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Abstract: This document describes the research questions methodologies, strategies and tools for the design of the I-Mass project.in, which the concept of the Virtual Reference Room will be elaborated. The aim is to reach interoperability between large heterogeneous databases of heritage institutions.

Keyword list: Intelligent agents, I-MASS, IST. Cultural Heritage, Interoperability, Virtual Reference Rooms

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1. Introduction to I-MASS

In this document we define the research question of the I-MASS project. Due to the transdisciplinary nature of this research project the research definition will have a dynamic character to some degree.

Heritage institutions, such as museums, libraries and archives are confronted with the need to digitize their books, records and artifacts. Unless users are provided with intelligent access solutions, they will face many problems in searching through the very large heterogeneous databases, which result of these digitization activities. The management of these databases is becoming more and more complex. On the user side it is ever more difficult to connect the various kinds of questions to the most suitable works. In the I-MASS project these problems will be studied and tools will be developed to realize access to heterogeneous sources. A so-called Virtual Reference Room (a digital version of a real reference room) will improve the deployment of the artifacts and works stored in the collections of the content providers. A reference room is a collection of works -the most important of which are typically stored in the catalogue room of a physical library- that were explicitly published with reference materials (in the form of names, terms, concepts, dictionary definitions, encyclopaedic explanations, titles, abstracts, reviews etc) to other works and artifacts. As such they are in contrast in a) to the works and artifacts themselves (which we call “primary sources”) and b) to general discussions and interpretations of such works and artifacts (which we call “secondary sources” in this document).

1.1. Outline

In chapter 1 we introduce the background ideas of the VRR and the goals of I-MASS. In chapter 2 we provide a high-level overview of the main components that constitute the I-Mass project. Chapter 3 further describes these components and outlines their connections with research issues and the work packages. Chapter 3 ends with a full list of research issues. Chapter 4 relates these research issues more specifically to individual work packages and to the overall project, ending with a summary and an overview.

1.2. Background idea of VRR

The rapid growth of the Internet has seen many research projects under the heading of digital libraries, virtual libraries, virtual museums and similar terms coined for the use of digital devices and techniques by heritage institutions to store, to archive, to provide access and to visualize their possessions or digital representations thereoff.

With the rise of the volume of digitised material and related problems of knowledge discovery, interfacing and representation, it became clear that publishers and the keepers of the cultural heritage must play a seminal role in these developments, which they did with fervor. During the 1990's they joined into many forms of cooperation to deal with problems regarding standards of description of content. This long-felt need was reinforced by the emerging possibilities to exchange information concerning content(s) in a machine-readable cataloguing (MARC) format. These efforts at developing new kinds of metadata descriptions to serve as new finding aids, were paralleled by a quest to provide detailed tools for full-text analysis. Here efforts towards a Standardized General Markup Language (SGML) have led to a new Internet based extensible Markup Language (XML). In the past two years there has been an increasing convergence between these two efforts. The general quest for access to sources in the form of new finding aids and the more specific goal of access to the contents of sources are becoming increasingly linked.

At the same time, the end-user has been enabled to search or browse contents via the Internet This has implied that methods for indexing (i.e. assigning classification codes and keywords) had to be re-invented or that those methods available in the world of the traditional heritage institutions for ages needed to be reanimated and/or revised. Experience with full text searching by means of the well-known search engines and web crawlers has confirmed that current provision of content on the Web is hopelessly naïve. This underlines the need for rethinking the organization of knowledge in general and that of cultural heritage in particular.

Hence, the process of digitization with a view to providing content over the Internet motivated the heritage institutions to rethink a) standards of description of their contents and b) the methods for providing access to these contents. To achieve this in optimally an integrated way, the term "interoperability of content" has been coined [Veltman 1999, Koch, 2000].

The reference rooms of great libraries and heritage institutions serve as the search engines of the collective memory of civilization. Hence, an initial hypothesis of the I-MASS project is that a Virtual Reference Room (VRR) [Veltman, 1999] will help the end users in finding their way through vast bases of information by means of layered structures of reference works. The VRR will work in much the same way as a traditional reference room in a large library, with some notable differences. In a physical reference room, users searching for primary or secondary sources on a specific subject of interest can enter the reference room and there find classifications, thesauri, definitions, explanations and other references. They can follow such references to a catalogue or database to retrieve descriptions of primary sources (i.e. titles of books) which potentially of interest. After reading these books and articles they can return to the reference room to find further information on the names of people, places and the concepts therein. In a physical reference room, each consultation of a reference dictionary, encyclopaedia etc requires physical movement by the user from one shelf to another.

In a Virtual Reference Room this running to and fro is spared. In a physical reference room the reference material is linear and static in keeping in keeping with the limitations of print media to which McLuhan drew attention. In a VRR much more is possible. The reference material can be translated into dynamic lists. With the aid of agents one can aggregate existing knowledge in new ways to arrive at augmented knowledge. Virtual reference rooms can thus build dynamically on existing reference works to provide users with value-added knowledge and information.

Pointers	1. Terms, Concepts (Classification Systems, Thesauri)
	2. Definitions (Dictionaries)
	3. Explanations (Encyclopaedias)
	4. Titles (Catalogues, Bibliographies)
	5. Partial Contents (Abstracts, Reviews)
Primary Sources, Secondary Sources	6. Full Contents (Books, Paintings, Instruments etc)
	7. Internal Analyses
	8. External Analyses
	9. Restorations

	10. Reconstructions

Figure 1.1 Basic levels of categories of pointers to sources in a reference room and the primary/secondary sources elsewhere in a library.

A physical reference room typically has at least five levels of reference materials, which serve as pointers to the full text sources elsewhere in the library stacks (figure 1.1). In a physical reference room the only explicit links between the reference pointers and the specific collection of a library or heritage institution are in terms of titles and full contents (i.e. links between levels 4 and 6). Moreover these explicit links are typically limited to author catalogues (Who?) and title catalogues (What?)

1.3. The goals of I-Mass

As digital libraries become mature and complicated systems, they are encountering numerous research and development issues. Within the library and heritage communities, these research activities are focussed on syntactic and semantic interoperability. At first, this quest for interoperability was almost exclusively directed to linking distributed catalogues with their respective collections (levels 4 and 6). In the past years there has been increasing attention to linking terms and concepts in classification systems and thesauri with these catalogues and collections (i.e. integrating levels 1,4 and 6). To be sure there have been many sporadic attempts to digitise dictionaries, encyclopaedias and other reference materials, but these efforts have typically not been integrated with classification systems and catalogues.

I-MASS will build on these important efforts but also go further on four significant fronts.

First, as noted above physical reference rooms typically limit their access methods to answering Who? (Author catalogues) and What? (Title and subject catalogues). I-MASS will create a prototype virtual reference room, which expands this range of questions to include dimensions of space (Where?) time (When?), manner or condition (How?) and purpose (Why?).

Second, the prototype reference room will expand the range of explicit links to interrelate all six levels such that one can go directly from a term in a classification or a thesaurus to a dictionary definition, an explanation in an encyclopaedia, a title, an abstract and/or a review.

Third, physical reference rooms typically give access to their collections with no explicit indication concerning the level of their materials. Hence a local or regional library typically gives access to unique local or regional materials. International libraries such as the British Library or the Bibliothèque de France, typically provide access specialized international sources. I-MASS will attempt to indicate these different levels, such that a user can see whether these materials are available at a local, regional, national or international level and then make choices as the wish. All of the above three innovations will give users greater access to materials and provide them with more precision and control when navigating through this material.

Fourth, I-MASS will attempt to use this virtual reference room as a starting point for developing a knowledge landscape. With the aid of agents this landscape will aggregate distributed, static knowledge sources in the form of catalogues, lists and databases in order to produce dynamic forms of augmented knowledge whereby a given knowledge level can be presented according to a certain perspective in the knowledge landscape.

This approach, as will explained in paragraph 3.3, differs from most interoperability research and development-work in the world of digital libraries. Our aim is to connect basic information questions, “who”, “what”, “where”, and “when” with levels of knowledge, names and terms, definitions, explanations, titles, partial contents and finally full contents and eventually such in-depth levels as restorations and reconstruction of knowledge. The development of tools and prototype applications for delivery of new (virtual) reference services will go hand in hand with the development of new methodologies to address this new area. Our hypothesis is that digital culture is much more than a simple problem of digitising cultural objects. Once they exist in digital form the collections of heritage and memory institutions need to be reorganized to be optimally accessible. Hence virtual reference rooms as foreseen by I-MASS are a first step towards a future reorganization of knowledge.

2. I-MASS project general overview

2.1. The general problem of I-MASS

As might be expected the VRR is filled with reference works. Reference works are those works that provide references to and for other works in the form to terms, classification codes, the concepts they represent and the intellectual context represented by classifications and thesauri. Furthermore in our common sense understanding of a reference room, dictionaries and encyclopaedias are also included. Sometimes so-called “canonical” works are also included, such as handbooks (such as Bibles, and basic texts as Teubner series of Greek Mathematics). In most traditional libraries the catalogue, which gives access to their collections, is be included in the reference room, where catalogues of other libraries (mostly in printed form) also are. In larger libraries the reference room also contains some (usually printed) catalogues of other libraries, such as National Union catalogues.

In a traditional library such reference works are directly available on open stacks. Because they are part of the regular collection they can also be accessed via entries in the catalogue of the library or the library or heritage institution. Alternatively, reference librarians are trained to help novice users gain access especially in the case of more recondite reference works.

One problem of I-MASS is how to represent the workings of a reference room in a digitized or digital environment. For this problem we need a model of the reference room and its contents that can be dynamically accessed. Therefore it is necessary to get in-depth knowledge of the contents and daily practices of the content providers. We also need to be able to assess how new content providers will join the I-MASS system, i.e. to address questions of scalability of I-MASS.

The VRR aspires to integrate different kind of levels of reference works and present them to the user in various perspectives -which perspectives depend on the kind of questions posed and how these are represented and manipulated within a Knowledge Landscape (KL). This KL is an important component in I-MASS. It will serve also to capture the complex cultural knowledge kept by heritage institutions, and also help to trace the behavior of the user in virtual reference rooms within (distributed) heritage institutions. All these (sub)-problems are interrelated and described below.

2.2. The six components of I-MASS

In the project we find six main components that constitute the structure of the I-MASS system mediating between users and the digital sources of the heritage institutions - as shown in figure 2.1. Each number in figure 2.1 will be described shortly in the next six sections and a detailed view on each paragraph in chapter 3. For the sake of convenience, we shall use abbreviations such as DS for Digital Sources for referring convenience in the rest of the document.

