.5.1.4. "Wrapping"
      3.5.2. Communication based
         3.5.2.1. "Generative integration"
            3.5.2.1.1. "Generative integration" life-cycle
               3.5.2.1.1.1. Integration synthesis
```

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                /
                3.5.2.1.1.2. Integration operation
                /
                3.5.2.1.1.3. Integration termination
```

5.4 VE outputs or results

```
4. Output ( | Result )
   4.1. Distributed Enterprise
   4.2. Agile Enterprise
   4.3. Agile/Virtual Enterprise
   4.4. Virtual Enterprise
   4.5. Ubiquitous Enterprise
   4.6. Virtual Organization
   4.7. Others
```

5.5 VE tools, mechanisms or resources

```
5. Tools ( | Mechanisms | Resources )
   5.1. Infrastructures
      5.1.1. Organizational infrastructures
         5.1.1.1. "Market of Resources" (MR)
         5.1.1.2. E-alliances
         5.1.1.3. E-market places
         5.1.1.4. Electronic institutions
         5.1.1.5. Virtual clusters
         5.1.1.6. E-business community (Value-net)
         5.1.1.7. "Guilds"
         5.1.1.8. Breeding Environments
      /
      5.1.2.   Information infrastructures
         5.1.2.1. WWW directories and search machines
         5.1.2.2. Portals
         5.1.2.3. Internet-based catalogues
         5.1.2.4. Electronic negotiation platforms / environments
         5.1.2.5. E-marketplaces
         /
         5.1.2.6. Attributes and Functionalities
            5.1.2.6.1.  Localization (language, currency, date format,
                        etc.)
            5.1.2.6.2.  User and Role Management
            5.1.2.6.3.  Catalogue / Content Management
            5.1.2.6.4.  Private Exchanges
            5.1.2.6.5.  B2B Marketplaces
            5.1.2.6.6.  Forward Auction
            5.1.2.6.7.  Reverse Auction
            5.1.2.6.8.  ATP - Available to promise
            5.1.2.6.9.  RFP/Q - Request For Proposals/Quotation
            5.1.2.6.10. Order Status Tracking
            5.1.2.6.11. Order Fulfillment
            5.1.2.6.12. Order Brokering
            5.1.2.6.13. Multi-protocol Order Routing
            5.1.2.6.14. Negotiation Mechanisms
            5.1.2.6.15. Logistics and Delivery Support
            5.1.2.6.16. Consolidated Invoicing
            5.1.2.6.17. Security (SSL / HTTPS)
            5.1.2.6.18. Digital Authoring (PKI, X.509)
            5.1.2.6.19. E-Business Analytics (OLAP, KPIs)
            5.1.2.6.20. Contract Management
```

```
            5.1.2.6.21. Workflow
            5.1.2.6.22. Project Management
            5.1.2.6.23. Survey & Campaign Management
            5.1.2.6.24. Messaging
            5.1.2.6.25. Interactive Forum Support
            5.1.2.6.26. Collaboration planning forecasting &
                        replenishment (CPFR)
            5.1.2.6.27. Complex product configuration
            5.1.2.6.28. High Availability (24 x 7)
            5.1.2.6.29. M2M Interconnection/Integration
      /
      5.1.3.  Legal infrastructure
      /
      5.1.4.  Integration infrastructures
/
5.2.  Integration dimensions
      5.2.1.  Language
      5.2.2.  integration domain
      5.2.3.  architectures / organization
      5.2.4.  dynamics
      5.2.5.  automation
      5.2.6.  performance metrics
      5.2.7.  normalization / standardization
      5.2.8.  management
      5.2.9.  "intelligence location"
      5.2.10. technology
      5.2.11. task coordination
      5.2.12. legacy issues
      5.2.13. knowledge
      5.2.14. integration process elements
      5.2.15. aspects of integration
      5.2.16. integration concerns
      5.2.17. methods and technologies
      5.2.18. mechanism or tools
      5.2.19. quality
      5.2.20. legal issues
      5.2.21. life-cycle
/
5.3. Information models, systems and procedures
      5.3.1. Integration support
         5.3.1.1.  file ( | document )
         5.3.1.2.  shared database
         5.3.1.3.  procedure call ( | operation invocation )
         5.3.1.4.  messaging
         5.3.1.5.  blackboard (publish and subscribe shared memory,
                   etc.)
         5.3.1.6.  human interface mechanisms (such as display,
                   keyboard, mouse, etc.)
         5.3.1.7.  portals
         5.3.1.8.  semantic-representation language
         5.3.1.9.  negotiation protocol
         5.3.1.10. semantic equivalence metric
         5.3.1.11. reasoning
         5.3.1.12. inferencing
         5.3.1.13. ontologies
         5.3.1.14. common technology for the transmission and reception
                   of the data
         5.3.1.15. common protocols for the exchange
         5.3.1.16. rules for the elementary interactions
```

