Method fragments for agent design methodologies: from standardisation to research

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Abstract: The method engineering paradigm enables designers to reuse portions of design processes (called method fragments or chunks in literature) to build processes that are expressly tailored for realising a system that is specific for some problem or development context. This paper initially reports on the standardisation attempt carried out by the FIPA Methodology Technical

Committee (TC) and then presents the research activities we did starting from that work; these resulted in a slightly different definition of some of the most important elements of the approach in order to support a multiview representation of the fragment (the views are process, reuse, storing and implementation). The paper also describes the documents we used for representing a fragment and concludes with an example.

Keywords: Software Engineering Process; SEP; methodologies; Multi-Agent Systems; MASs.

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1 Introduction

In the last few years, the agent-oriented approach (Bauer *et al*., 2001; Jennings, 2001) has been recognised as very suitable for the development of complex software systems, since it fully exploits the well-known techniques of *Decomposition, Abstraction* and *Organisation* (Booch, 1994) to help manage complexity. In particular, in the context of complex software systems:

- the agent-oriented decomposition is an effective way of partitioning the problem space
- the key abstractions of the agent-oriented mindset (agents, interactions and organisations) are a natural means of modelling
- the agent-oriented philosophy for modelling and managing organisational relationships is appropriate for dealing with existing dependencies and interactions (Jennings, 2001).

The development of complex software systems using the agent-oriented approach requires suitable agent-oriented modelling techniques and methodologies which provide explicit support for the key abstractions of the agent paradigm.

To date, several methodologies supporting the analysis, design and implementation of Multi-Agent Systems (MASs) have been proposed in the context of Agent-Oriented Software Engineering (AOSE) (Lind, 2001). Some of the emerging methodologies are Adelfe (Bernon *et al*., 2002), Gaia (Zambonelli *et al*., 2003), MaSE (DeLoach *et al*., 2001), Message (Caire *et al*., 2002), Passi (Cossentino, 2005), Prometheus (Padgham and Winikoff, 2003) and Tropos (Bresciani *et al*., 2004). Although such methodologies have different advantages when applied to specific problems, it is a fact that a unique methodology cannot be general enough to be useful for everyone without some level of customisation. In fact, agent designers, in solving specific problems in a specific application context, often prefer to define their own methodology, specifically tailored to their needs, instead of reusing an existing one. Thus an approach that combines the designer's need to define his/her own methodology with the advantages and the experiences coming from the existing and documented methodologies is highly required.

A possible solution to this problem is to adopt the method engineering paradigm, thus enabling designers of MAS to (re)use parts coming from different methodologies in order to build up a customised approach to their own problems (Henderson-Sellers, 2003). According to this approach, the 'development methodology' is constructed by assembling pieces of other methodologies (*method fragments*) from a repository of methods (*method base*). The method base is built up by taking method fragments coming from existing methodologies or *ad hoc*-defined methods. This approach has been adopted, in the past few years, by the FIPA Methodology Technical Committee (TC) (FIPA – Foundation for Intelligent Physical Agents),[1] in which the authors were active members. FIPA had recently moved to the IEEE Computer Society under the name of *IEEE FIPA Standards Committee* and with this occurrence the activities of the Methodology TC were stopped.

The FIPA Methodology TC was constituted in 2003 with the aim of capitalising on the efforts of many researchers in the area of MAS design and contributing to the reuse of parts of existing methodologies (and the related knowledge), through an appropriate set of specifications. For more details, the main goals of the TC were:

- Definition of the method fragments meta-model – It is necessary to formally represent method fragments in order to facilitate their identification, representation, integration and storage in the method base.
- Identification of the method base architecture – This is the method base needs of a technological infrastructure for the instantiation of the previously defined method fragment meta-model.
- Collection of method fragments – They can originate from the most diffused methodologies and other specific contributions. After formalisation, they can be introduced into the method base.
- Description of techniques for methods integration – It is necessary to define guidelines for methods integration in order to both construct the new methodology (by retrieving the method fragments from the method base and integrating them) and apply it to the real design work.

A more ambitious goal was enabling the use of:

- Computer-Aided Process Engineering (CAPE) tools that could enable the construction of the new design process; these tools should be able to support the definition of the process life-cycle as well as the reuse of fragments from the method base. They should enable the adoption of a specific process life-cycle (waterfall, iterative/incremental, spiral, *etc.*) and the placing of different fragments in it. The CAPE tool should 'instantiate' a proper CASE tool (see below) that is specifically customised to support the designer in working with the composed methodology.
- Computer-Aided Method Engineering (CAME) tools that could offer specific support for the composition/maintenance of a method fragment; these tools should enable the designer to define a method fragment according to the definition, provided by the FIPA Methodology TC, and the prescriptions coming from the method base. Besides, they would allow the modification of these fragments when assembling needs or other customisation requests emerge.
- Computer-Aided Software Engineering (CASE) tools that assist the designer in performing the development process based on the composed methodology. These tools should be the evolution of existing CASE instruments, since they enforce the execution of the design phases in the order defined at the time of methodology composition (according to the adopted process life-cycle (Cernuzzi *et al.*, 2005) and they guide the designer in profitably applying it.

The work done by the FIPA Methodology TC can be summarised as follows: definition of a method fragment meta-model (including an XML-based method fragment representation); definition of a method base general architecture; representation of some methodologies using a process description language, for which the TC adopted OMG SPEM (Software Process Engineering Metamodel) (SPEM, 2002), with the described methodologies being ADELFE, Gaia, and PASSI (see the TC documents – Gleizes *et al.*, 2003; Garro *et al.*, 2004a; Cossentino *et al.*, 2004); collection of method fragments, which was done by extracting method fragments from the previously listed methodologies according to the defined method fragment meta-model (see the TC documents – Gleizes *et al.*, 2004; Garro and Turci, 2004; Cossentino, 2004), and a new fragment that is specific for dealing with complex systems was listed too (Peña and Corchuelo, 2004); and finally, identification of some approaches and guidelines for methods integration.

This constitutes the first part of the work presented in this paper. From the activity of the Methodology TC, we started our own researches, aimed at applying the proposed specifications and eventually improving them. In the second part of the paper (Sections 4 and 5), we present the results of these studies. We made minor changes to the structure of the fragment and we introduced new elements in it (the explicit support for the workflow of design activities, and other elements aimed at a successful implementation of the method fragment). In order to really experiment with these definitions, we extended our interest to the study of the whole development process with a multiperspective approach that resulted in the representation of the fragments according to the following views: process, reuse, storing and implementation. We further improved the FIPA repository with new methodologies/fragments, produced a web-based method base and finally realised some experiments also with the support of some prototypical CAME/CASE tools.

In the next sections, these points will be discussed in detail.

2 Method engineering

The term 'method engineering' was coined by Kumar and Welke (1992), when they realised that a standard design methodology suitable for each kind of problem did not exist; so they proposed the engineering of new methodologies, starting from the composition of techniques, in order to meet a specific problem in a specific application context. Subsequently, Brinkkemper (1996) defined method engineering as "the engineering discipline to design, construct and adapt methods, techniques and tools for the development of information systems". All of them worked in the field of information systems, where the growing complexity of systems led designers to modify and adapt the design methodology in order to meet the needs arising from the particular problem/context they were working on and the specific skills they had; as a consequence of this trend, the term 'situational method engineering' developed (Harmsen and Brinkkemper, 1996).

Situational method engineering is mainly based on the concept of reuse and on the belief that each methodology can be decomposed into parts (components), so that a designer can create an *ad hoc* methodology by starting from these reusable parts (called method fragments); hence the method fragment is the most important element when applying the method engineering paradigm. Method fragments have to be extracted from existing design methodologies and stored in a repository, called the method base, from which they are retrieved during the process of new method construction by the designer (the method engineer); obviously the definition of a proper assembly technique is of fundamental importance to the successful application of this approach.