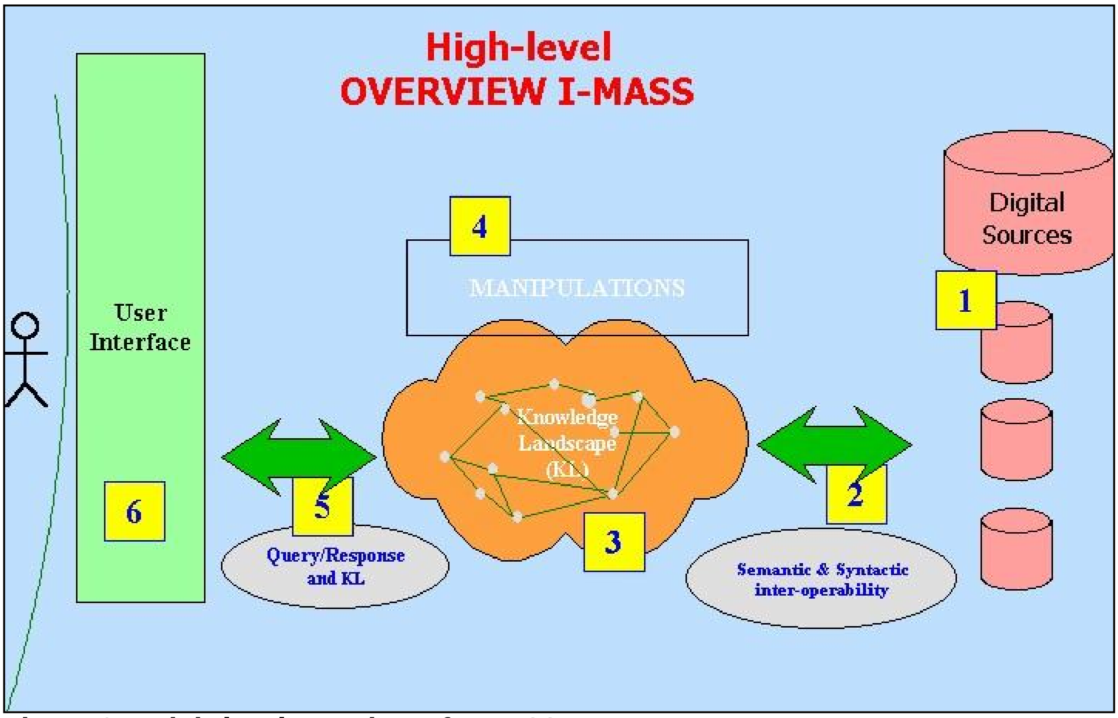

Figure 2.1 High-level overview of I-MASS

2.2.1. Digital Sources (DS)

On the right hand side of figure 2.1 are the Digital Sources denoting the contents of the heritage institutions. These contents (i.e. collections and objects) of these institutions are very disparate and dissimilar in nature: books, manuscripts, paintings, sculptures, monuments, coins, archaeological artefacts, and even whole landscapes. These are sometimes described and indexed as single entities or as belonging to sub-collections within larger collections. The only thing they have in common is that they belong to our shared cultural heritage.

An overview of the digital sources (primary and secondary) of the content providers must be given. Furthermore it should be known which sources are formally described in a machine-readable format. Therefore, among other things, information about the database management systems of the content providers is needed. An inventory will be made of the details on DBMS, daily practices and indexing methods (thesauri, classification systems). Questions that will arise include which standards are used or what the nature of the digital source; how are they are accessed; how they can be (re-) organised and made available during the I-MASS development.

2.2.2. Syntactic & Semantic Interoperability[1] (SS)

The digital sources among different content providers are by nature heterogeneous. Each content-provider uses its own method for storing and retrieving their data within the digital sources. Mechanisms of syntactic interoperability are required to ensure a standard, system-wide format for data source access. Once such uniform access is obtained, mechanisms of semantic interoperability can operate to integrate the heterogeneous data elements into

[1] Within this project, we denote by interoperability the dynamic transformation of data in order to be used within an application, possibly together with the 'classical' notion of interoperability that is used regarding exchange of data between applications.

cohesive, structured knowledge. Both these mechanisms of syntactic and semantic interoperability – mediating between the knowledge landscape and data sources - will be implemented within an agent-based software paradigm.

Agents are software programs that operate on behalf of other entities, without the direct intervention of humans or others, and have some kind of control over their actions and an internal state. They perform their actions with some degree of pro-activity and/or reactivity. Furthermore an agent operates within a specific domain and possesses a knowledge level. With this knowledge level it has the ability to communicate with persons and other agents with a language, more resembling human-like “speech acts” than typical symbol-level program-to-program protocols.

Multiple (co-operating) agents, situated at several levels to handle the meanings that are relevant for the user, are necessary to compose an answer to the user. These agents must be able to face problems of traffic, transformations and persistency between levels of knowledge. Questions that can be asked are: What methods (e.g. agent-based mechanisms) are available for propagating a user query (framed within the knowledge landscape) down to the various digital sources, such that relevant (valid) responses may be obtained. What are the problems of routing (directing queries through the system) and traffic (multiple queries & multiple users) that might be faced? It is possible that some answers to these questions can be found in the specifications of the FIPA [FIPA, 2001]. FIPA is a standards organisation that is developing standards for software agents to allow interaction between heterogeneous agent systems.

2.2.3. Knowledge Atlas and Landscape (KL)

The Knowledge Landscape is the metaphorical designation of the multi-dimensional space of knowledge objects and their inter-relationships. Knowledge objects exist at varying levels of granularity, and can, in principle, be expanded into objects at a finer ***granularity***.

Knowledge objects represent pieces of cultural knowledge such as all kinds of artefacts, events, processes, histories, etc. As such the knowledge landscape is the primary medium for manipulation procedures that transform, present and search for information about in the content sources, i.e., the knowledge landscape is ***the*** internal **representation** for content found in the sources *and* their embeddedness in a wider framework of **knowledge** as provided by any pertinent reference work regarding the cultural domain. We shall also introduce an abstract layer in which we try to capture general concepts of 'artistic movements' and other processes. Examples of 'artistic movements' could be cubism and structuralism, which can appear in the knowledge landscape (see figure 2.2 at the 'Atlas' (processes/societies) axis).

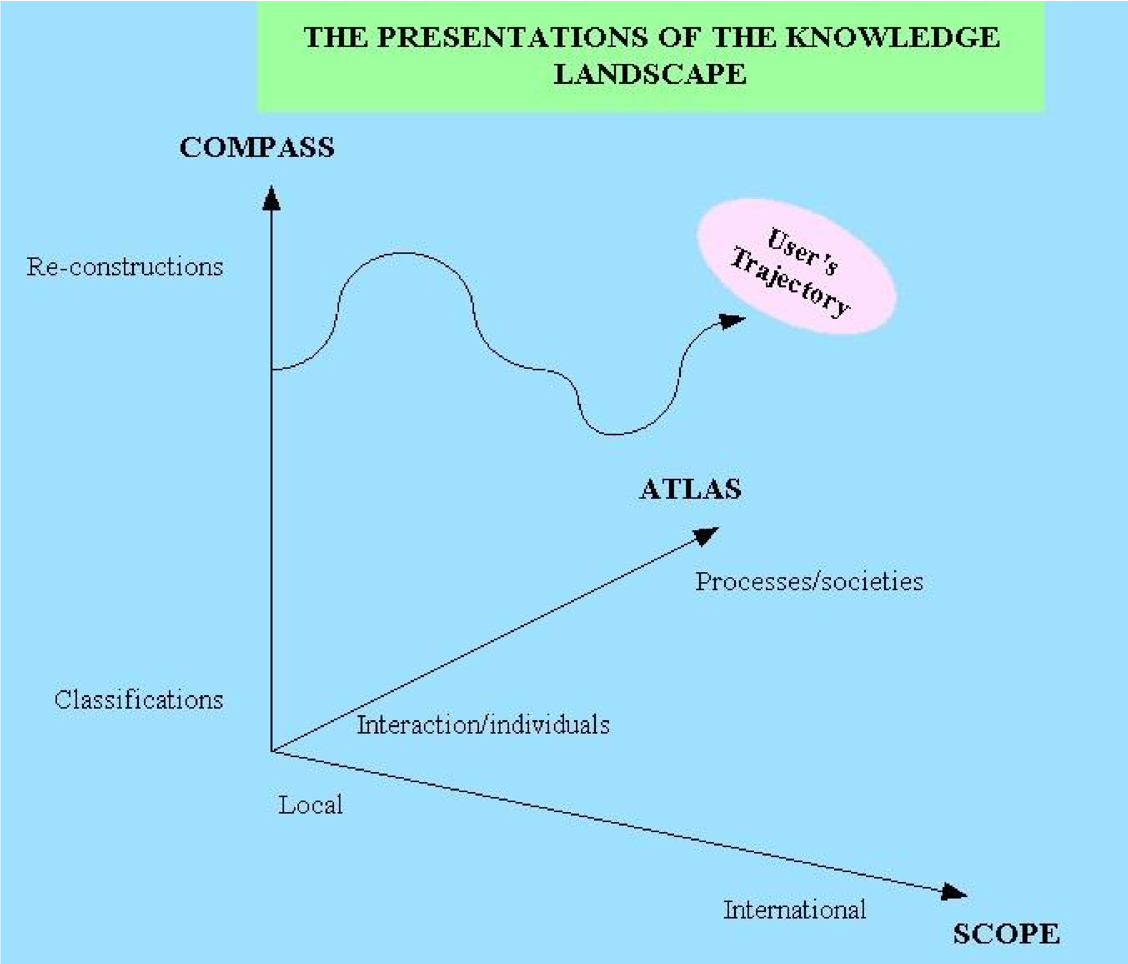

Figure 2.2 The Presentations of the Knowledge Landscape

In this figure we can also find the compass, the atlas and the scope, which can be seen as metaphorical external presentations of this knowledge landscape.

Questions that will arise during the project for the core of the I-MASS system: “What does the KL need to represent and what is the best language for representing them”, (and for facilitating the required manipulations) “Which aspects of the KL can be automated and which aspects require long term human management and validation?”

