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Management Summary

The aim of this deliverable is twofold. First, it summarizes the S-Cube activities and results for what concerns the release of a research roadmap on service-based applications. Secondly, it describes the activities and outcomes to update the S-Cube Knowledge Model (KM) as well as to ensure its sustainability.

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Consiglio Nazionale delle Ricerche	Italy
Center for Scientific and Technological Research	Italy
The French National Institute for Research in Computer Science and Control	France
Lero - The Irish Software Engineering Research Centre	Ireland
Politecnico di Milano	Italy
MTA SZTAKI – Computer and Automation Research Institute	Hungary
Vienna University of Technology	Austria
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Published S-Cube documents

All public S-Cube deliverables are available from the S-Cube Web Portal at the following URL:

http://www.s-cube-network.eu/results/deliverables/

The S-Cube Deliverable Series

Vision and Objectives of S-Cube

The Software Services and Systems Network (S-Cube) will establish a unified, multidisciplinary, vibrant research community which will enable Europe to lead the software-services revolution, helping shape the software-service based Internet which is the backbone of our future interactive society.

By integrating diverse research communities, S-Cube intends to achieve world-wide scientific excellence in a field that is critical for European competitiveness. S-Cube will accomplish its aims by meeting the following objectives:

- Re-aligning, re-shaping and integrating research agendas of key European players from diverse research areas and by synthesizing and integrating diversified knowledge, thereby establishing a long-lasting foundation for steering research and for achieving innovation at the highest level.
- Inaugurating a Europe-wide common program of education and training for researchers and industry thereby creating a common culture that will have a profound impact on the future of the field.
- Establishing a pro-active mobility plan to enable cross-fertilization and thereby fostering the integration of research communities and the establishment of a common software services research culture.
- Establishing trust relationships with industry via European Technology Platforms (specifically NESSI) to achieve a catalytic effect in shaping European research, strengthening industrial competitiveness and addressing main societal challenges.
- Defining a broader research vision and perspective that will shape the software-service based Internet of the future and will accelerate economic growth and improve the living conditions of European citizens.

S-Cube will produce an integrated research community of international reputation and acclaim that will help define the future shape of the field of software services which is of critical for European competitiveness. S-Cube will provide service engineering methodologies which facilitate the development, deployment and adjustment of sophisticated hybrid service-based systems that cannot be addressed with today's limited software engineering approaches. S-Cube will further introduce an advanced training program for researchers and practitioners. Finally, S-Cube intends to bring strategic added value to European industry by using industry best-practice models and by implementing research results into pilot business cases and prototype systems.

S-Cube materials are available from URL: http://www.s-cube-network.eu/

Table of Contents

1 Introduction

The aim of this deliverable is twofold:

- First, this deliverable summarizes the S-Cube activities and results for what concerns the **release of a research roadmap on service-based applications (Section 2)**. Beyond other activities, S-Cube has secured a dedicated ICSE 2012 workshop to showcase the research challenges as identified by the network and its collaborators and to foster follow-up roadmap activities.

- Secondly, this deliverable describes the activities and outcomes to **update the S-Cube Knowledge Model (Section 3)** as well as to ensure its **sustainability (Section 4)**. S-Cube members took great strides such that the Knowledge Model will remain publicly available and will be updated after the end of the funding period of the network.

2 S-Cube Research Roadmap

The Future Internet will see the convergence of the physical ("Internet of Things"") and digital worlds, into a completely new reality, where richer real-time and mobile communication modalities will arise. Services will play a key role as building blocks, providing abstraction and virtualization, not just of data storage, processing and networks, but also of devices, connectivity, physical goods and applications, content and associated intellectual property, and even physical presence.

Future software technology and methods thus will need to cope with trends such as the convergence of the Internet of Things and the Internet of Services; novel life-cycle models where the boundary between design and runtime will increasingly blur; online quality assurance and self-adaptation; as well as novel architectural styles for large-scale, long-living service-oriented systems.

To understand which challenges the services community should address in the longer term and also to involve communities beyond the S-Cube network, the network set out to identify a research **roadmap on "Adaptive Software and Services in the Future Internet"**.

The identification of the S-Cube Research Roadmap constitutes the following major activities:

1. In November 2011, S-Cube gathered 40 experts in the field (including S-Cube full and associate members, as well as invited scientists) to openly identify and discuss long-term challenges of the field. As part of the S-Cube plenary meeting in Barcelona, a whole day was devoted as an **S-Cube Research Roadmap Workshop**. The day was organized into four topical sessions:
    - "Service life-cycle and software engineering"
    - "Service technology foundations"
    - "Multi-layer and mixed-initiative monitoring and adaptation for service-oriented systems"
    - "Online service quality prediction for proactive adaptation".
2. The workshop led to two major kinds of outcomes, which are individually **published as papers** at **ICSE 2012**:
    a. An assessment of the **relevance of the research challenges** identified (in terms of their impact). Based on a survey study, the findings of the Roadmap Workshop have been analyzed and prioritized according to their expected impact on research and industry. Those results are published in [1].
    b. For each of the topical sessions, workshop participants jointly authored papers providing **detailed research challenges** and **relating those challenges to the state of the art** in the field. Those results are published in [2], [3], [4] and [5] respectively.
3. To conclude the roadmap activities and to foster wider discussion and uptake by the community, S-Cube has been successful in securing a dedicated **ICSE 2012 workshop on "European Software Services and Systems Research - Results and Challenges"** (http://www.s-cube-network.eu/icse). During this workshop, they key findings from above will be presented and openly discussed with other researchers in the field. The workshop is thus intended to serve as a springboard to discuss software engineering research challenges for future service-oriented systems.