Thus it is a fact that three elements have to be considered during a method engineering process: the method fragment, the repository and the assembly techniques.

Different approaches exist today for the application of the method engineering paradigm (Brinkkemper, 1996; Henderson-Sellers, 2002; 2005; 2006; Ralyté and Rolland, 2001a; 2001b; Rolland and Prakash, 1996; ter Hofstede and Verhoef, 1997; Tolvanen *et al*., 1996), all of them starting from the same consideration that the growing complexity of systems needs *ad hoc* methodologies and that the three previously cited elements are the core points, but each of them providing different meanings and definitions based on the specific domain they are working on and the specific development context, even if they all share the same main phases for a method engineering process: method requirements definition, method fragments selection and method fragments assembly.

The (situational) method engineering paradigm, which until now we illustrated referring to the information system context, can obviously be used and extended to all the cases in which a complex system has to be developed using a purposefully created methodology; and in particular, we are working on adapting this approach to the development of MAS design methodologies.

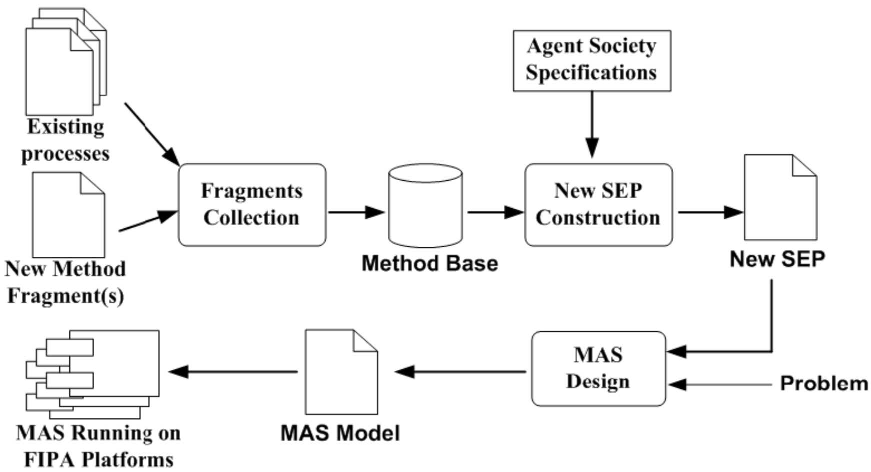
Before introducing the work done within FIPA on the matter, we would like to adopt a unique denomination for the process consisting in applying the method engineering paradigm (but also for the process from which the method fragments were extracted). In the literature, we can find authors using the terms 'methodology' (the preferred one in the agent context), 'process', 'design process' and also 'software design process'. In order to avoid confusion and not to participate in this debate, we will adopt a wide-enough definition coming from Fuggetta (2000), who defined a Software Engineering Process (SEP hereafter) as "the coherent set of policies, organisational structures, technologies, procedures, and artefacts that are needed to conceive, develop, deploy, and maintain (evolve) a software product".

The approach proposed by the FIPA Methodology TC is an extension of the method engineering paradigm as proposed in Brinkkemper (1996), Kumar and Welke (1992) and Saeki (1994). As already mentioned, according to this approach, SEP is built up by assembling pieces of the process (method fragments) (Brinkkemper *et al*., 1996; 1999; Ralyté and Rolland, 2001b) taken from a repository of methods that has been built by extracting pieces from existing design processes. Besides (and this has been decisive in the FIPA context), this approach allows the contribution of a large community (several design processes for MAS design already exist in the literature (Luck *et al*., 2004)) without imposing any kind of discrimination on what is 'compliant' and what is not. Compliant SEPs would simply be composed by reusing parts from the repository according to the proposed guidelines, nothing more than that. Most of all, different contributions to the repository are valuable because they are the consequence of some specific need, development context, application environment or theoretical background, and as such they can be profitably reused when something similar is found when facing a new problem (just as a bridge pattern (Gamma *et al*., 1994) can be reused whenever it is necessary to decouple an interface from an implementation, regardless of the original context that allowed the identification of this pattern).

Method engineering and agents

Some authors have already started to work in this direction in the agent community (Cossentino and Seidita, 2004; Garro and Palopoli, 2003; Henderson-Sellers, 2005; Juan *et al*., 2002), thus confirming that the method engineering paradigm can be profitably applied to the MAS design too. Figure 1 describes the approach to the whole method engineering process studied by the FIPA Methodology TC. Although this was not intended to be a standardisation issue, its definition was supposed to help members in practising the construction of new SEPs. It includes three main phases: the fragments repository construction, the SEP definition and the SEP enactment. The fragments repository is built by conveniently modularising the existing design processes and converting them to the method fragment structure defined by the TC (see Section 3). The identification of guidelines for fragment extractions from existing processes was not studied during the FIPA Methodology TC activity, although it has some effect on the fragment structure (for instance, on its granularity). This problem is still an open research issue and some contributions can be found in Ralyté and Rolland (2001b), Brinkkemper *et al*. (1999) and Cossentino and Seidita (2004). The method base can also list fragments not coming from an entire process but conceived as stand-alone contributions to the repository. This is the case of the MaC-MAS fragment, which allows dealing with the analysis phase of complex systems (Peña and Corchuelo, 2004). The TC members regarded this as a relevant contribution to the research on AOSE: it proved that it was no longer necessary to prepare an entire design process in order to study one single aspect of an agency. A researcher can focus his/her attention on the specific problem he/she wants to study and then complement the resulting method fragment(s) with others coming from the method base, thus quickly completing a process that he/she can use to test the results of his/her work.

Figure 1 The discussed agent-oriented method engineering process



During the SEP construction, the method engineer has to consider several different factors that affect his/her work:

- The SEP should be fit for the specific family of problems to which it will be applied. This means that if the problems are typically affected by some constraint (*e.g.*, real-time or security issues), the SEP should include proper methods to explicitly deal with them.
- The SEP is to be used by persons. This means that method engineering should compose a SEP that is coherent with their skills (or at least not too far); a group of designers already skilled in some design practice should not be forced to change their use of it if it is possible to adopt (finally part of) the old approach to solve the new problem.

- Designing agents is different from designing objects. Several papers deal with this issue (this is out of the scope of this paper; see Odell, 2002; Zambonelli *et al.*, 2003 for further details); by now it is worth noting that designing an agent society is characterised by fundamental choices about the social structure (peer agents, hierarchical organisations and so on) or the agent architecture (reactive, BDI, state-based, *etc.*), which becomes a kind of requirement for the SEP. They often descend from the development context or the specific problem to be solved: a company that has a consolidated tradition in adopting BDI agents organised in groups of peer agents will more likely choose a similar form of society for solving future problems rather than changing it if not really necessary (or remarkably profitable); as a consequence, the new SEP should encompass these choices.
- The agent is not a well-defined concept; several different definitions can be found in the literature (Russell and Norvig, 1995; OMG Agent Platform, 2000; Franklin and Graesser, 1996), and this also includes most of the concepts used when defining a MAS (role, task, behaviour, goal, *etc.*). The MAS is usually designed and implemented by considering abstractions and components that could be significantly different. Several studies have been carried out during these past few years about MAS meta-models (Odell *et al.*, 2005; Bernon *et al.*, 2004; Caire *et al.*, 2002; Ferber and Gutknecht, 1998; Bernon *et al.*, 2005) and a final result has not been achieved. The same absence of a real, pure agent-oriented coding language is the consequence of this situation (most diffused solutions are Java based). The FIPA Methodology TC approach encouraged studies in this direction and allowed an easier application of their results, since the method fragment definition given by this TC explicitly considers the MAS meta-model elements involved in the fragment's workflow and artefacts.