2.2.4. Knowledge Landscape Manipulations (KM)

The Knowledge Landscape will be generated dynamically in response to the actions of a user. Depending on a user’s queries some dimensions will be explicated, and others will not. Some representations need to be persistent during a user session and others will be more transient. It must be determined which parts of the Knowledge Landscape have a general character and must therefore be preserved (or embedded) as a part of the system and which other parts are specific only to some (categories of) end users. Depending on the collections employed in the test beds, and the implications for the agent architecture, a selection will be made of the reference works that will be used in the Knowledge Landscape. It will certainly not be necessary to cram the KL with all kinds of reference works. An inventory of digital reference works, which are freely available on the Web, is now in progress. From this list a selection will be made. The number of freely available reference works is growing, and the I-MASS consortium is currently seeking permission from publishers of reference works to make use of their publications.

The reference works themselves must be classed according to their scope of use (e.g. specialty vs. genericity, regional or international), complexity and type. It also needs to be determined if the end users themselves need to access these works or if automatic deployment via agents is sufficient, and who (or better what agent) will monitor the rise and fall of reference works on the web. In all likelihood, there will be times when users will insist on direct consultation and other times when they rely on agent mediated access to these reference works.

Questions that will further arise: What methods (e.g. agent-based mechanisms) and services are invoked in constructing, maintaining & transforming the KL? And how are these services to be accessed and managed?

2.2.5. Query/Response and the Knowledge Landscape (QK)

The core of the I-Mass system is a Knowledge Landscape (KL), within which user queries and responses are framed. Between this KL and the user interface lie a set of mechanisms, which transform user activity (e.g. queries) into manipulations of the KL, and the resulting, modified KL into system responses to the user's activity. Various user activity patterns (e.g. user scenarios) need be supported, as do varying levels of user competence. In addition it is expected that a great deal of system behaviour will be pro-actively generated in anticipation of user activity. As such, the mechanisms (i.e. agents) mediating between the user interface and KL will likely comprise the more 'intelligent' aspects of the system – e.g. in anticipating user activity, in encapsulating expert reference librarian/curator (tacit) knowledge, and in determining what type/degree of support to provide. Active research issues include the characterization and/or modeling of user activity, the extent of such modeling, and what mechanisms exist for inferring 'intent' from user activity.

The mechanisms mediating user activity and manipulations of the KL, however, remain largely unspecified. Hence the more general, primary question for this component is: What manipulations are required to translate user activity at the user-interface into valid queries framed by the KL, and to present responses framed within the KL to the user?

2.2.6. User Interface (UI)

The user interface is the part of the I-MASS system that forms the connection between the users and the functionality of the I-MASS system. From a technical point of view, the user interface is a mere module, which takes input from a user and presents the output produced by the system.

From the point of view of the user, however, the user interface *is* the system. The user interface should then be defined as all the aspects that users come into contact with while interacting with the system. As such, the user interface consists of the "look and feel" of the I-MASS system, its functionality and behaviour, and the expectations and knowledge that users may develop about the system when interacting with it.

From this point of view, it is not sufficient to identify a user interface module as a go-between between the user and the system, and, guided by a number of questions from a system's point of view (cf. "how does the user *input queries* into the system?"), to define the user interface such that it satisfies the technical requirements of the architecture and functionality of the system and the feasibility requirements of the project. Rather, from an analysis of who the users are, their background and knowledge, their way of working, their tasks and information needs. As such the I-MASS system as a whole, including its architecture and functionality, such as to satisfy the actual and possible information needs of the users. Instead of asking simply how responses are to be presented (e.g. visualisation techniques for complex knowledge domains) or what user scenarios (e.g. interactions / discourse levels) need be facilitated, the questions should be asked: what ways of working do the users have and how should the I-MASS system support them? Users do not input queries into systems. Users may want knowledge and information and to get it they may ask questions!

As such, the user interface has to fulfil two different sets of requirements. On the hand, the requirements put forward by the users. In order to satisfy the information needs of a wide variety of users, the user interface should address the reality that users differ with respect to information needs, knowledge, etc. On the other hand, the user interface as an interface between the users and the technical system should be able to cope with the information requirements of the I-MASS core system.

With respect to the role of the I-MASS user interface as an intermediary between the user and the system, the user interface should address two basic questions. First, how does the user **input** queries into the system, and secondly, how are **responses** presented to the user?

In order to address the main differences between users for the I-MASS user interface module, an important research question is to ask what user interaction scenarios need to be facilitated, with respect to the various ways of working (cf. **interaction scenarios**) and with respect to the different information needs (cf. **discourse levels, background knowledge of user groups**). With respect to the differences in the amount of domain knowledge among users, a question is the necessity and mechanisms to provide more expert users with **direct access** to the Knowledge Landscape, and to provide more novice users with the help of an **expert-like agent** which acts in the manner of a virtual reference librarian/curator to provide guidance and navigation.

Given that I-MASS should aim to address and adapt to user characteristics this raises the question whether this user modelling information should be stored persistently or be newly specified or inferred during each session from the user-system interaction. In this respect, a main research question is: "Are user models **necessary?**" With respect to their role, or utilization, within the I-MASS system, a derived question for investigation is: (if the user models are necessary) "**how** are these models to be constructed, maintained and utilized by the system as a whole?"

3. Detailed overview of I-MASS project and introduction of research issues

In this chapter we will give more descriptions about the research issues and in the end we will give an elaborate list of research questions. As in chapter 2 we use abbreviations such as DS, but sometimes provide them with a number, so that readers can relate a given passage with the particular research issue listed in the last paragraph.

3.1. Digital sources (DS)

The collections of heritage institutions vary greatly in character, due to different traditions and functions of the heritage institutions. Roughly we speak of museums, libraries and archives. Some (e.g. university and research libraries), besides making available their collections to the public, also strive to preserve and conserve their collections. Others (e.g. many public libraries in Europe) concentrate on making their collections available, without assuming a task of preserving their collections. In archives there is a basic distinction between public archives (e.g. state and municipal archives), and archives that concentrate on special research interests or family archives. The State and Municipal archives keep records of the acts of authorities to enable authorities to be accountable of their past acts/actions. They also have a heritage function. Hence, public archives are both part of the public administration and keepers of heritage. By contrast, research archives frequently have no role in public administration and can thus concentrate on the heritage aspect of their collection.

Many research archives can be found at universities as a result of research activities, such as the Virginia Heritage project[2]. A very good example of a research archive is the International Institute of Social History[3], which keeps the collections of the socialist movement in Europe, archives of important leaders of socialist or social-democratic parties, such as the pre-war SPD and the writings of Karl Marx.

Museums very often grew around kernels of private, city, provincial or state collections, which were then further developed as newly acquired items were added. The motivations to develop museums collections vary. Some began much like public archives aimed at building collections, which are representative of the deeds and acts of some authority. Others began with a more representative role to further the fame of an individual, a city, a state, or a country. With other museums to motivation was more specifically of a scholarly or artistic nature.

A library builds its collections for several reasons: to develop its specialty, to serve a particular group or the public at large, to act as a repository (for instance a legal deposit) or simply to conserve and preserve a particular collection.

Despite the fact that they both collect documents, there are further differences between libraries and archives. The documents of archives are in most cases unique, because they are not meant for publication. Libraries primarily collect publications, of which will usually be copies in several libraries at the same time. This fact lead led to co-operation between libraries for many years. The tying in of the collections of archives with the history of authorities and organizations has lead to a widely different method for collection building of archives. The documents are always associated with the organization or department, which produced the documents (e.g. archives of the Duchy of Gelre, Archives of the province of Limburg, etc.).

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[2] http://spec.lib.vt.edu/VIVA/VHPT/

[3] http://www.iisg.nl/

These different motivations, purposes and various raisons d'être of the heritage institutions have consequences for the way they describe the items and collections to which they belong, whether these are analog, digitized or originally digital. (DS01)

Museums items are collected and described individually and as part of (sub) collections with the main collection of a museum. As with archival records the items of museums collections are often unique. The main difference is that a primary source of a museum is complicated to describe. Description of an object does not only exist of administrative data, but also involves interpretative information, about its artistic and/or historical context. This can be seen in the catalogues raisonnés, published about collections by museums and galleries. The catalogues use many external references, give information on the provenance of works of art, etc. This kind of publications is now very expensive to publish and since the eighties has gradually been replaced by art books, which are mainly produced on a commercial basis. These catalogues raisonnés are real treasuries where one can find systematic references to objects (paintings, sculptures etc.) to literature concerning them and other external sources. In short such works should be included in the Virtual Reference Room, provided that they are available in a digital form (DS01, DS03).

The items of museum collections are only partially available in a digital form. It should be known how these items are stored: XML, SGML, full text, Word Files, with or without metadata. It should be sorted out whether these are embedded metadata or added to the primary sources into a header and according to which standard (DS02, DS04).

Many of them are only described in a described in a digital form, be it in a database, a digital text or some XML formatted document. When archival or museum items are digitized, it must be documented how the digitization process has been executed. A painting can be reproduced in the form of a thumbnail, a picture of reasonable quality, or a high quality image. Each of these digital copies need a separate description, otherwise no choices can be made. Furthermore an account of the parts that have been digitized or not, should be given (like empty leaves of archival records). These extended item descriptions are subjected to metadata standards (commonly called “technical metadata”) (DS02).

A general inventory of the content of the participant content providers needs to be made in order to get an overview of the variation in content and form of the data. Furthermore it should be made clear which part of the collection is already digitized and which should be digitized for the test collections of I-MASS (DS10). These digitization activities should reckon with the testing of semantic and syntactic interoperability as described in the DoW. This is important because within a collection items may have a repetitive character. For instance, an archive has thousands of deeds of conveyance (Gichten as they are called in Flanders and the Southern provinces of the Netherlands). It is not necessary to digitize all of them to test interoperability. They are too similar, to gain much from mass digitization. However, mass digitization most probably will be of influence in performance tests.

When a proper selection of digital materials has been made to include in the test beds of I-MASS, we shall have an overview of the ways in which these items are indexed, i.e. which classification systems and thesauri are used. It is clear that these indexing systems must be integrated in digital form in the test beds (DS03, DS07).

Also third party indexing systems, i.e. those, which are not used by the heritage institutions, should be included. In the first place, reference librarians and curators use these as reference works to help with the checking of the indexing practices. Secondly these external indexing tools will function as terminological sources for end-users (including agents) to find a way though the masses of item descriptions and to retrieve individual records. In other words they are or should be part of the virtual reference room (DS03).

An inventory of third party classification systems and thesauri (preferably) available on the Web will be made. Examples of these are the Art and Architecture thesaurus and Iconclass.