5.3.1.17. common data structure and representation
5.3.1.18. data adapters
5.3.1.19. enterprise application adapters
5.3.1.20. transaction systems adapters
5.3.1.21. emulation adapters
5.3.1.22. protocol adapters
5.3.1.23. technology adapters
5.3.1.24. standards on enterprise engineering and integration
5.3.1.25. enterprise reference architectures
5.3.1.26. standard languages
5.3.1.27. standard (product) data exchange formats
5.3.1.28. standards for data share and access
5.3.1.29. data communication protocols
5.3.1.30. standards for system's interoperability
5.3.1.31. code mobility
5.3.1.32. information modelling
5.3.1.33. translator ("horizontal" integration)
5.3.1.34. wrappers ("vertical" integration)
5.3.1.35. distributed systems
5.3.1.36. programming languages
5.3.1.37. agents
5.3.1.38. operating systems
5.3.1.39. metadata
5.3.1.40. virtual meta-data
5.3.1.41. model metadata
5.3.1.42. metamodels
5.3.1.43. meta-metamodels
5.3.1.44. query management
5.3.1.45. connection technology (for available information systems)
5.3.1.46. direct humans communication
5.3.1.47. training
5.3.1.48. management
5.3.1.49. coordination
5.3.1.50. enterprise organization/architecture
5.3.1.51. teamwork
5.3.1.52. job rotation
5.3.1.53. deterministic translators or translation algorithms (fixed automation)
5.3.1.54. soft algorithms
5.3.1.55. data mining
5.3.1.56. expert system
5.3.1.57. machine learning
5.3.1.58. self-describing systems
5.3.1.59. self-integrating systems
5.3.1.60. negotiation
5.3.1.61. negotiation protocols
5.3.1.62. brokering
5.3.1.63. meta-organizations