The construction of a new SEP is a well-studied phase within the method engineering community; nonetheless, it is still open to new contributions. During the Methodology TC activity, no specific work had been done on it; members of the committee applied the techniques they considered more productive. Generally speaking, we can say that, in order to compose a new process, the activities to be done are usually selection of fragments from the method base, assembly of fragments, and adaptation of fragments that do not perfectly fit the new process in their native structure. These activities will be further described in the following subsection. The resulting SEP will be composed essentially of the flow of activities to be done, the descriptions of a set of artefacts, the related guidelines and the suggested notation for the required artefacts.

During the last phase (SEP enactment), the system designer adopts the new process (and the supporting CASE tool) to design a MAS-based solution to the problem he/she is facing; and in so doing, he/she produces the required artefacts according to the process guidelines.

In the following section, the *method fragment definition* will be introduced.

3 A proposal for the fragment from the FIPA TC

The FIPA Methodology TC started its work by giving a definition of the method fragment and complementing it with some studies on MAS meta-models and a glossary of terms. As regards the method fragment (Method Fragment Definition, 2003), it is considered to be a portion of the development process, composed of the following parts:

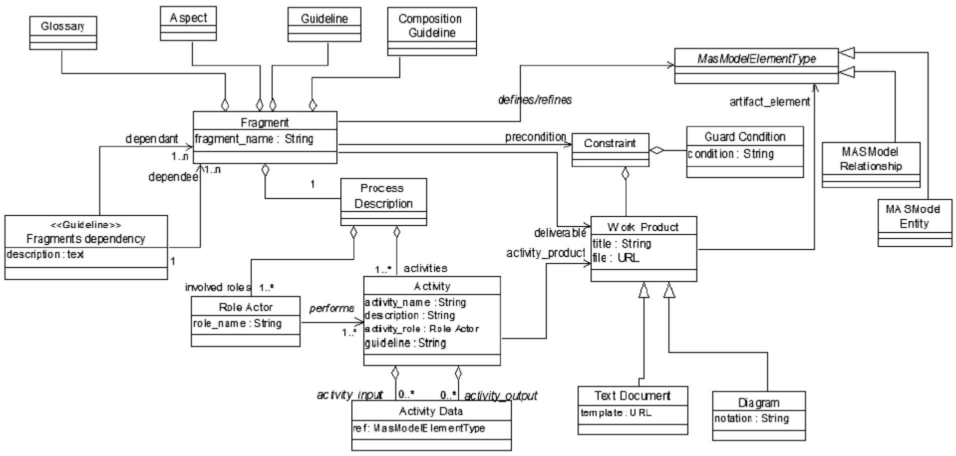
- A specification of the portion of the process, which defines what is to be done by the involved stakeholder(s) and in what order. The fragment specification prescribes the use of the OMG SPEM (SPEM, 2002) for describing its procedural aspect. According to SPEM, the FIPA fragment can be regarded as a *process component.*
- One or more deliverables such as AUML/UML diagrams (Bauer *et al*., 2001) and text documents; these should be part of the fragment specification in the form of a description of their structure (in order to clarify what is the expected output of the presented activities), including also a reference to the suggested (or adopted, in the original methodology from which this fragment has been extracted) modelling notation.
- Some preconditions, which represent a kind of constraint, specifying when it is possible to fire the activities specified in the fragment. They are usually related to the required input data; these preconditions can be thought of as similar to the preconditions in a contract between two classes. In particular, the preceding fragment (or the *n* preceding fragments) is (are) responsible for establishing the conditions that will enable the successful execution of the following fragment. The formalisation of these preconditions would allow the introduction of some kind of automatic assistance in the composition of the fragments, but a formal language has not been specified or adopted yet and the only considerations that can be easily automated according to this specification, concerns the required input set in terms of already-defined MAS meta-model components (see next item).
- A list of components of the MAS meta-model to be defined or refined through the specified process (they belong to the MAS meta-model adopted by the methodology from which the fragment was extracted); while this list, theoretically speaking, could be void (this is, for instance, the case of a fragment whose purpose consists in selecting between two different paths in the design process according to the evaluation of some aspects of the actual design), all the fragments that have been identified up to now are concerned with some components to be defined/refined, thus showing that the community is, even now, still more concerned about a product-oriented identification of fragments than a process-oriented one.
- Application guidelines that illustrate how to apply the fragment and the related best practices; the same formalisation of these guidelines in the existing agent-oriented methodologies has its own specific importance, since otherwise, except for a few well-documented approaches, guidelines often remain bound to the personal knowledge of some skilled designers or the methodology creators.
- A glossary of terms used in the fragment; this prevents misunderstandings if the fragment is reused in a context that is different from the original one; in order to facilitate this part of the fragment documentation, the members of the TC discussed a list of definitions for many commonly used terms.[2]
- Composition guidelines which describe the context/problem addressed by the specific fragment and that are behind the methodology from which they have been extracted.

- Aspects of the fragment; these are textual descriptions of specific issues, such as the platform to be used for system implementation and application area; they help in delimiting the proper application field for the fragment.
- Dependency relationships useful for assembling fragments. When the fragments' granularity is fine grained (and the FIPA repository was conceived to allow the introduction of different-sized fragments), it is common to reuse more fragments from a specific methodology since their adoption probably corresponds to adopting some philosophy for the composition of a specific portion of the SEP.

It should be noted that although a complete description of the fragment in all of the above-listed fields is advisable, if possible, not all of these elements are always mandatory; some of them (for instance, deliverable notation or guidelines) could be inapplicable or unnecessary for some specific fragment.

The resulting method fragment is represented by using a UML Class Diagram in Figure 2 at the level of refinement reached during the work of the TC; our further works on it are presented in the following sections.

Figure 2 The method fragment defined by the FIPA Methodology TC



According to the reported definition of method fragment, the *method base* structure proposed by the FIPA Methodology TC is an XML-based repository storing a collection of XML documents, each one representing a method fragment, validated by a Document Type Definition (DTD) or an XML Schema. In fact, the proposed method fragment meta-model can be easily translated into an XML DTD or in an XML Schema that can be used for validating an XML document representing a particular method fragment. The validation process ensures that the method fragment was extracted and defined according to the prescribed meta-model. It is worth pointing out that the XML document representing a fragment is not self-contained, but could contain some URI-addressing resources that cannot be coded in XML but that are nonetheless part of the fragment.

The repository is oriented towards a MAS meta-model-based classification of fragments; each one of them is in fact labelled with the MAS meta-model components that are defined or refined during its activities. Each activity has some inputs and produces some outputs in terms of defined/refined components of the MAS meta-model.

The instances of these components are reported in the fragment work products (text documents or diagrams with a link to the adopted notation) that are related to those activities. The fragment preconditions are represented in terms of required work products or guard conditions (these can, for instance, detail the required refinement level of some elements of the MAS meta-model).

Further details about the repository implementation or querying approaches have been considered to be out of the scope of the work of the TC and have been left to tool implementers.

The definition of the fragment meta-model was the main aim of the FIPA Methodology TC and had been proposed to the FIPA board, but the interruption of the activities and the subsequent moving of FIPA to within the IEEE Standards Society stopped the publication process of the work as a preliminary specification.

In the following subsection, an important phase of the construction of the new SEP, the *method fragments integration*, will be discussed.

3.1 Method fragments integration

Method fragments integration is the process of composition of the new SEP and usually consists of two different and complementary phases: the selection of the reused fragments from the method base and their assembly (here including the modification of fragments when necessary). Several approaches exist in the literature to deal with these crucial phases, among others the work of Ralyté, in which fragments are composed by association and integration (Ralyté and Rolland, 2001b), and Brinkkemper *et al.*'s (1999) paper, where the composition process is based on three orthogonal dimensions: perspective, abstraction and granularity.