This again gives rise to a new problem. Agents that will manipulate the data from these third party reference works must understand the structure of the lemmas and entries of theses works. The structure of the lemmas is coded with the help of embedded meta-tags, in XML or SGML. Just as must be done for the databases and inventories of the content providers these embedded metadata of the third party reference works will be inventoried and brought into a metadata repository. This will be worked out in WP 4. It will also be sorted out in how far these structuring methods comply with generally accepted standards, such as ISO 2788:1986 for thesaurus building.

Most heritage institutions use databases to store the descriptions of their possessions. We need to know how these databases are organized, how they are documented, what metadata sets are embedded into their database definition languages, in short we need a full and detailed overview of the data dictionaries (DS07).

The problem is that there are several methods to document the structure of a database: a written documentation, embedded documentation or no documentation at all. Furthermore, it is necessary to know on which computers and with which operating systems these databases run (DS08, DS09). A point in case that we must find out which methods exist to get agents connected to these databases (DS09).

When I-MASS will be an operational system, agents will access the distributed databases on the machines of the content providers. During the project itself it is risky to give the agents directs access to fully operational systems. Therefore we will investigate on which machines copies of databases of the content providers will run. On these experimental machine a real life situation will be emulated as much as possible (DS10, 12,13).

3.2. Syntactic and Semantic Interoperability (SS)

In this section we will divide issues of syntactic and semantic interoperability into two parts:

1 an agent-based (technological) solution, and

2 in terms of the steps heritage institutions may themselves take to facilitate interoperability (although both are highly inter-related).

3.2.1. The Syntactic and Semantic Interoperability model for agents

At the heart of the I-Mass system is the knowledge landscape (KL) within which user queries and responses are framed (see section 2.2.3 for details). The basic task for the agent mechanisms underlying syntactic and semantic interoperability is to transform KL-based representations of user queries into data source specific querying formats - and likewise, data source specific results into KL-based user responses. To this end, the agent model is conceived of a series of successive transformations between some highly expressive Knowledge Representation Language (KRL), which provides a base for the KL, and the low-level query languages employed by data sources (e.g. SQL). Figure 3.1 depicts these successive transformation layers (detailed below). Moreover, to ensure that the integrity of knowledge is maintained throughout the transformation process, a series of monitoring agents are hypothesised – which agents act to constrain transformations based on contingencies within the KL (see Figure 3.1).

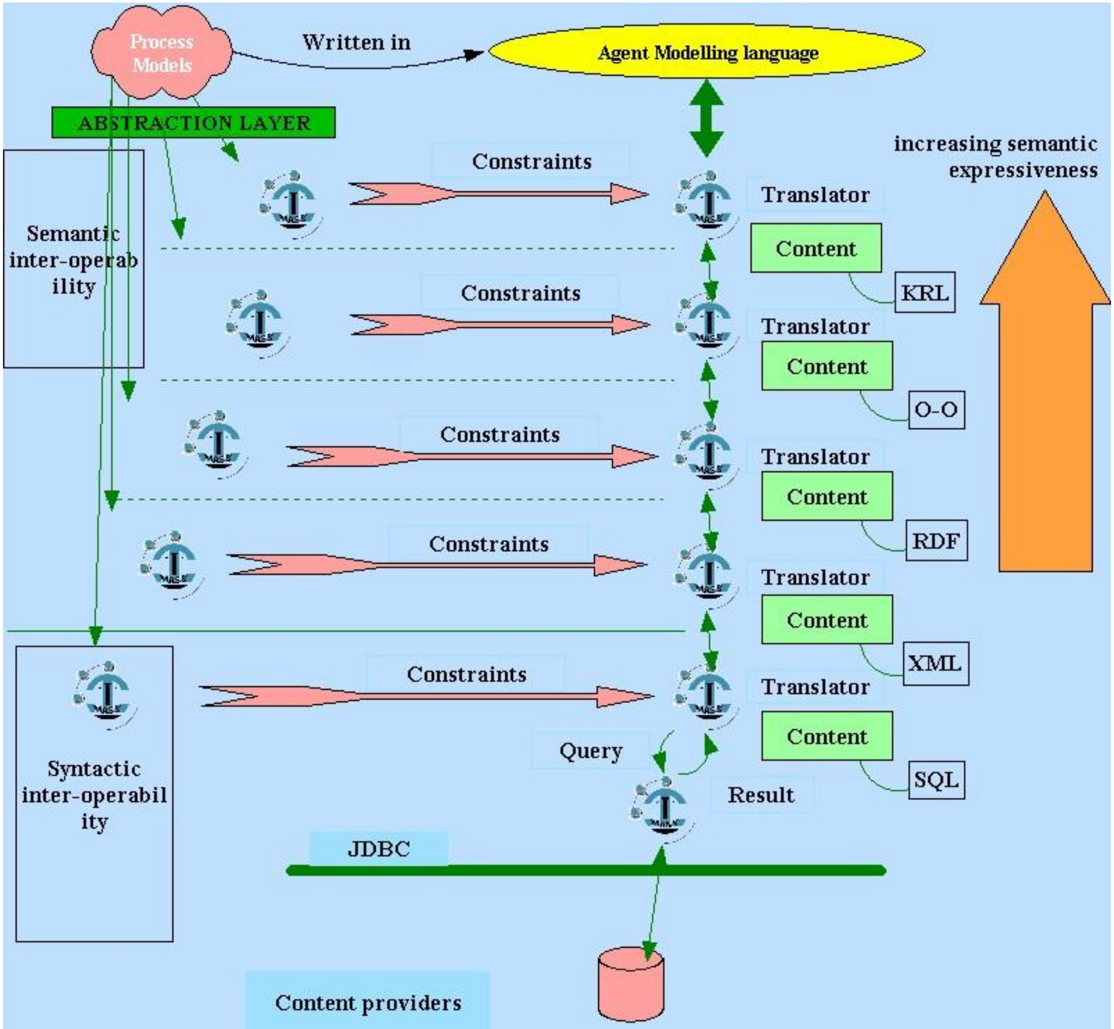

Figure 3.1 Semantic and syntactic interoperability model in I-MASS

On the right-hand side of the figure we have user queries, which will be propagated down to the data sources via a series of transformations. Between the knowledge representation layers we find agent-based mechanisms fulfilling the functional role to make transformations on the content level and to use the language of that knowledge level as the medium. That is why we classify them as functioning agents. The agents on the left-hand side of the figure keep track of changing events in the process models. These agents will be classified as monitoring agents, which will also constrain the functioning agents in their transformations. This brief classification of agent types provides a preliminary view of the agents in our S&S model. For a more detailed description we refer to Work package 4.3.

We have agents on several levels, which can have a translating role. With respect to semantic interoperability, we have on the highest level the Knowledge Representation Language level, the Object Oriented level on the next and then the Resource Description Framework level. With respect to syntactic interoperability we have the eXtensible Markup Language level and the SQL level. On each level itself it may be preferable to call it the XML query layer because all the agents situated on this level are querying in the XML language.

For all levels we have to find out how to express the queries as posed in the knowledge landscape and what is already available. **(SS01 and SS02)**

For the monitoring agents on the several layers, there is a possibility we may not need them on the lower levels. The research question is "What high-level (pragmatic/semantic) constraints need to be applied to transformations to maintain the intentionality of the queries/responses – and how are these constraints applied (e.g.) via monitoring agents)?" **(SS09)**

We now describe some research issues, which deal with the incorporation of techniques, with the underlying platform on which the agents reside (the platform is 'situated below' the S&S model but also in other components of the I-MASS architecture), and which deal with the Agent modelling language. In this Agent modelling language do we try to represent all the knowledge representation levels so that all the agents (except the agents in the S&S coupling component) can use this language as the base language for their operations. So some research issues cannot be divided to the S&S interoperability component but do belong to the Agent Modelling language.

*Research about the main enabling technologies that should be incorporated into the core system **(SS07)**:*

Several technologies from different kinds of fields are related with Agent technology in general. The enabling technologies that have to be incorporated also have diverse backgrounds like information retrieval, ontological engineering and knowledge engineering. To achieve semantic interoperability the system has to utilize several services including authority files, thesauri, and dictionaries.

*Research about existing options for using a suitable agent platform on which the agents of the I-MASS system may enter their life-cycle, and an assessment of the different services that additionally need to be realized depending on a particular choice of the agent platform. **(SS 23)***

One of the action plans at the 20th FIPA meeting was to generate an XML Schema for the SL (Semantic Language) of FIPA's ACL and to investigate the possibilities of RDF encodings of the SL expressions. The various FIPA platforms use the same specifications but have different implementations regarding services, schemes, parsers and Service Ontologies. So research about the most suitable agent platform and additional services is required to minimize interoperability problems while trying to achieve the ambitious targets of I-MASS.

Agent modelling language as the medium for knowledge representation

The authority files, reference works, lexicons, terminologies, directories, catalogues and databases used in I-MASS were once constructed for a specific reason. Humans have made interpretations for organizing and using signs to represent these reference works, terminology's etc to someone for the purpose to share this knowledge with others. Saussure (1916) defined the following definition: *"Language is a system of signs that express ideas, and is therefore comparable to a system of writing, the alphabet of deaf mutes, symbolic rites, polite formulas, military signals, etc. But it is the most import of all these systems."* This science of signs do we call semiotics and can be divided in three branches: syntax, semantics, and pragmatics.

To answer the (search-) questions of users in the I-MASS system also has to deal with these three branches. In the S&S interoperability model the mental connections among the standard works need to be made explicit by tagging the data with more signs. (And linked with documented primary cultural artefacts) These meta-level signs have further interconnections, which can be tagged with meta-meta-level signs. The tags of the meaning of the metadata will acquire the meaning for the agents.

The S&S interoperability component and the Knowledge landscape component will constitute the knowledge structure and making the agents knowledgeable about interpreting frameworks and rules, which are actually applicable of interpretation depending on the context [Sowa, 2000].

3.2.2. Semantic and Syntactic interoperability issues at the heritage institutions

A higher degree of interoperability can be reached when all heritage institutions adhere to the same standard for the description of their objects. However, this situation does not exist, because, as noted earlier, both the objects they collect and the motivations for collecting these objects differ enormously. In principle there are two ways to get at some degree of interoperability:

1. One-to-one switching descriptive metadata schemas
2. Describing the syntactic metadata schemas in comparative metadata registries. The syntactic metadata, as we call them in this document, such as the fieldnames and field labels of databases, schemas for the formal description of content descriptions and the procedures how to fill the information systems of the content, must be documented in such a way that the meaning of fieldnames or data-elements can be made known to agents. Therefore a kind of repository of the meanings is necessary. The repository must be organised in such a way that fieldnames can be compared in order to reach some degree of complexity reduction. Such a repository is generally called a metadata registry (DESIRE Metadata Registry). It is possible to give such a registry the form of a thesaurus (cf. Hunter, 2000).