3 Knowledge Model Status and Advances

The below sections summarize the activities performed during year 4 of S-Cube to update the Knowledge Model.

3.1 Interlinking KM Terms

For the purpose of enhancing the browsing experience of S-Cube KM visitors, the S-Cube team has initiated a set of enhancements in the KM structure and presentation, which included the analysis of visitors' browsing patterns using Google Analytics. In order to increase visitors' retention time and discovery of terms, it was decided to increase the interlinking between KM terms and pages.

As a result of coordinated partner efforts, the number of links in the KM has risen from ~300 to over 1000 by the end of October 2011, which we believe will improve the retention-time and the overall browsing experience of future KM visitors.

3.2 Paper on the S-Cube Knowledge Model Endeavor

S-Cube's experience in establishing the KM has been published [1] and presented at one of the premier conferences on knowledge management – KMIS 2012 (International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management)[1].

The paper is a description of the motivation, methodology and implementation of the S-Cube KM and a presentation of S-Cube's experiences in capturing, curating, managing and refining the knowledge gathered from researchers in the S-Cube NoE. It describes how a large, multidisciplinary research project went about ensuring a common understanding of research, capabilities and outputs by using a holistic and consistent knowledge management framework and a set of procedures for content validation and quality assurance.

[1] KMIS 2011: http://www.kmis.ic3k.org/KMIS2011/

4 Sustainable S-Cube Knowledge Model

S-Cube aimed at creating strong, long lasting and evolving links among the different research communities to ensure durability and sustainability of the network objectives [7]. S-Cube established consensus on a common research agenda, consolidation, as well as integration and exploitation of research results from European initiatives and institutes (within and outside the network beneficiaries). One instrument employed for achieving this objective is the S-Cube's Convergence Knowledge Model (KM), which aimed at mapping and structuring the complementarities of beneficiaries' knowledge, identifying research gaps, determining the research issues that are of importance for the next generation services technologies, and harmonizing research results.

The KM provides a common understanding of diverse knowledge in the form of a free, open-content 'living' encyclopaedia, accessible through the Web. It provides public, read-only access for non-network users through the S-Cube Web Portal. It also offers a dynamic, interactive application for network beneficiaries and external bodies interested in contributing to the knowledge, to define concepts, approaches and methodologies, as well as associations between them. The KM helps users to negotiate a large body of knowledge by providing them with mental cues for navigating knowledge from different knowledge domains related to all aspects of service-oriented research and associated methodologies and supporting environments.

Promoting the use of the S-Cube KM outside the network, encouraging its use in academia, industry through dissemination and 'spread of excellence' activities have been essential agenda items for ensuring durability and sustainability of the knowledge model. This section of the deliverable summarizes the efforts towards this key objective. It highlights the activities performed for furthering the use and integration of KM by external bodies, broadening its reach and subsistence in the community, and thereby ensuring that it 'lives on' after the network ends. Further importance has been placed to align these activities to address the reviewers' recommendation in the 3rd year review regarding the sustainability of the KM.

4.1 Experiences with Wikipedia

S-Cube reviewers recommended the KM workpackage (WP-IA-1.1)

> *"shall look into tooling support (requiring reasonable but limited efforts) to transform the content of the knowledge model into a self-contained Wikipedia section."*

As for the network's objectives of promoting research into Service-Based Applications and SSME in general through effective means, the S-Cube consortium has put extensive effort to integrate with Wikipedia since the early stages of the project. However, our previous experiences with Wikipedia have led us to be wary of adding content as it is reviewed and removed almost immediately, with only limited success. Having experienced severe difficulties and considered how to achieve this request, we doubted this task could be completed to the reviewers' satisfaction. This section sets out the reasons why we think this is the case and our experiences with Wikipedia to support those reasons. In the remaining sections, we introduce our alternative efforts for ensuring the sustainability of the KM and contributing to its expanded and continual use.