The FIPA Methodology TC members discussed this topic and mainly studied two basic approaches for the integration of methods during the construction of the agent-oriented SEP (Garro *et al*., 2004a):

1 *meta-model driven* – this is based on the MAS meta-model adopted by the designer for the development of a MAS for a specific problem in a specific application domain

2 *development-process driven* – this is based on the instantiation of a software development process in which each phase is carried out using appropriate method fragments selected on the basis of the supported activities and of the resulting work products.

Both of the proposed approaches have been experimented on by the authors in various applications and case studies. For instance, the meta-model-driven approach to method fragments integration was exploited for the construction of a SEP suitable for developing a MAS for the prediction of the three-dimensional structure of proteins (Garro *et al*., 2004b) and a MAS for the e-learning and skill management context (Garro and Palopoli, 2003). The development process-driven approach to method fragments integration was exploited for the construction of a SEP for modelling and validation through the simulation of MAS (Fortino *et al*., 2004). These two approaches will be further explored and then compared in the following subsections.

3.1.1 The MAS meta-model-driven approach for method fragments integration

To build a SEP by exploiting the meta-model-driven approach, the designer has to:

- choose or define the MAS meta-model suitable for the specific problem and/or the specific application domain
- choose the method fragments that are able to produce the identified meta-model elements; the first criterion here is related to the complete coverage of the meta-model instantiation procedure
- define a development process characterised by a method fragments-execution order on the basis of the relationship existing among the meta-model elements produced by each fragment; in this phase, a kind of dependency matrix among the artefacts produced by the fragments could help, together with opportunity considerations (for instance, in an agile approach, test planning is done as soon as possible).

Hence, the obtained SEP is able to completely ensure the MAS meta-model instantiation for the given problem in a specific application domain.

3.1.2 The development process-driven approach for method fragments integration

The development process-driven approach focuses on the instantiation of a software development process that completely covers the development of MAS and complies with some specific needs related to it (like the creation of an extensive documentation or the flexibility in managing new requirements).

To build a SEP by exploiting the development process-driven approach, the designer must:

- choose or define a SEP life-cycle suitable for the specific problem and for the specific application domain; this means, for instance, the adoption of a waterfall life-cycle if the customer explicitly requires it (as happens in some government contracts) or an iterative/incremental one to cope with evolving requirements and development risks management
- instantiate the development process by selecting, for each phase of the life-cycle, some suitable method fragments, chosen from the method base or even defined *ad hoc*.

It is worth noting that if two subsequent phases (P1 and P2) are carried out by using method fragments coming from different methodologies, it may be necessary to elaborate the work products of P1 to obtain the information needed to drive the construction of the work products of P2. In other words, the work products produced in a given phase might constitute the input for the subsequent phase, provided that they contain all the information required for initialising it.

3.1.3 Comparison of the approaches

As usual in software engineering, each of the proposed approaches has advantages and drawbacks; beginning with the first, the meta-model-driven approach provides flexibility for the definition of many aspects of the MAS to be developed; this is probably the most suitable one if social rules coming from a specific domain play a relevant role in the problem to be solved. Conversely, it is characterised by a difficulty in integrating different fragments, owing to the different semantics of the concepts they can represent in the meta-models subsumed by the methodologies from which they have been extracted; furthermore, the *a priori* selection and/or definition of the meta-model to adopt for the specific problem and/or application domain is a difficult and at the same time crucial task.

The development process-driven approach is characterised by the following advantage: flexibility for the construction of a SEP by means of the instantiation of each stage of the selected process life-cycle. On the other hand, the disadvantages are the following:

- low flexibility of the MAS meta-model, since it results from the sum of elements defined by the selected method fragments
- adaptation among the work products, which is sometimes difficult to achieve
- having to choose and define the process life-cycle to instantiate for the specific problem and/or application context
- low level of help in selecting the fragments that descend from the process life-cycle choice (several degrees of freedom still exist and other guidance is needed to select the proper method fragments).

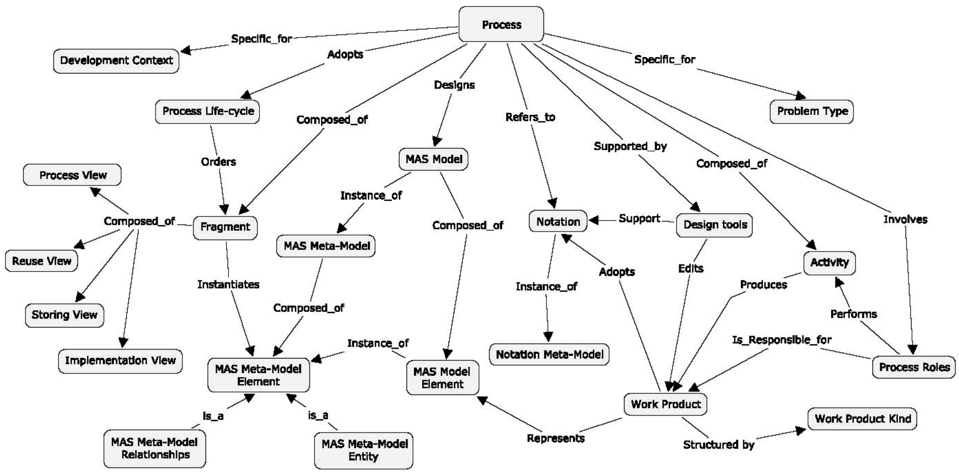
Each one of the above-listed points represents an open problem and a challenge for the agent community (most of these issues are indeed not specific to agent-related researches); the first one to be explored consists in some peculiarities that are related to the agent paradigm, the most important probably being the role that the agent social organisation plays in the composition of the new process.

The proposed approaches to the integration of method fragments (meta-model driven and development-process driven) are not mutually exclusive; rather, hybrid approaches containing features of both of them might be defined as well. An example of a process composition that mixed the two proposed approaches has been used to create one of the first agile processes for MAS design, PASSI Agile (Chella *et al*., 2004); it started with the selection of the life-cycle of an agile process, and then a MAS meta-model was defined by conveniently reducing the conventional PASSI approach. Different approaches can be considered as well (for instance, some are based on the attributes of the resulting process (Juan *et al*., 2002)) and their use is not in conflict with the presented approaches.

4 A refinement of the proposal

Figure 3 shows the elements that a process for an agent-based development is composed of, and explicates and includes all the concepts we took into account when we started the refinement of the results obtained by the Methodology TC. At this stage of the work, we prefer to adopt an informal representation of our (meta-)models in order to achieve a better readability of images containing a large number of elements and, most of all, to draw attention to the concepts and their relationships (explicitly named in the diagrams), just as would happen in an ontological representation of the interest domain. As we can see in Figure 3 (and as already proposed in Cernuzzi *et al.*, 2005), we consider the process as the set of steps to be performed in order to produce an output, the way of performing some activities, and the resources and constraints this requires. As we have already said, it is now well recognised that a standard process does not exist, so each process is specific for a particular development context, which relates to resources, people and competence aspects, and for a problem type – it can in fact solve a specific problem or a family of related problems; these two elements constitute a precise indication of the requirements of the process.

Figure 3 The proposed representation of the software engineering process, including the fragment element used to compose it



A process is composed of activities, pieces of work to be done in order to produce a specific output (an activity in fact may produce a work product); each activity is performed by a process role that is responsible for one or more work products that are structured by a work product kind representing a specific category, for instance, text document, code and so on. In the case of text or structured documents (including texts, diagrams and/or other elements), the work product kind also specifies the document template (outline in terms of sections and subsections, position of figures, number of columns in tables, and so on).