Both methods are used widely and will, of course, be used in I-MASS. Since the descriptive metadata schemas themselves differ, because of the diversity of the participating heritage institutions, it is impossible to use only one switch. When taking into account the collections of the content providers, it should be determined how far we can go in creating such switching mechanisms and what the limits of the switching mechanisms will be.

Interoperability will also be furthered by defining new object types, such as (sub) collections within a larger collection of objects. In this way we can subsume the works that belong to the reference collection under the object type “Reference Works”. The class “Reference Works” is to be divided in other object types such as, “Dictionaries, “Encyclopaedias”, “Classification Systems”, “Catalogues”, “Indexes” and “Canonical Texts”, according to the basic levels of Knowledge in the System for Universal Multi-Media Access (SUMMA) [cf. Figure 1 1 above and Veltman, forthcoming]. In this way it becomes possible for agents to recognise these reference works, such that they “know” what to do with them and how to connect them to questions of users. Precisely how this will happen is, in fact, a major part of the research question. The reference room thus becomes a series of processes that can best be labelled as a “contextualising” of terms on the basis of objects belonging to a special class “Reference Works”. The VRR becomes something dynamic and permanently changing in this way.

The definition of object types provides the basis of the rules for the generation of metadata. Therefore the definition of object types is essential in the research question. This can be done on the basis of the inventory and the collection profile we have made. (See WP 1)

Semantic standards influence the meaning of content in the fields of the descriptive schemas, because of their influence on the definition of the elements of these descriptive schemas. They also exert their influence on the contents directly when the procedures (i.e. cataloguing rules) prescribe their use in indexing object descriptions (see also par 3.5). Most semantic standards are domain specific, i.e. thesauri. General libraries, such as public and university libraries, and many state archives use universal classification systems. The technologies to reach semantic interoperability that are now under development in the semantic web initiative of the European Commission look very promising. These technologies are diverse and related to each other in complex ways. They can be summarized as *formalizing* (XML, RDF, ontology languages), *grounding* (formalisms and content analysis), *acting* (knowledge discovery, intelligent agents for information filtering, etc.) and *interacting* (visual user interfaces).

A number of technologies, methods, and formats have evolved in recent years, mainly based on XML as the common denominator. RDF as a formalized method for representing and visualizing conceptual data structures ISO 13250 which defines and specifies Topic Maps™ also contribute to the array of technology-driven methods for processing and representing knowledge structures in the form of ontologies. ISO CD 14481 specifies a method for modeling conceptual schemas.

Ontology engineering approaches are evaluated and reviewed comparatively in order to study the possibility of using ontology engineering approaches and results for the purposes of the project and Multi Agent Systems (MAS) implementations.

The goal is the interchange and convergence of systems using diverse ontologies. The problem of convergence applies on two levels – on agreement between the subject field classification and on agreement covering the definition of a particular concept. In a multilingual context this is problematic – for example, there is no equivalent for the English term *pet* in Italian. This can result in so-called *ontological gaps*. Such problems as these will not necessarily be investigated within the scope of this project. Instead, we will focus on the mechanisms available for ontology convergence and investigate the extent to which these mechanisms provide solutions to this convergence.

3.3. Knowledge Landscape (KL)

The Knowledge Landscape as outlined under 2.2.3 is erected by means by using a knowledge representation language, which, ideally, should be a mixture of a recent KL-ONE variant (e.g., LOOM) and an Agent Representation Language. At present, it is unknown how that language should be set up. However, the language must have a canonical character, as it should function as both a high-level medium for formulating *queries* (to be solved by successive downward transformations towards the information sources coupled to the system) and *answers* (to be solved by successive upward transformations of the preliminary answers found in the information sources). Both kinds of transformations may make use of information found in relevant reference works.

Since the Knowledge Landscape is basically a multi-level graph of which the nodes are knowledge objects whereas the arcs stand for relationships, there is a need for basic path algebraic tools in order to traverse the graph at different levels of granularity.

Moreover, other KL manipulations will address the *presentation* of the knowledge landscape to the user, again at different levels of granularity *and* at different levels of detail. That is, the user may sometimes only wish to view the highlights within the underlying knowledge landscape, a wish that amounts roughly to viewing only the mountain formations in an ordinary atlas. The *presentation* of the knowledge landscape to the user will be called the knowledge 'atlas'. This atlas allows the user to orient her in the landscape and is enhanced by tools like a *knowledge compass* by means of which the user may decide to *travel* through the knowledge landscape. The knowledge compass contains 'directions' depending on the type of user question such as what, how, why, who, where and when.

In addition, the knowledge landscape may be utilized in order to solve ambiguities as they arise during the questioning of the system by all kinds of users. Such tools heavily depend on sufficient cultural knowledge representation and the availability of appropriate reference works to update and/or enhance the Knowledge Landscape.

In summary: there are three primary kinds of tool-sets, namely those that
1) Manipulate multi-level graphs
2) Present the knowledge level according to certain perspectives, and
3) Resolve syntactic, semantic and pragmatic inter-operability issues.

These tools can also be found in the following picture, which zooms in on the knowledge landscape, the reference works and its manipulation.

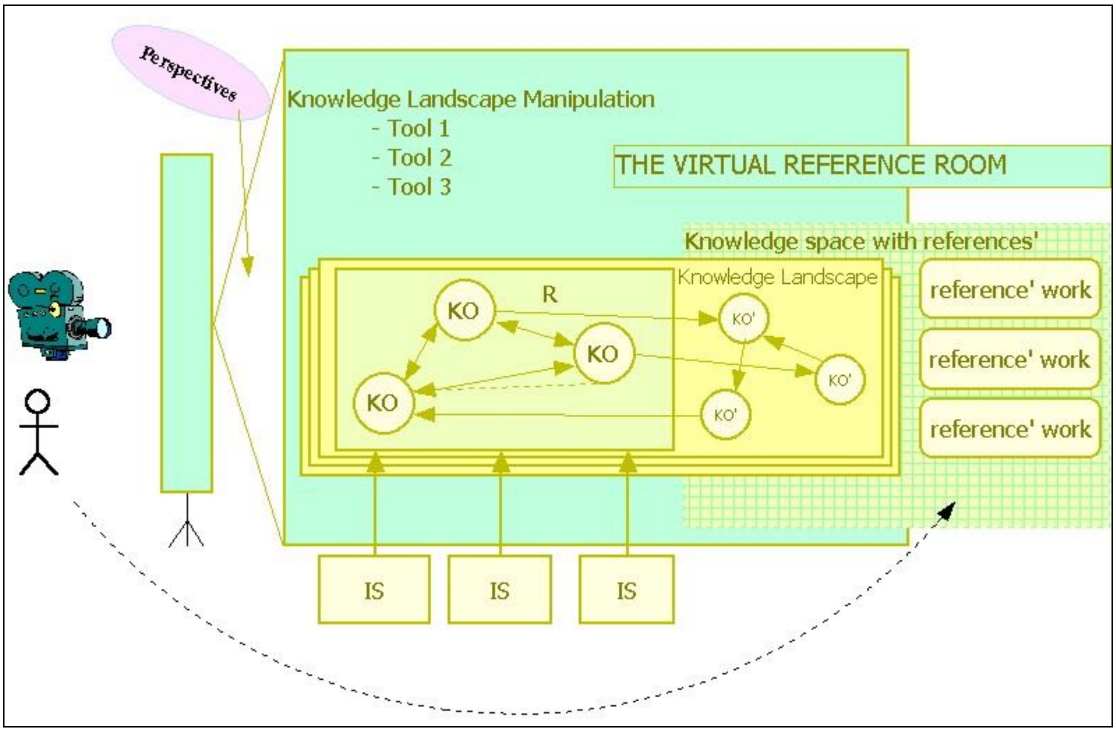

Figure 3.2: The User, the Knowledge Landscape (Manipulation) and the Virtual Reference Room

It is clear that these tools set will be gradually developed (in parallel) during the course of the project. The role of these manipulating play a role and how these tool-sets can be used in the construction of the KL will be described in the next paragraph, which also a description of the figure can be found there.

3.4. KL Manipulations (KM)

As can be seen in picture 3.2, reference works play a role in the manipulation of the knowledge landscape. On the left border we have the user who sees the knowledge landscape and the VRR in a particular perspective. At the bottom of the figure we find the artefacts in the information sources, which are lifted up to a higher level in the knowledge landscape. In this landscape they are raised to what we will call a Knowledge Object (KO). Within this landscape, these knowledge objects can be connected with **reference** works (Which we depicted with **KO'**). The big question is which works are to be included into the digital reference room of I-MASS, in other words, which works to subsume under the object type "reference works" and its sub classes: encyclopaedias, dictionaries, thesauri, classifications and chronological systems?

Theoretically standard works and canonical texts should be included in the object type "reference works". Practically, this immediately confronts us with at least three problems:

1. The selection of these canonical texts
2. Canonical texts are also subject to scholarly and scientific discourse[4]. Therefore the problem of setting the boundary between reference room and the collection proper to which it refers should be further investigated (see also Research topics), i.e. which works to class as "Reference Works" and which works not to class as "Reference Works".
3. Furthermore it is highly important in what subclass these reference works are classed. Each kind of reference work is fit for the level of information questions of the end user: dictionaries for finding definitions, encyclopaedias for explanations, catalogues and bibliographies for variants of titles of the same work, abstract journals for selecting the works to read fully.

3.5. Query/Response and the knowledge landscape (QK)

A part of the knowledge landscape will be static or retained after a session of the user. A combination of the knowledge compass, the levels the user addressed and the knowledge atlas will help determine a user's discourse levels.

In a pre-contextualisation phase, manipulations are needed to translate user's activities before a user can admire their own[5] knowledge landscape. Pro-activity of the agents is also important during the user orientation in the knowledge landscape: e.g. to solve ambiguous queries, responses and transformations between other agents and to help users with the tools they have got and provide with new ones.