5.3.2. Operation support
5.3.2.1. Database management systems
5.3.2.2. Distributed database management systems
5.3.2.3. E-Business development platforms
5.3.2.4. Portals
5.3.2.5. Intelligent agent technology
5.3.2.6. Electronic negotiation tools
5.3.2.7. Algorithms or protocols
5.3.2.8. Regulation of negotiation
5.3.2.9. Intelligent decision making systems

```
      5.3.2.10. Electronic payment
      5.3.2.11. Digital signature
      5.3.2.12. Certification
      5.3.2.13. Other security mechanisms
      5.3.2.14. Simulation tools
      5.3.2.15. Workflow technology and collaboration techniques
      5.3.2.16. Regulation
      5.3.2.17. Messaging and conferencing
      5.3.2.18. Algorithms
      5.3.2.19. Management procedures
      5.3.2.20. Standards for product/services description
      5.3.2.21. Collaboration tools
      5.3.2.22. Data translation standards and tools
      5.3.2.23. Communication protocols
      5.3.2.24. heuristics and computer aided tools
      5.3.2.25. Intelligent decision making systems
      5.3.2.26. Artificial intelligence
   5.3.3. Decision making support
      5.3.3.1. Operational research methods and algorithms
         5.3.3.1.1. Programming techniques
            5.3.3.1.1.1.   …
         5.3.3.1.2. Simulation
            5.3.3.1.2.1. Centralized simulation
            5.3.3.1.2.2. Distributed simulation
      5.3.3.2. Expert systems
      5.3.3.3. other
/
5.4. Architecture ( | Reference models )
   5.4.1. Informal
      5.4.1.1. PRODNET Reference modle
      5.4.1.2. VERAM Reference model
   5.4.2. Formalized
   5.4.3.  Formal
      5.4.3.1. BM_VE Architecture Reference Model
         5.4.3.1.1. Business centered
         5.4.3.1.2. Resource centered
/
5.5. Reference Models and specifications
   5.5.1. Reference model representations
      5.5.1.1. Informal Reference Models
      5.5.1.2. Formalized Reference Models
      5.5.1.3. Formal Reference Models
         5.5.1.3.1. Algebraic reference models
   /
   5.5.2. Reference model(s) integration
   /
   5.5.3. Reference model modifications
   /
   5.5.4. Reference model extensions (for other views, e.g.
          information system, implementation, domain specific)
   /
   5.5.5. Metrics and certification criteria for VE models and
          software developed under the particular reference model
   /
   5.5.6. Other issues
/
5.6. Theories
   5.6.1. Informal
      5.6.1.1. PRODNET
```

```
         5.6.1.2. VERAM
         5.6.1.3. ...
      5.6.2.  Formalized
         5.6.2.1. ...
      5.6.3. Formal
         5.6.3.1. BM_VE structure (or architecture) theory
   /
   5.7.  Representations classes for VE
      5.7.1.  Informal
         5.7.1.1. Metaphor theory
         5.7.1.2. Semiotics
      5.7.2.  Semi-formal
         5.7.2.1. Flowchart
         5.7.2.2. IDEF
         5.7.2.3. Social actors networks theory
         5.7.2.4. Multi-agent systems
      5.7.3. Formal
         5.7.3.1. Graphs
            5.7.3.1.1. Tree
            5.7.3.1.2. Network
         5.7.3.2.  Petri-nets
         5.7.3.3.  Game theory
         5.7.3.4.  Deontic logic
         5.7.3.5.  Operational research
         5.7.3.6.  Ontology
         5.7.3.7.  1st order Logic
         5.7.3.8.  2nd order Logic
         5.7.3.9.  Algebra
         5.7.3.10. Grammar
         5.7.3.11. Automata
         5.7.3.12. FDTs
            5.7.3.12.1. SDL
            5.7.3.12.2. LOTOS
            5.7.3.12.3. ESTELLE
         5.7.3.13. Programming/Representation languages
            5.7.3.13.1. UML
            5.7.3.13.2. UEML
            5.7.3.13.3. ...
         5.7.3.14.  Hybrid
      5.7.4.  Hybrid
      5.7.5.  Other
   /
   5.8. Communication tools
      5.8.1. Face-to-face
      5.8.2. Documents
      5.8.3. E-mail
      5.8.4. Video-conference
      5.8.5. CSCW
   /
   5.9. Data base
   /
   5.10. Knowledge base
   /
   5.11. Data base manipulation mechanism
```

5.6 VE management, control or constraints

```
6. Management ( | Control | Constraints )
```

```
6.1. Processes
/
6.2. Performance measures
/
6.3. Tools
```

6 Conclusions

This is the first systematized and extended categorization covering part of the VE paradigm and associated concepts, and hence a totally innovative proposal. It is a large depiction of the VE concept, but without repeating commonplaces already covered by literature (e.g. the description of the manufacturing or the other domains, in entry 1.1.2.4. in Annex 2). However, under this perspective, one can say that this work is never complete!

Besides the magnitude and effort that a deeper and more complete taxonomy would require (unbearable with the limitations of the present text), the literature already contains a number of contributions that could allow to complete many concepts. For example, the item 1.1.5.1.1.8. (Breeding environment) could be completed from [Romero, 08], [Romero, 09], [Ermilova, 07], [Camarinha-Matos, 10], [Paszkiewicz, 09]. [Msanjila, 10]. Another example, could be to complete the taxonomy with taxonomies of VE subprocesses; VE for production processes, for instance, could be developed at more detailed levels in the hierarchy, with the support of existing literature on Manufacturing/ Production and Operations Management, such as [Miller, 94], [White, 96], [Mccarthy, 00], [Gunasekaran, 02], [Capar, 04], [Zhao, 06], [Koenigsberg, 10].

This taxonomy represents a starting point towards a structured method for understanding a VE under a system-based view, with the potential to help identifying areas for future research and development, and to drive the design of new applications and environments to support this model. As said along the text, it is not meant to be a complete tool; instead it can be always upgraded /complemented, that is, a living tool.