A process can be supported by a design tool for helping the designer in editing a work product; since each work product adopts a specific notation, the design tool has to be aware of this notation, also providing some consistency checks on the work products it produces during the development of the process, and some semantic and syntactic checks. A process in the agent-oriented context aims at designing a MAS model whose elements (MAS model elements) are represented in the work products; for instance, when enacting an activity of a development process, a designer may specify an agent that encapsulates some specific functionalities or (at a different stage of the design process) the roles the agent has to play to reach its goals; all these elements are represented in the work product produced by the specific activity. A MAS model is obviously an instance of a MAS meta-model that gives a structural representation, in terms of elements and relationships, of the concepts belonging to the system under construction; a MAS meta-model is composed of MAS model elements that are instances of MAS meta-model elements; these latter elements can be either a relationship or an entity. A process can be decomposed into (method) fragments that are self-contained pieces of the whole process, with all the elements characterising (comprising) the process itself (activity, process role, *etc.*); each fragment instantiates/refines/relates one or more MAS meta-model element(s) that are represented in the fragment output work product(s) in the form of portions of the MAS model that will solve the problem under study; each method fragment produces one or more work product(s) (of the same kind, of different kinds or even structured by composing different elementary documents like diagrams, tables and text). We understand that defining our fragment as a *method fragment* (or even a *chunk*) could generate some confusion because of the existence of previous definitions for these concepts. Probably the name *process fragment* would better address our actual point of view on the matter, but we prefer to maintain the old denomination in order to indicate the continuity of our work with the activities reported in the previous sections.

In the figure, we also represent the process life-cycle element; each process adopts the life-cycle that more properly fits the problem, which will order the activities according to a well-defined structure in order to cope with some philosophy; for instance, the iterative/incremental life-cycle is well suited to solve all the problems where requirements are not stable. Therefore, the life-cycle is useful for ordering fragments when we are assembling them in a new process.

We think that the fragment is such a complex and fundamental element of the method engineering approach that it should be explored from several different points of view in order to achieve the deepest comprehension of its implications during design time. More specifically, we identified four different views: process, storing, reuse and implementation; these views will be described in the following subsections.

4.1 The fragment-process view

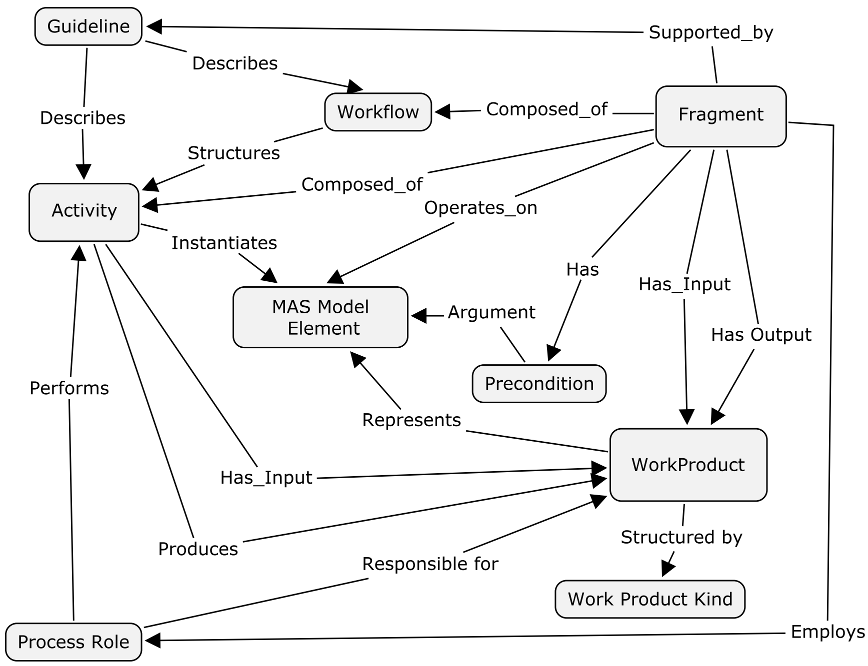
The fragment-process view is aimed at representing the process-related aspects of the fragment. It includes the elements reported in Figure 4. The most important ones are probably workflow, activities and work products. The workflow that we now introduce in the fragment structures the activities; for its definition, we refer to the Workflow Management Coalition (WfMC, 2005) specifications (Management Coalition, 1999): "The automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules", with the obvious assumption that we are not dealing with business processes but rather software engineering ones. In our approach, this workflow is described using activity diagrams (mostly SPEM activity diagrams) that also report the produced work products (see Section 5). As already reported, each work product belongs to a work product kind. In Seidita *et al.* (2006) we identified two main sets of work product kinds: graphical and textual. Graphical work product kinds include behavioural (describing the dynamic behaviour of the system or one of its parts/views) and structural artefacts (describing the structure of the system or one of its parts/views). Textual work products include:

1 Free-text documents – here we mean documents not observing a specific grammar like it happens for XML documents; they could nonetheless be organised according to an outline specified in a template of the work product.

2 Structured documents – they observe a rigid grammar (such as happens for XML documents and programming language code), include structured text (for instance, tables) or can be composed of a mixture of the previous described work product kinds (for instance, an analysis document that includes diagrams and the related textual description belongs to this type).

In Figure 4, we can see that an activity has a work product as an input and produces other work products. It is interesting to note that we explicitly represent fragment preconditions (already introduced by the FIPA Methodology TC) as conditions on the MAS model elements represented in the fragment input work products. Finally, in this view we can also find the process roles employed in performing these fragment activities and the guidelines that can support their work.

Figure 4 The fragment-process view



4.2 *The fragment-reuse view*

This view is concerned with the reuse features of the fragment and lists the elements that could be helpful in reusing the fragment in the composition of a new SEP. The elements of the fragment meta-model that belong to this view are:

- MAS Meta-model Element – this defines the scope of the fragment, the elements that it will instantiate in the produced work products.
- Aspect, Glossary, Composition Guideline, Fragment Dependency – these have the meanings given by the FIPA Methodology TC, as reported in Section 3.

4.3 The fragment-storing view

This view concerns the storage of the fragment in the method base and its retrieval. This view includes the following elements:

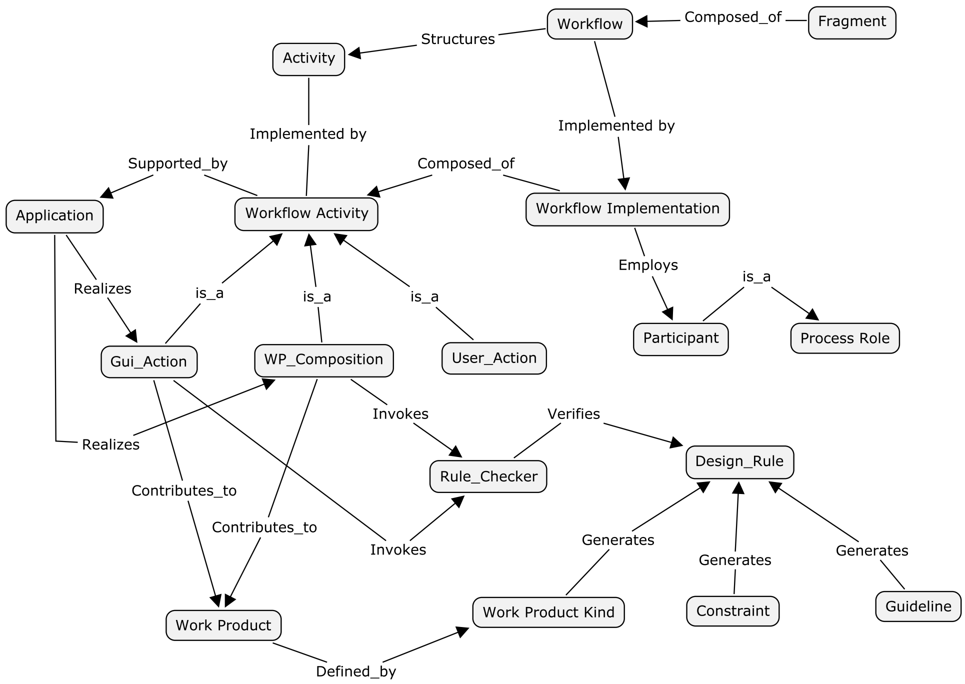
- Phase – this is seen, according to the SPEM definition, as a specialisation of Work Definition that is usually built up from several finer activities. Examples of phases can be Requirements Elicitation and Requirements Analysis. The need for such phases is evident if we think that a fragment conceived for use in the early stages of the design process is unlikely to be useful in later phases such as coding or testing.
- Work Product Kind – the meaning of this element has been discussed before; its usefulness in this view comes from the opportunity of retrieving fragments on the basis of their final outcome. For instance, the method engineer can be interested in a fragment that produces a structural diagram, for reusing it in a specific position in his/her new SEP.
- Process Role – already introduced before, it is reported in this view since it would make no sense in some specific development context to select fragments employing process roles not available to the intended developing team of the new SEP.
- MAS Meta-Model Element – this is one of the central points of our approach and appears in this view in order to support the construction of a new SEP starting from the initial definition of its MAS meta-model. As a consequence, the method engineer can select all the fragments that deal with the elements of this meta-model, thus drastically reducing the dimension of the fragment set he/she has to choose from.