3.6. The User Interface (UI)

The basic question concerning the user interface is the extent to which the system allows users to search for, retrieve, and navigate the information they want in efficient, effortless, easy to learn, and pleasant ways. This depends on all the aspects with which users come into contact while they are interacting with I-MASS, including aspects such as the (perceived) functionality of the system, which goes beyond the user interface proper. The usability of I-MASS depends on the behaviour of the system as a whole and cannot be reduced to the characteristics of particular modules or parts of it. From a user's point of view, not only the User Interface as a module but also aspects of the KL Manipulations, the Query/Response and the KL, and the Knowledge Landscape are part of the user interface as a conceptual entity: i.e. the representation of the users task within the computer system. It consists of three basic elements: namely the:

[4] An example of a field wherein this discourse about the validity of "canonical texts" is subject to discussion is the history of non-European cultures and societies. Authors such as Edward Said wrote a great deal about that problem.

[5] With the help of underlying agents that is to say that they can make inferences a user didn't think of beforehand (e.g. a user seeking myths in Athens could give results in the form of catalogues, canonical texts, encyclopaedias, literature but also travel guides).

1. Functionality of the system, or what users can do with it,
2. Interaction language, or how users should specify the actions to invoke the system's functions,
3. Presentation interface, or the way in which the system will react to the users actions and change the state of the users task world.

The user's task world as represented within the system should not only be usable as such, but it must also be compatible with and support the user's task world outside of a particular software tool. For this reason, the user interface is being designed as a conceptual entity. Hence, the user interface module and all the aspects in the other system modules that the user comes into contact with should be subjected to the scenario-based design process that is driven by the incremental specification of the user requirements. Within the I-MASS project, it is not possible to do a complete user requirements study before starting to specify and build the software components of the system, and since it is unclear how users might use or might need to use the system, this paragraph will be restricted to identifying what seem to be the most relevant, preliminary research issues regarding the user interface issues in I-MASS.

I-MASS is a system to help users find information, references and representations of heritage objects with cultural and historical dimensions. I-MASS is basically a search and answer service for multimedia objects, to provide an information context adapted and adaptable to a variety of different purposes and different types of users. Searching as a psychological process can be divided into a number of sub processes, including: finding out what may be searched, establishing what to search for, specifying the search or navigating the search space, perceiving the results, and interpreting the results relative to the original intentions [Norman, 1986]. It may be noticed that interpreting the search results closely corresponds to finding out what may be searched. Research issues can be formulated for each of these processes by themselves and in relation to the different types of users, the different purposes, and to the issue of adaptation and adaptability.

With respect finding out what may be searched no specific research questions are posed. It is assumed that the Knowledge Landscape is presented to the users in such a way that, during the whole process of interacting with I-MASS, it is clear which information is, in principle, available. The same applies to supporting the users in establishing what to search for. The presentation of the knowledge landscape continuously presents the state of the search process in a context from which the user is able to recognize where they are and to develop ideas about how to proceed.

With respect to specifying the search or navigating commands, the question asked is: how does the user input a query into the system? Note that the term "query" only applies to the system's interpretation of the user's actions. Users will have a choice from a number of different input methods. Expert users may chose to use a textual query interface with Boolean operators, whereas more novice users may prefer to use the click-and-browse interface familiar from the internet. The question asked is: which input methods should be made available to the users and how to the input methods should be made available? [UI01]

Regarding supporting users to perceive the results of search actions, the research question is put: how are responses presented to the user? [UI02] This question refers to both the presentation of the Knowledge Landscape, as well as to the presentation of particular items outside the Knowledge Landscape. For example, one view of the Knowledge Landscape may consist of a page with hyperlinks to different items. Selecting a hyperlink may subsequently create a new page with hyperlinks or it may open a window outside the Landscape where a picture is shown. In addition to user-oriented issues, a number of derived questions may be asked, about the technical aspects of delivery of content, such as how to accommodate various content file formats, and about the commercial aspects of handling the delivery of content.

With respect to supporting the users in interpreting the results the research question is asked: what content analysis tools exist or might be useful? It is assumed that users have available a number of different views of the Knowledge Landscape in order to inspect the search results. Most if not all of these views will need to be automatically generated by the multi-agent system, based on an analysis of the content of the search results. For this purpose, analysis tools are required which, additionally, may or may not be made available to the users. [UI08]

Regarding the support that I-MASS should provide to different types of users, the questions are asked: how are possible user discourse levels (e.g. naïve, expert) to be identified, how to accommodate the different types of users by e.g. agent assistance or direct access to the Knowledge Landscape, and, aiming at the more novice users, can expert knowledge be made explicitly available to the user and how? [UI04, UI05]

With respect to the different purposes for which the I-MASS system may be used, the central question underlying the whole of I-MASS is: what are the possible and critical user scenarios, and which need be accommodated? I-MASS may be used for a wide range of different purposes and different ways of working but not all of these uses will be equally relevant or frequently utilised. As such, it is necessary to investigate how an I-MASS system might be used, and guided by data about frequency, importance, etc. to select which user scenarios I-MASS should support. [UI03]

Regarding the (automatic) adaptation of the I-MASS system to characteristics of the users, the following questions are asked: how are possible user discourse levels to be identified and processed by the system? [UI05] Are user models necessary or is unconstrained navigation sufficient? [UI06] How are user models to be constructed, maintained and utilised by the system [UI07], and how should the various reasoning processes underlying the system be made available?

Apart from automatic adaptation, I-MASS also features user controlled adaptability or customisation of the system. Here, important questions are: what opportunities exist for user customisation of services and tools? Will users be able to (the state of) save sessions, and how may customised services be stored and re-used? Underlying the distinction between automatic adaptation and user-controlled adaptability, there is the more general question of user versus system control.

Finally, it may be noted that not only users, but also systems managers require access to the system. This raises the question about how to fulfil the need for a system management interface, e.g. for analysis and management of system performance, for modification of the KL abstract framework, and for incorporation and removal of data sources.

3.7. A list of research issues and questions

The next list contains the research issues, aspects and questions made up after the technical workshop in week 24 and 25. This list is open for discussion. It is a **coarse grained** division to relate the research issues and aspects with the work-packages. In a lot of cases the particular research issue is also a (smaller) part of the other work packages.

Digital Sources (DS)

DS01 What subject material do the content providers maintain? (WP 1, 4, 5)

a) Basic categories for machine readability: (WP 1)

1. Non-digitized materials
2. Materials with digitized metadata (descriptions)
3. Digitized full content (with metadata)
4. Digitized materials with non digitized metadata
5. Digitized materials with no physical, analog equivalent

b) Basic categories for utility:

1. Mapping utility (e.g. thesauri, dictionaries) (WP 4)
2. References utility (e.g. catalogues) (WP 5)

DS02 what is the range of the digital content formats? (WP 1)

DS03 a) What are the characteristics and the distinctions between the various types of reference works used and maintained by the content providers (catalogues, dictionaries, thesauri, encyclopaedias, authority files) (WP 1)

b) Including definition of terms (ontology, schema, terminological system, etc)? (WP 5)

DS04 what systems (software, DBMS etc) are employed? (WP 1)

DS05 on what machines and operating systems do databases run? (WP 1)

DS06 What are the provisions for remote access (Internet servers, number of access lines)? (WP 1)

DS07 How are materials organised within databases? (WP 1)

DS08 In what form do the databases schemas exist (i.e. metadata on Database structures, field labels, etc)? (WP 1)

DS09 How and where are databases schemas stored and what are the provisions for remote (machine) access? (WP 1)

DS10 What constitutes the test data (as input for test beds)?

- Material useful for syntactic interoperability (test bed 1) (WP 4)

- Material useful for semantic mappings (test bed 2) (WP 5)

DS11 What do the content providers need to make available during the development cycle? (WP 4, 5)

DS12 Where and how will the test data be managed (inc. storage)? (WP 4, 5)

DS13 How are the test data to be accessed by machine? (WP 1)

Syntactic & Semantic Interoperability (SS)

SS01 How are the queries that are posed in the KL to be expressed at the various semantic & syntactic levels (KRL, OO, RDF, XML & SQL)? (WP 4, 5)

SS02 What research / models already exists for representing queries in these languages? (WP 4,5)

SS03 What subset of SQL needs to be encapsulated by the various query representations (e.g. create table is not a requirement)? (WP 7)

SS04 What are the differences in expressibility and/or capability of the different knowledge representation languages – and what degrees (types) of expressiveness are required for syntactic & semantic interoperability at the various levels? (WP 7, 8)

SS05 What type and degree of reification of knowledge is required (e.g. reification of relationships between concepts for reasoning about such relationships)? (WP 3, 4)

SS06 How are transformations to be performed between layers (e.g. agents) – what metadata needs to persist between layers about the transformation process and how is it to be maintained? (WP 4)

SS07 Which main enabling technologies have to be incorporated into the core system? (WP 3)

SS08 What services (e.g. reference works, thesauri, dictionaries) are required for transformation – and how are these to be accessed? (WP 4) [WP 7, 8]

SS09 What high-level (pragmatic / semantic) constraints need to be applied to transformations to maintain the integrity (or intentionality) of the queries/responses – and how are these constraints applied (e.g. via monitoring agents)? (WP 3)

SS10 How do structural changes in the *abstract framework (see below)* of the KL affect these constraints? (WP 3)

SS11 How are the queries to be propagated (routed) down towards the digital sources? (WP 3)

SS12 What (learning) mechanisms exist to maximise query routing efficiency? (WP 3)

SS13 How are responses to be formulated and propagated back up through the layers? (WP 3)

SS14 What are the dynamics of query & response routing & how do these influence system performance (e.g. constraints on cycling queries through the layers)? (WP 3, 7, 8)

SS15 How is incremental development / construction of the various levels to be achieved? (WP 3, 7, 8)

SS16 Where are the running processes underlying the various layers to be located (i.e. distribution: content provider sites, centralised MMI site and/or user machine)? (WP 3, 7, 8)

SS17 How is traffic from multiple users to be handled (e.g. centralised system with high bandwidth traffic capabilities or via distributed threads, possibly running on user machines)? (WP 7, 8) [note: traffic issues are not really an issue for computational architecture]

SS18 If agents are to be run on user machines, then how are agent-platforms to be invoked on user machines (mobile platforms / agents)? (WP 3, 7, 8)

SS19 How is metadata about the diverse databases (data source repositories) to be made available to the transformation layers (does it need to be available) – e.g. propagated upward through the layers, or accessible via distinct 'metadata' agents? (WP 3)

SS20 What database metadata exists, in what form, and how is to be accessed (e.g. via JDBC methods, externally maintained schemas)? (WP 1)

SS21 If database metadata is unavailable (e.g. because the JDBC driver does not implement JDBC metadata methods, and no machine accessible external schema exists) – then what mechanisms, if any, are available to effect syntactic & semantic interoperability (e.g. inference over content)? [Contingency plans] (WP 5, 7, 8)

SS22 How may *transient* mappings between concepts / relationships at the various levels be recorded and utilised for future queries (e.g. the dynamic construction of a super-meta, wide-domain, universal thesauri)? (WP 3, 5)

SS23 What agent platform best facilitates all the above? (WP 3)

Knowledge Landscape (KL)

What needs to be represented within the knowledge landscape (or the knowledge 'atlas')?