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ANNEXES

Annex 1 – VE agility or VE Dynamics as a VE attribute

```
2.3.3. Agility ( | Dynamics )
   2.3.3.1. Structural dynamics
      2.3.3.1.1. Criteria
         2.3.3.1.1.1. For every new product or project
         2.3.3.1.1.2. Along the product life-cycle
      /
      2.3.3.1.2. Enablers
         2.3.3.1.2.1. Transaction cost
         2.3.3.1.2.2. Knowledge protection
         2.3.3.1.2.3. Chaordic System Thinking
   2.3.3.2. Operational dynamics
```

Annex 2 – "Market of Resources" as an infrastructure / environment for VE integration

```
5.1.1.1.  "Market of Resources" (MR)\
   5.1.1.1.1. Input to MR
      5.1.1.1.1.1. Members
         5.1.1.1.1.1.1. Companies
         5.1.1.1.1.1.2. Brokers
         5.1.1.1.1.1.3. Customers
      5.1.1.1.1.2. Data
         5.1.1.1.1.2.1. External regulation
         5.1.1.1.1.2.2. Standards
         5.1.1.1.1.2.3. External data
         5.1.1.1.1.2.4. …
   5.1.1.1.2. MR Processes
      5.1.1.1.2.1. MR Design
         5.1.1.1.2.1.1.Creation of DB
         5.1.1.1.2.1.2.Search patterns definition
         5.1.1.1.2.1.3.Regulation definition
         5.1.1.1.2.1.4.Brokerage implementation
         5.1.1.1.2.1.5.MR institutialization
      5.1.1.1.2.2. MR Operation
         5.1.1.1.2.2.1. Resources ( | VE partners ) subscription
         5.1.1.1.2.2.2. Resources ( | VE partners ) updating
         5.1.1.1.2.2.3. Brokerage management
         5.1.1.1.2.2.4. VE processes monitoring
         5.1.1.1.2.2.5. Regulation enforcement
         5.1.1.1.2.2.6. DB/KB management
      5.1.1.1.2.3. Other MR sub-processes
```

5.1.1.1.2.3.1. Market contents presentation: user/buyer profile, catalogues, historic, database of resources
5.1.1.1.2.3.2. Negotiation: request for quotes, auction/reverse auction, optimal selection
5.1.1.1.2.3.3. Transactions: payment, contractualisation

5.1.1.1.3. Tools

5.1.1.1.3.1. ICT
5.1.1.1.3.1.1.
5.1.1.1.3.1.2.
5.1.1.1.3.2. Broker
5.1.1.1.3.2.1. Input
5.1.1.1.3.2.2. Processes
5.1.1.1.3.2.2.1. "External"
5.1.1.1.3.2.2.1.1. Initiation of the virtual enterprise
5.1.1.1.3.2.2.1.2. (Focused) market of resources creation (resources identification)
5.1.1.1.3.2.2.1.3. Resources selection
5.1.1.1.3.2.2.1.4. Resources systems selection
5.1.1.1.3.2.2.1.5. Resources systems Integration
5.1.1.1.3.2.2.1.6. Resources Integration scheduling
5.1.1.1.3.2.2.1.7. Resources systems reconfiguration
5.1.1.1.3.2.2.1.8. Resources monitoring and reliability analysis
5.1.1.1.3.2.2.1.9. Resources control
5.1.1.1.3.2.2.1.10. Information dissemination
5.1.1.1.3.2.2.1.11. Virtual environment provision between the client/server levels
5.1.1.1.3.2.2.2. "Internal"
5.1.1.1.3.2.2.2.1. Interaction with other brokers
5.1.1.1.3.2.2.2.2. Resources market / virtual net creation
5.1.1.1.3.2.2.2.3. Resources market maintenance
5.1.1.1.3.2.2.2.4. Selection of resources
5.1.1.1.3.2.2.2.5. Negotiation
5.1.1.1.3.2.2.2.6. Guarantee confidentiality between client /supplier
5.1.1.1.3.2.2.2.7. Create mechanisms that support transactions risks
5.1.1.1.3.2.3. Tools
5.1.1.1.3.2.3.1. Data base
5.1.1.1.3.2.3.2. Selection algorithms
5.1.1.1.3.2.3.3. Negotiation algorithms
5.1.1.1.3.2.3.4. Communication protocols
5.1.1.1.3.2.3.5. ...
5.1.1.1.3.2.4. Management
5.1.1.1.3.2.4.1. monitoring
5.1.1.1.3.2.4.2. performance evaluation
5.1.1.1.3.2.4.3. analysis of operation results
5.1.1.1.3.2.4.4. decision making
5.1.1.1.3.2.5. Output

5.1.1.1.4. Management

5.1.1.1.5. Output