Finally, it is worth noting that for the purpose of classification, each of these elements is complemented by a well-formalised taxonomy, as reported in Seidita *et al.* (2006); we realised our method base according to this view. The results will be discussed later.

4.4 The fragment-implementation view

This view strictly concerns the implementation (using this term, we address here the possibility of putting to work the designed SEP and supporting it with the necessary CASE tools) of the main elements we explained in the process view: workflow, activity and work product. In fact, Figure 5, representing the implementation view, partly overlaps Figure 4. The Workflow is implemented by a Workflow Implementation, which in our tools (Cossentino *et al.*, 2006) we realise with a workflow engine that attends to the process execution and its data interpretation, the surfing into the flow of activities for scheduling deadlines and organising parallel activities, the registration of users and the invocation of specific external applications for supporting the designer in his/her work (for instance, design tools). The Workflow employs a Participant (a specific stakeholder), which is the implementation counterpart of the process role.

Figure 5 The fragment-implementation view



Each Activity is implemented by a Workflow Activity that corresponds to a real piece of work. It can be of three kinds: GUI_Action, a WP_Composition and User_Action, and the first two can be supported by an application that could be a word processor or a personal production tool, whereas in our case an agent is always responsible for interactions with the designer (the user). This point will be better explained later in the paper.

1 A *GUI_Action* is an activity performed by the designer using a GUI. It relates to each work product; in fact it is involved in its composition.

2 A *WP_Composition* is an activity performed by the tool to create a new artefact (for instance, it can correspond to the instantiation of a new UML diagram) and/or its population with elements already defined in previous steps of the process (this is usually done with the help of the expert system). The update of a work product, in order to be consistent with other documents, is another kind of possible activity (suppose that a design element is renamed elsewhere from someone else, it is necessary to spread the change all over the design process). Obviously, WP_Composition activities are related to the WorkProduct element too.

3 A *User_Action* is an activity specified in the workflow but not supported by a tool (for instance, the application of heuristics); the application supporting the workflow activity obviously realises the GUI_Action and the WP_Composition.

As we have already discussed, each work product is defined by a work product kind that generates a set of design rules depending on the kind itself, on some specific constraints and a set of guidelines; for instance, if a designer has to draft a work product of a structured kind, he has to respect and to constantly check the notation he is using, the relationships and the constraints among notation elements, and he has to follow guidelines for composing the work product. The GUI_Action and the WP_Composition activities invoke a rule checker for the production of the work products they are responsible for. In the following section we will detail how we applied this new method fragment proposal, providing also some examples of its application to a real design process.

5 Applying the new proposal of method fragments

In the previous sections, we initially showed the definition of a fragment proposed by the FIPA Methodology TC and then a possible extension that is the result of our further work. We are now going to introduce the documents that actually represent the documentation in which such a fragment is described. The documents representing a fragment are the following four:

1. *a text document* detailing the process and the reuse view
2. *an XPDL file* representing, in the implementation view, the 'Workflow Implementation' of the fragment activities
3. *the design rules* that generate a set of composition rules defined for a specific work product
4. the *Applications* realised in the form of Activity Agents (Cossentino *et al*., 2006).

Each Activity Agent interacts with a designer in order to allow him/her the realisation of the design activities he has been assigned to do; this includes the interaction with the workflow engine for accepting, starting and committing an activity, but also the use of modelling tools or text/code editors when necessary.

In the following, these documents will be further detailed and an example of the use of this representation introduced. The example is a fragment extracted from the PASSI design process (Cossentino, 2005); it is the Domain Ontology Description (DOD) fragment, and in the PASSI process it is used for defining the system ontology. Finally, a description of the method base we realised to store our fragments is reported in Section 5.2.

5.1 Documenting a fragment

5.1.1 The text document

The text document is organised taking into account the work a method engineer has to do when he/she is extracting a method fragment from an existing design process. For this reason, we will now briefly introduce our approach to fragments extraction: the first step is to represent the uppermost activities of the entire process from which the fragment is extracted; then with a top-down approach, the method engineer details the activities (using SPEM activity diagrams) until he/she can identify the work product he/she wants to deliver (as we have already said, we consider a method fragment to be positioned at a work product level of granularity); this is the suggested level of detail for extracting the portion of the process that will become the new fragment.

In the following portions of this subsection, we report and comment on some excerpts from the text document related to the DOD fragment extracted from PASSI (Method Fragment Definition, 2003; Cossentino, 2005).

The process-related aspects of the fragment are documented according to the old definition (the FIPA TC one). It describes which is the aim of the process in the fragment and lists the process roles involved and the delivered work products. The portion of the process, the deliverables and the preconditions are described in this way:

Objective

The main objective of this fragment is to design the ontology. The ontology is composed of concepts and predicates, as is common in the literature. The inclusion of actions in it comes from the FIPA specifications of the ResourceDescription Framework (RDF) (FIPA RDF).[3]

Process

The process that is to be performed in order to obtain the result is presented in Figure 6. The adopted notation is an extension of the SPEM activity diagram, where we added MAS meta-model elements (such as Concept, Predicate) to SPEM specifications (which already included activities like Define Concepts and work products like DOD) in order to clearly show which work definition produces a specific instance or refinement of a MAS meta-model element. The first swim lane clusters the work definitions that are under the responsibility of the Ontology Expert. He/She is an expert in the domain who can produce a formal representation of its categories according to the prescribed notation. The System Analyst (second swim lane) is an expert in agent-oriented solutions and in this fragment he/she is responsible for verifying the quality of the ontology defined by the Ontology Expert and for ensuring its practical feasibility.