KL01 What knowledge about the digitised items (reference works & digitised artefacts) needs to be represented? (WP 3)

KL02 How is the cultural domain to be modeled (relationships between individuals, societies, roles, activities, time, space, influence, interactions, dialogues, discussions, processes)? (WP 5, 8)

KL03 How to represent the additional dimensions of the knowledge landscape (e.g. 10-levels, scope of terms) (WP 4, 5)

KL04 What abstract framework needs be developed as base for these representations (knowledge models) - e.g. models of significant cultural patterns / processes / activities / structures? (WP 8)

KL05 What aspects of user activity have an impact on the structure of the KL (e.g. how might the KL best facilitate required user activities)? (WP 2, 6)

KL06 How are the basic question types (who, what, where, when, how & why) to be denoted, and what constitutes a response to such questions? (WP 3)

KL07 What aspects (views) of the KL need to be presented to the user? (WP 3, 6)

KL08 What aspects of the KL need to be manipulated and in what way *(and how – see below)*? (WP 3, 4, 5)

What is the best language in which to build the KL? (WP 7)

KL09 What language has sufficient expressiveness to capture all that needs be represented?

KL10 What language facilitates the required manipulations?

KL11 How is the KL to be implemented (e.g. as a centrally stored representation / distributed among various agents i.e. decentralized) (WP 7, 8)?

KL12 How is the abstract framework to be implemented and to be managed? (WP 6, 7)

KL13 What expert knowledge need be utilized to develop the abstract framework (and how is this to be acquired)? (WP 8)

KL Manipulations (KM)

KM01 How is the KL to be generated & managed – i.e. as a dynamic construction centered on the user query (e.g. query templates, open-ended queries)? (WP 3, 4, 5)

KM02 What features of a query-local KL need remain persistent throughout the user session – and how are these features to be maintained? (WP 3, 4, 5)

KM03 What features of the KL dynamically generated during a user session need be made available in the other sessions, or to other users (& how)? (WP 4, 5, 6)

KM04 What tools/services (e.g. reference works) are to be used in constructing the KL? (WP 1, 3) Including the considerations of both:

- Agent architecture implications

- Selection of standard materials

KM05 How are these services to be accessed? (WP 3)

KM06 Which services may be of general use (e.g. basic to all or common queries)? (WP 1)

KM07 What additional services might be required for more domain specific / unusual / expert level requirements? (WP 5, 6)

KM08 What possibilities exist for the dynamic generation of services in response to the user demands (e.g. automated wrapping of reference works)? (WP 5)

KM09 How are services to be managed / stored? (WP 7)

KM10 How are the KL manipulations to be implemented (e.g. agent-based methods)? (WP 5, 7)

KM11 How is the abstract framework for the KL to be managed / maintained? (WP 8)

KM12 What expert knowledge need be utilized for KL manipulations (and how is this to be acquired)? (WP 4)

Query / Response <> KL (QK)

QK01 What manipulations are required to translate user activity at the user-interface into valid queries framed by the KL, and to present responses framed within the KL to the user? (WP 3, 8)

QK02 It is envisaged that aspect QK01 of the I-Mass architecture encapsulates most of the potential pro-activity of the system – hence, we have to ask the question what level of pro-activity is needed and what form does this pro-activity take? (WP 3)

QK03 On what services do these transformations depend, and how are such services to be accessed? (WP 8)

QK04 What mechanisms (e.g. agent-based methods) are available to effect the required transformations? (WP 8)

QK05 What possibilities exist for pre-semantic query processing (e.g. for logical processing of user queries prior to the transformation into the KL representation)? (WP 6, 8)

User Interface (UI)

UI01 How does the user input a query into the system (natural language, text-based, menu selection, graphical manipulation, hybrid, voice command, virtual reality interface), from a user point of view and to satisfy technical requirements? (WP 2)

UI02 How are responses presented to the user (e.g. visualization techniques for complex knowledge domains)? (WP 2)

UI03 What are the possible / critical user scenarios, and which scenarios need be accommodated? (WP 2)

UI04 How are possible user discourse levels (e.g. naïve / expert) to be identified during development? (WP 2, 5)

UI05 How are possible user discourse levels to be identified / processed by the system? (WP 5, 6)

UI06 Are user models necessary - e.g. is unconstrained navigation through the KL sufficient (if not, then how is navigation to be constrained – and what is off bounds)? (WP 2, 7, 8)

UI07 How are user models to be constructed, maintained & utilized by the system (what needs to be represented about the user, what language should be employed for the representation, how does this language interface with, or impact on the KL)? (WP 2, 6, 7, 8)

UI08 What kind of content analysis tools exist or might be useful - e.g. automatic methods for hyper-textualising flat text files? (WP 2, 6)

UI09 What opportunities exist for user customization of services / tools? (WP 2)

UI10 How may the customized services be stored and be re-used? (WP 7, 8)

UI11 How are various content file formats to be accommodated (e.g. pdf, ps, jpg, mpg) – e.g. remote invocation of external applications? (WP 6)

UI12 How is delivery (technical & commerce problems) of content to be handled (including rights issues, data protection, etc)?

- Delivery of partial content (WP 3)

- [External to I-Mass] Delivery of, payment for, full content (inc. business models) (WP 9)

UI13 Do we have to give the users an ability to save the sessions – e.g. for analysis, or for restarting from where they left off? (WP 7, 8)

UI14 How should the various reasoning processes underlying the system be made open to the user (not least the developer) for analysis (WP 2, 3)?

UI15 Can expert knowledge be made explicitly available to the user (e.g. as a reference guide), or should it be built implicitly into the interface, and if so how [*note:* only badly designed user interfaces require ‘office assistants’] (WP 2)

Addendum: The above points relate mainly to the user interface. There is also a need for a system management interface - e.g. for analysis / management of system performance, for modification of the KL abstract framework, for incorporation / removal of data sources. This possibility is only for an expert. (To be compared with the Global Schema Builder of MOMIS)

4. Summary of the Research issues according to the work packages

As noted earlier, the research issues are **coarse-grained** divided over the work-packages but to give the reader a good overview of the whole project we depicted the relations in figure 4.1. In the left corner we can find a legend in which the leading participant[6] of a work-package can be found. For instance we can see that MMI is the leading participant of work packages 1,2 and 4 and UniVienna of work package 5. Each work-package contains the number of man months (mm) and an inner rectangle with the number of research issues of the six components. Between several work packages we have also some relations, which are represented by arrows. These relations indicate dependencies between the work packages but these dependencies can also be found in the (numbered) red circles. In Work packages 7 and 8 a number of milestones will be delivered.

In the former chapters we showed the different representation levels, the agents on these levels and the semantic and syntactic interoperability model. Difficult requirements for this component are how to find the degree of expressiveness, what high level (semantic and pragmatic) constraints need to be applied, how to find transient mappings to make the agents knowledgeable enough of the high-level medium for formulating and answering queries. As can be seen in figure 4.1 most of the research issues regarding the semantic and syntactic interoperability appear in Work package 3. Logically the most user interface issues appear in Work package 2 and 6. The issues regarding the inventory at the digital sources can mainly be found in Work package 1, although several issues are also important in Work packages 4 and 5. The other research issues that can be found in these two last work packages are mainly concerned with the semantic & syntactic interoperability component and the knowledge landscape. Finally work packages 7 and 8 are related with almost all issues because they will constitute the practical results of I-MASS.

In figure 4.2 we see the Research issues again divided over the work packages. The issues depicted in the color purple are allocated to that specific work package. In figure 4.2 we can see how 'heavy' the specific is loaded with the research issues, although we have to say that the list is not complete and the division can't be justified on all places for the full hundred percent. But we can say that the list and the figures are used as a 'planning' guide in the project.