Each activity of the diagram is detailed in a specific section of the document in order to describe the work to be done. It is common for this description to include its decomposition in lower-grained activities by using other activity diagrams. The diagram reported in the previously cited figure is divided into two swim lanes delimiting the responsibility of the involved process roles. It is to be noted that SPEM also permits the responsible process role to be assisted by another in performing the activity; this cannot be reported in the activity diagram. The diagram is essentially composed of three different elements (leaving aside traditional well-known UML elements like join, fork, swim lanes and so on):

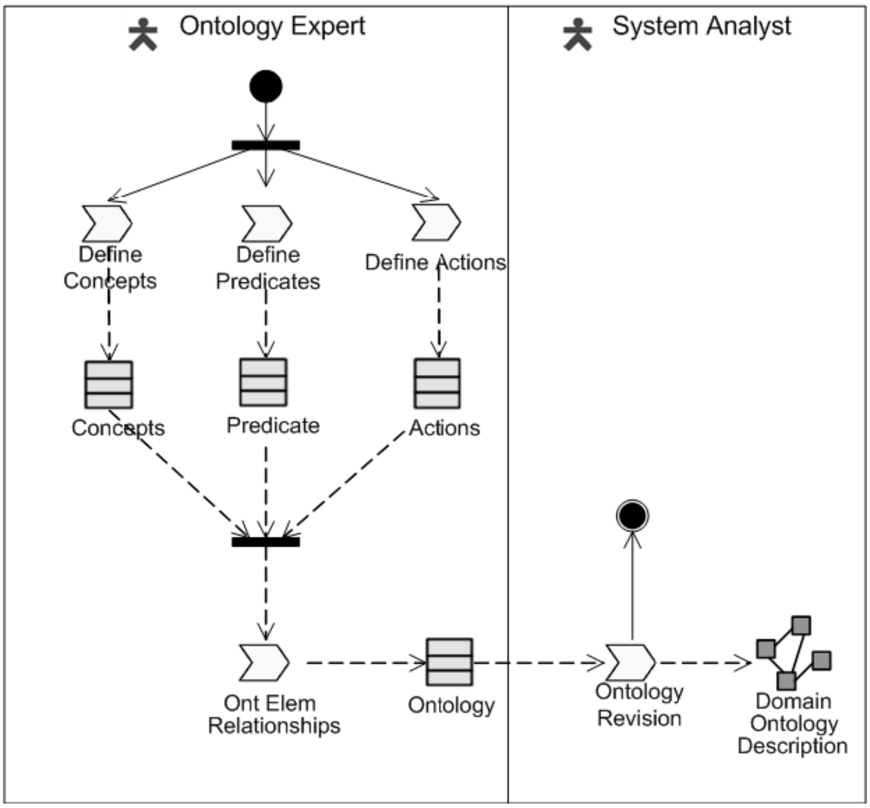
1 The activity (represented by an arrow directed to the right) – each activity may produce a result in terms of refinement of the MAS meta-model or production of a work product.

2 Elements of the MAS meta-model are represented by an icon that is similar to the class icon used in UML class diagrams (this is not part of the SPEM notation, we introduced it for our own purposes).

3 Work products can be diagrams (like the one shown in Figure 6 with the Domain Ontology Description label) or text documents.

This section is completed by a description of the suggested notation that is particularly useful when it does not refer to a well-known modelling notation (several methodologies, such as Tropos and Prometheus, adopt proprietary notations).

Figure 6 DOD fragment-procedural aspect



Deliverables

This fragment produces a structured text document (called DOD document) that includes a class diagram whose classes represent concepts, actions and predicates with the following details:

- Concepts are described in terms of their attributes.
- Predicates report the value of an attribute of a concept or the value of a relationship between two concepts.
- Actions have an Actor (who is responsible for doing the work), a ResultReceiver (who is to be notified of the action results) and an Act that describes the action to be done with the required input and prescribed outcome.

The document includes tables for introducing the (textual) description of each of the elements of the class diagram.

Preconditions

Inputs, outputs and elements to be designed in relation to the fragment are detailed in the following table.

Table 1 Inputs, outputs and elements to be designed in the fragment

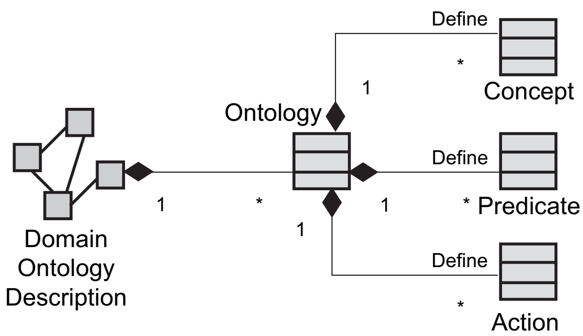
Input	*To be designed*	*Output*
System requirements document	Concepts	Ontology (MAS meta-model component)
Glossary	Actions	Ontology (MAS meta-model component)
	Predicates	Ontology (MAS meta-model component)
	Ontology elements relationships	DOD diagram

Input column – Obviously, in order to design an ontology we need to read the application domain description reported in the System Requirements document and we need a glossary of terms.

Output column – The fragment produces the DOD document, composed as described in the Deliverables paragraph.

To be designed column – The elements of the MAS meta-model that are defined or refined in this fragment are listed here. This is reported in Figure 7, where we specify the work that is to be done on the element, thus declaring if the element is to be newly defined or just refined. We also list here the elements that are just quoted in the fragment, but no refinement work is done on them. For instance, in a diagram where already-defined agents are enriched with new roles, the Agent element is reported in the table with the *quote* label, while Role is reported with the *define* label.

Figure 7 Relationships of the DOD work product with MAS meta-model elements



Relationships with the MAS meta-model

This section usually reports the complete MAS meta-model of the design process from which this fragment has been extracted. This helps in explaining the role of this process component in the original approach and minimises the risk of reusing it in an inappropriate context.

Composition guidelines

The only inputs for this fragment are the system requirement descriptions (text document) and the glossary of terms; as a consequence, this fragment could be reused in almost all the stages of a design methodology. Its aim is to provide a description of knowledge-related issues.

Aspects of the fragment

This fragment is conceived to produce (possibly with the support of an automatic code generation tool) an RDF description of ontology categories. This makes it general enough but it could not be appropriate in some conditions. Ontology designed with this fragment is supposed to be 'static'. It supports some kind of *a priori* (design-time) ontology and no type of dynamic discovery (at run-time) of new categories/relationships. This fragment is suitable for describing ontology in an RDF-like way, as specified in W3C[4] and FIPA RDF.

A large portion of the document is dedicated to the description of the fragment's work products in their principal aspects: notation and guidelines on how to compose them, relationships with MAS meta-model elements, preconditions (that principally relate to specific constraints for putting the fragment to work but that can obviously influence the produced work products), and suggested templates if needed.

The description of the fragment in the document is completed with a SPEM activity diagram (see Figure 6) representing the fragment as a workflow, so it shows the procedural rules allowing the sequence of activities among process roles and the input/output work products needed. In Figure 6, we can see the flow of work in the activity diagram that points out (with the presence of the swim lanes) which process roles perform a specific activity; in this diagram we can also see the flow of data, the work product delivered after each phase and, in this specific fragment, the MAS meta-model elements related to each activity that designs them (for instance, the Define Concept activity defines the Concept element of the MAS meta-model). This latter link is not necessarily shown in the activity diagram, since the diagram's main aim is to present the flow of events and products, and a more detailed diagram is provided to show the relationships between work product and MAS meta-model elements (Figure 7).

5.1.2 The workflow implementation document

In the previous section we discussed how we look at the fragment as composed of four views; in particular, we made a distinction between the definition of the process inside the fragment and its implementation; a direct consequence of this is that we represent the workflow of a fragment using the XPDL language (a standard from the Workflow Management Coalition (WfMC Groups, 1994)).

XPDL provides a rigorous definition of the activities, their transitions, their properties and their interfaces, and allows separating the process definition from its implementation; in addition, the definition of a process is based on four main groups, as we show in the XPDL file (see below); they are:

1 a group containing all the elements and their most important attributes

2 all the specific properties of main elements

3 elements referring to other elements

4 documentation and icons for activity representation.

In the following, we show a portion of the XPDL file of the studied fragment:

```
<?xml version="1.0" encoding="UTF-8"?>
<Package xmlns="http://www.wfmc.org/2002/XPDL1.0
" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance
" Id="D.O.D.Fragment_ID" Name="D.O.D.Fragment"
xsi:schemaLocation="http://www.wfmc.org/2002/XPDL1.0
http://wfmc.org/standards/docs/TC-1025_schema_10_xpdl.xsd">
<PackageHeader>
<XPDLVersion>1.0</XPDLVersion>
<Created>2006-07-31 10:23:38</Created>
</PackageHeader>
<ConformanceClass GraphConformance="NON_BLOCKED"/>
<Applications>
   Application Id="Eclipse_ID" Name="Eclipse"/>
</Applications>
<WorkflowProcesses>
   <WorkflowProcess Id="D.O.D.Fragment_ID
   " Name="D.O.D.Fragment">
<RedefinableHeader PublicationStatus="UNDER_TEST"/>
<Participants>
   Participant Id="Ontology_Expert_ID
   " Name="Ontology_Expert">
      <ParticipantType Type="ROLE"/>
   </Participant>
   Participant Id="System_Analyst_ID
   " Name="System_Analyst">
   <ParticipantType Type="ROLE"/>
   </Participant>
</Participants>
<Applications>
  Application Id="Eclipse_ID" Name="Eclipse"/>
 </Applications> <Activities>
   <Activity Id="Define_Concepts_ID
   " Name="Define_Concepts_">
<Implementation>
   <Tool Id="Eclipse_ID" Type="PROCEDURE"/>
   </Implementation>
<Performer>Ontology_Expert_ID</Performer>
<ExtendedAttributes>
   <ExtendedAttribute Name="Concepts"/>
</ExtendedAttributes>
</Activity>
   <Activity Id="Define_Predicates_ID
   " Name="Define_Predicates">
   <Implementation>
<Tool Id="Eclipse_ID" Type="PROCEDURE"/>
</Implementation>
<Performer>Ontology_Expert_ID</Performer>
```

5.1.3 The Activity Agents

As the WfMC specification suggests, using XPDL for the process definition, we can associate a development tool for each activity, giving its name as an attribute of a worklist (WfMC Groups, 1994).

In our work, the result of this association is a multi-agent system whose components (Activity Agents) can be invoked by the workflow engine during the execution of the design process defined in XPDL. These Activity Agents are devoted to interacting with the designer in order to control the design applications (UML design modules built as a plug-in of IBM Eclipse), to collect new data (through the necessary forms) and to request syntax/semantic checks (from the expert system) (Cossentino *et al.*, 2006). They also provide the user with the necessary graphical interface to interact with the workflow engine and perform routine operations such as accepting an activity, starting it and communicating the completion of the activity (this is an important event, since it usually triggers further activities). Referring to the previously discussed elements of our fragment, we can say that these agents are responsible for the implementation of the GUI_Action and WP_Composition activities presented in Section 4.4.

5.1.4 The Design Rules document

The multi-agent system is integrated with an expert system (realised in Jess Java Expert System Shell) whose rules are written in first-order logic; its primary aim is reasoning on the composition of work products and verifying the abidance to the Design Rules we discussed in Section 4.4; the expert system operates on a knowledge base maintaining an ontological representation of the designed system model. More specifically, we identified four kinds of rules:

1 *syntactic validation* for checking the constraints imposed by a specific work product notation

2 *semantic validation* for verifying the abidance to the structure imposed by the MAS meta-model (this means, for instance, that an agent can be related to roles only if this structure is permitted in the MAS meta-model)

3 *semantic interpretation* for allowing the system to construct the MAS model, starting from the analysis of an artefact (this, in practice, means that the expert system can parse the work product, for instance, an XMI representation of an UML diagram, and introduce in the knowledge base the information reported in it)

4 *autocomposition* for totally or partially composing a new work product, starting from the information retrieved from the knowledge base. In the following, an example of a syntactic validation rule regarding the use of a forbidden notation element is presented:

```
(defrule SYNTACTIC-VALIDATION::not-allowed-notation-element
(MAIN::object (is-a WorkProduct)
    (Name ?WP-NAME) (Kind ?WPK)
    (NotationElementList $? ?NE $?))
(MAIN::object (OBJECT ?WPK)
    (DomainNamespace ?WPK-DN) (Name ?WPK-Name))
 (MAIN::object
    (OBJECT ?WPK-DN) (Name ?WPK-DN-Name))
(MAIN::object (is-a-name ?NE-T) (OBJECT ?NE))
(not (MAIN::object (
is-a MMM-ElementNotationElementLink)
               (NE-Type ?NE-T) (
                MappingRuleOf $? ?WPK $?)
     )
)
(printout t "<Error>" crlf) (printout t "<![CDATA[")
(printout t "Syntax error, ")
(printout t "the work product " ?WP-NAME " is of kind "
(slot-get (slot-get ?WPK DomainNamespace) Name) "::"
          (slot-get ?WPK Name))
(printout t " so it can't contains " ?NE-T "::"
          (slot-get ?NE Name)"]]>" crlf)
(printout t "</Error>" crlf))
```

5.2 *The method base*

After refining the definition of method fragment, we created the method base with a twofold aim: storing the fragments and providing an easy way for their retrieval. Our method base is a database where method fragments are stored following a categorisation based on the main elements composing a SEP (activity, process role, work product and MAS meta-model element); since we consider the MAS meta-model element a key element of the agent-system design, we regard the lack of a unified MAS meta-model as an important issue for the implications it has on the classification of the fragments. This was a great problem for us when constructing our method base because we wanted to conceive it in such a way that fragments could be retrieved easily.

Our solution to this problem is based on the categorisation of the four cited elements of the fragments, and above all on the creation of a taxonomy within each of the four basic categories (process role, phase/activity, work product, MMM element) (Seidita *et al*., 2006). This solution, together with a web-based interface, allows the designer to retrieve the fragment he really needs when he/she is trying to create his/her own SEP; in fact the designer can easily find a list of all the fragments satisfying his/her search criteria. For instance, the designer could need a fragment involving a specific process role and producing a work product of a specific kind, so he/she could set all these choices in the application and then could receive a list of fragments as output; this list could contain several fragments and in this case another filtering may be necessary.

6 Conclusions and future work

This paper presents the activity done by the FIPA Methodology TC, aimed at adopting the method engineering approach for the design of MASs, and the research we did in order to refine and apply that proposal. Method engineering when applied to the agent-oriented context presents new research challenges that have been faced; the concepts of agent and agent societies are to be introduced and specifically managed in the whole process with the consequence of changes to the existing state of the art. As regards the actual results of these studies, they are:

- an initial specification (produced by the Methodology TC) of the method fragment structure (which includes agent-related aspects and formalises the reusable part of a design process)
- a refinement of this initial proposal in order to introduce a multiview approach allowing easy reuse, documentation and the introduction of the necessary supporting tools
- a description of the method base that could allow an easier interchange of fragments produced in different contexts.

We also discussed a few guidelines about assembling a customised design process. Some of these issues still have not found a definitive solution (and they are still a work in progress), but interesting papers have been presented that have evaluated/adopted the FIPA Methodology TC results (Chella *et al.*, 2004; Fortino *et al.*, 2004; Garro and Palopoli, 2003; Garro *et al.*, 2004b) or follow similar approaches (Henderson-Sellers, 2005; Juan *et al.*, 2002). We have already performed some experiments (Cossentino and Seidita, 2004) that were useful for improving our approach and further refined the definition of the fragment which we had adopted. Future works include the evaluation of the new release of the SPEM meta-model (SPEM, 2006), the attempt at enabling the interoperability between the TC specifications and other existing frameworks such as OPEN (Henderson-Sellers, 2003) and FAME (Beydoun *et al.*, 2006), the realisation of further experiments in order to achieve a deeper understanding of the possibilities offered by our approach and the completion of a versatile process composition and instantiation tool that is now at the prototype stage.

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Notes

1 Foundation for Intelligent Physical Agents (FIPA), http://www.fipa.org.

2 http://www.pa.icar.cnr.it/cossentino/FIPAmeth/glossary.htm

3 FIPA RDF Content Language Specification, FIPA document n.00011, http://www.fipa.org/specs/fipa00011/.

4 W3C Resource Description Framework (RDF) specification, http://www.w3.org/RDF/.