[6] That is to say as defined in the DoW

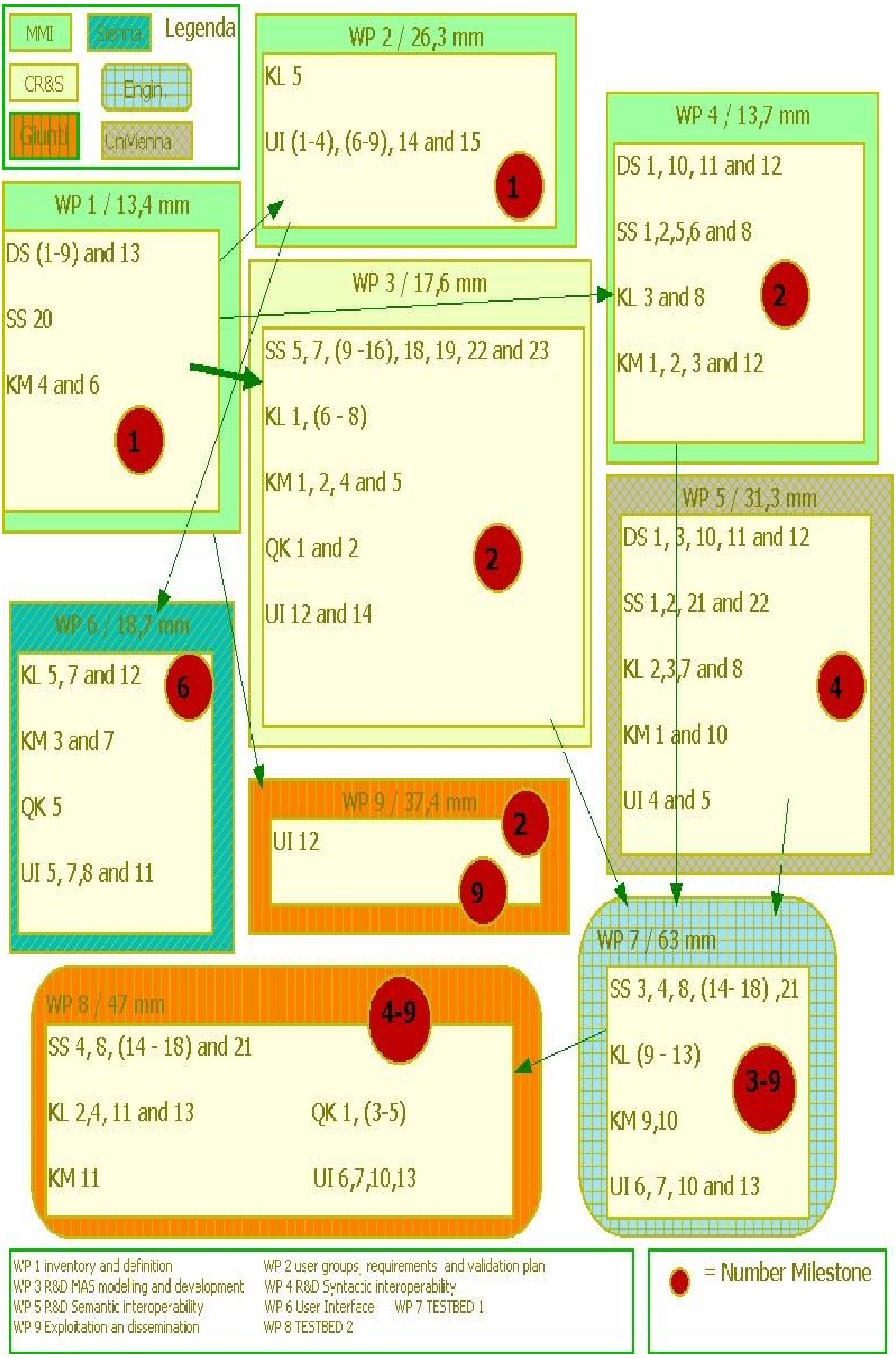

Figure 4.1 Overview of research issues in the work packages

Workpackage 1
Inventory and definition

13.4 manmonths

DS	SS	KL	KM	QK	UI
DS01	SS01	KL01	KM01	QK01	UI01
DS02	SS02	KL02	KM02	QK02	UI02
DS03	SS03	KL03	KM03	QK03	UI03
DS04	SS04	KL04	KM04	QK04	UI04
DS05	SS05	KL05	KM05	QK05	UI05
DS06	SS06	KL06	KM06		UI06
DS07	SS07	KL07	KM07		UI07
DS08	SS08	KL08	KM08		UI08
DS09	SS09	KL09	KM09		UI09
DS10	SS10	KL10	KM10		UI10
DS11	SS11	KL11	KM11		UI11
DS12	SS12	KL12	KM12		UI12
DS13	SS13	KL13			UI12
	SS14				UI13
	SS15				UI14
	SS16				UI15
	SS17				
	SS18				
	SS19				
	SS20				
	SS21				
	SS22				
	SS23				

Workpackage 2
User groups, user requirements and validation plan
26.3 manmonths

DS	SS	KL	KM	QK	UI
DS01	SS01	KL01	KM01	QK01	UI01
DS02	SS02	KL02	KM02	QK02	UI02
DS03	SS03	KL03	KM03	QK03	UI03
DS04	SS04	KL04	KM04	QK04	UI04
DS05	SS05	KL05	KM05	QK05	UI05
DS06	SS06	KL06	KM06		UI06
DS07	SS07	KL07	KM07		UI07
DS08	SS08	KL08	KM08		UI08
DS09	SS09	KL09	KM09		UI09
DS10	SS10	KL10	KM10		UI10
DS11	SS11	KL11	KM11		UI11
DS12	SS12	KL12	KM12		UI12
DS13	SS13	KL13			UI12
	SS14				UI13
	SS15				UI14
	SS16				UI15
	SS17				
	SS18				
	SS19				
	SS20				
	SS21				
	SS22				
	SS23				

Workpackage 3
R&D MAS modelling and development
17.6 manmonths

DS	SS	KL	KM	QK	UI
DS01	SS01	KL01	KM01	QK01	UI01
DS02	SS02	KL02	KM02	QK02	UI02
DS03	SS03	KL03	KM03	QK03	UI03
DS04	SS04	KL04	KM04	QK04	UI04
DS05	SS05	KL05	KM05	QK05	UI05
DS06	SS06	KL06	KM06		UI06
DS07	SS07	KL07	KM07		UI07
DS08	SS08	KL08	KM08		UI08
DS09	SS09	KL09	KM09		UI09
DS10	SS10	KL10	KM10		UI10
DS11	SS11	KL11	KM11		UI11
DS12	SS12	KL12	KM12		UI12
DS13	SS13	KL13			UI12
	SS14				UI13
	SS15				UI14
	SS16				UI15
	SS17				
	SS18				
	SS19				
	SS20				
	SS21				
	SS22				
	SS23				

Workpackage 4
R&D syntactic interoperability

13.7 manmonths

DS	SS	KL	KM	QK	UI
DS01	SS01	KL01	KM01	QK01	UI01
DS02	SS02	KL02	KM02	QK02	UI02
DS03	SS03	KL03	KM03	QK03	UI03
DS04	SS04	KL04	KM04	QK04	UI04
DS05	SS05	KL05	KM05	QK05	UI05
DS06	SS06	KL06	KM06		UI06
DS07	SS07	KL07	KM07		UI07
DS08	SS08	KL08	KM08		UI08
DS09	SS09	KL09	KM09		UI09
DS10	SS10	KL10	KM10		UI10
DS11	SS11	KL11	KM11		UI11
DS12	SS12	KL12	KM12		UI12
DS13	SS13	KL13			UI12
	SS14				UI13
	SS15				UI14
	SS16				UI15
	SS17				
	SS18				
	SS19				
	SS20				
	SS21				
	SS22				
	SS23				

Workpackage 5
R&D semantic interoperability

31.3 manmonths

DS	SS	KL	KM	QK	UI
DS01	SS01	KL01	KM01	QK01	UI01
DS02	SS02	KL02	KM02	QK02	UI02
DS03	SS03	KL03	KM03	QK03	UI03
DS04	SS04	KL04	KM04	QK04	UI04
DS05	SS05	KL05	KM05	QK05	UI05
DS06	SS06	KL06	KM06		UI06
DS07	SS07	KL07	KM07		UI07
DS08	SS08	KL08	KM08		UI08
DS09	SS09	KL09	KM09		UI09
DS10	SS10	KL10	KM10		UI10
DS11	SS11	KL11	KM11		UI11
DS12	SS12	KL12	KM12		UI12
DS13	SS13	KL13			UI12
	SS14				UI13
	SS15				UI14
	SS16				UI15
	SS17				
	SS18				
	SS19				
	SS20				
	SS21				
	SS22				
	SS23				

Workpackage 6
User modelling and interaction

18.7 manmonths

DS	SS	KL	KM	QK	UI
DS01	SS01	KL01	KM01	QK01	UI01
DS02	SS02	KL02	KM02	QK02	UI02
DS03	SS03	KL03	KM03	QK03	UI03
DS04	SS04	KL04	KM04	QK04	UI04
DS05	SS05	KL05	KM05	QK05	UI05
DS06	SS06	KL06	KM06		UI06
DS07	SS07	KL07	KM07		UI07
DS08	SS08	KL08	KM08		UI08
DS09	SS09	KL09	KM09		UI09
DS10	SS10	KL10	KM10		UI10
DS11	SS11	KL11	KM11		UI11
DS12	SS12	KL12	KM12		UI12
DS13	SS13	KL13			UI12
	SS14				UI13
	SS15				UI14
	SS16				UI15
	SS17				
	SS18				
	SS19				
	SS20				
	SS21				
	SS22				
	SS23				

Figure 4.2 Overview of Research issues in work packages 1 to 6.

Workpackage 7
Testbed I

63.0 manmonths

DS	SS	KL	KM	QK	UI
DS01	SS01	KL01	KM01	QK01	UI01
DS02	SS02	KL02	KM02	QK02	UI02
DS03	SS03	KL03	KM03	QK03	UI03
DS04	SS04	KL04	KM04	QK04	UI04
DS05	SS05	KL05	KM05	QK05	UI05
DS06	SS06	KL06	KM06		UI06
DS07	SS07	KL07	KM07		UI07
DS08	SS08	KL08	KM08		UI08
DS09	SS09	KL09	KM09		UI09
DS10	SS10	KL10	KM10		UI10
DS11	SS11	KL11	KM11		UI11
DS12	SS12	KL12	KM12		UI12
DS13	SS13	KL13			UI12
	SS14				UI13
	SS15				UI14
	SS16				UI15
	SS17				
	SS18				
	SS19				
	SS20				
	SS21				
	SS22				
	SS23				

Workpackage 8
Testbed II

47.0 manmonths

DS	SS	KL	KM	QK	UI
DS01	SS01	KL01	KM01	QK01	UI01
DS02	SS02	KL02	KM02	QK02	UI02
DS03	SS03	KL03	KM03	QK03	UI03
DS04	SS04	KL04	KM04	QK04	UI04
DS05	SS05	KL05	KM05	QK05	UI05
DS06	SS06	KL06	KM06		UI06
DS07	SS07	KL07	KM07		UI07
DS08	SS08	KL08	KM08		UI08
DS09	SS09	KL09	KM09		UI09
DS10	SS10	KL10	KM10		UI10
DS11	SS11	KL11	KM11		UI11
DS12	SS12	KL12	KM12		UI12
DS13	SS13	KL13			UI12
	SS14				UI13
	SS15				UI14
	SS16				UI15
	SS17				
	SS18				
	SS19				
	SS20				
	SS21				
	SS22				
	SS23				

Workpackage 9
Exploitation and dissemination

37.4 manmonths

DS	SS	KL	KM	QK	UI
DS01	SS01	KL01	KM01	QK01	UI01
DS02	SS02	KL02	KM02	QK02	UI02
DS03	SS03	KL03	KM03	QK03	UI03
DS04	SS04	KL04	KM04	QK04	UI04
DS05	SS05	KL05	KM05	QK05	UI05
DS06	SS06	KL06	KM06		UI06
DS07	SS07	KL07	KM07		UI07
DS08	SS08	KL08	KM08		UI08
DS09	SS09	KL09	KM09		UI09
DS10	SS10	KL10	KM10		UI10
DS11	SS11	KL11	KM11		UI11
DS12	SS12	KL12	KM12		UI12
DS13	SS13	KL13			UI12
	SS14				UI13
	SS15				UI14
	SS16				UI15
	SS17				
	SS18				
	SS19				
	SS20				
	SS21				
	SS22				
	SS23				

Figure 4.2 (continued) Overview of Research issues in work packages 7 to 9.

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