Appendix A lists some of our previous examples where our efforts to integrate with Wikipedia left fruitless. Our early experiences start with the removal of the links in Wikipedia terms to S-Cube KM definitions (such as 'Software Services', 'Web Services', 'Service Networks', etc.), with no explanations. Despite a repeated series of discouraging experiences, in our latest attempt in September 2011, the network members created links to 16 KM terms in Wikipedia with a collective effort. Table

1 (in Appendix A) lists these terms and the details regarding the effort of integrating with Wikipedia. *Eight out of sixteen terms were removed by Wikipedia without any valid explanation.*

Our investigations on the cases we have faced also revealed parallel experiences in other European projects. In the Internet of Services 2011 Collaboration Meeting, Ad Emmen of the Contrail project[2] shared their project's experiences of adding content to Wikipedia in his presentation in the Dissemination Working Group session. Emmen states that any contributions from their project were removed immediately and adds:

> *"Be ready to face: Wim C, who has a night job as remover of European project descriptions on Wikipedia"*

Daniel Field from Atos Origin confirmed the same experience with Wikipedia in the BREIN and BEinGrid projects - i.e., the content they added was immediately deleted.

As illustrated by the experiences in the community, adding our own work to Wikipedia is difficult under Wikipedia's content standards mainly due to a conflict of interest - defined as:

> *"… adding material that appears to promote the interests or visibility of an article's author, its author's family members, employer, associates, or their business or personal interests."*

We describe Wikipedia's Content Standards and corresponding justifications from Wikipedia in Appendix A. According to the Wikipedia policy, the KM could be considered a 'self-published source', which is largely 'not acceptable'. It is not allowed to add knowledge to Wikipedia from 'self-published' sources as it is considered 'original research'. As the S-Cube KM is an aggregation of knowledge of project deliverables and original publications of S-Cube members and third parties, much of the content is not considered to be independent or not allowed as it is not from a reliable source according to Wikipedia. Although the addition of term definitions from third parties (with references to the sources) would be allowed, a link back to the KM term from these articles seems possible only if it is *not* considered advertising by a more assertive editor. In our last attempt, half of such links were removed. The benefit to S-Cube of carrying this out was therefore debatable, as we could not promote our own work in Wikipedia.

In addition to the concerns discussed above, we cannot find a previous instance of a self-contained section in Wikipedia for a particular topic. The categorization of articles is possible but - with the same reasons mentioned above – we could not promote S-Cube using a category page as these are usually provided without motivation and any extra content would be considered 'advertising'. We have not found any category pages that have links to sources external to Wikipedia, such as to the KM.

Furthermore, we feel there is a mismatch between goals of Wikipedia and the Knowledge Model:

1. The objective of a Wikipedia article is in conflict to a KM term: In Wikipedia homonyms (words that share the same written form but have different meanings) must be on separate pages. In the KM we place these on the same page to demonstrate the relationship between service technology layers and cross-cutting issues.

2. Wikipedia articles are encyclopaedic accounts with a much broader scope than the focused knowledge the KM contains. Transforming KM terms into Wikipedia articles would require additional information (e.g., links to other Wikipedia articles, use context explanation, history, "see also", external links) that is currently not encoded in the KM.

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[2] Internet of Services 2011, Dissemination WG (Brussel, 2011-09-28), Presentation by Ad Emmen (Contrail Project), Titled "Cloud communication in the Cloud" at http://ec.europa.eu/information_society/events/cf/ios11/item-display.cfm?id=7402

4.2 Alternative Means to Ensure Sustainability

S-Cube has been in collaboration with several institutes and bodies renowned in the field to foster the use and sustainability of the KM, as well as to secure and to ease the hand-over process for its reliable and continual hosting and maintenance. In this section, we discuss two bodies that S-Cube has contacted in particular for the latter purpose. Among these efforts, the discussions with IFIP Working group on Service-Oriented Systems yielded successful results.

4.2.1 Schloss Dagstuhl

Schloss Dagstuhl - Leibniz Center for Informatics is a non-profit institute funded jointly by the German federal government and a number of state governments. The center promotes fundamental and applied research, continuing and advanced academic education, and the transfer of knowledge between those involved in the research side and application side of informatics. Dagstuhl supports computer science by organizing high ranked seminars, which bring together internationally renowned leading scientists from academia and industry for the purpose of exploring innovative topics in informatics.

S-Cube communicated with Dagstuhl on the possibility of Dagstuhl hosting the KM. As outcome of the correspondence between the Founder and Scientific Director of Dagstuhl Prof. Dr. Reinhard Wilhelm, and Prof. Dr. Frank Leymann (the director of the Institute of Architecture of Application Systems at the University of Stuttgart – USTUTT) and the Scientific Director of S-Cube Prof. Dr. Mike Papazoglou (Tilburg) on the subject matter, Dagstuhl expressed their interest on the activity and results. However, they were concerned with the effort that is required for establishing the infrastructure to migrate and host the KM.

4.2.2 IFIP Working group on Service-Oriented Systems (WG 2.14/6.12/8.10)

The International Federation for Information Processing (IFIP)[3] is a non-governmental, non-profit multinational organization in Information & Communications Technologies and Sciences. It was established in 1960 under the auspices of UNESCO, and currently represents members from 56 countries and regions with a total membership of over half a million. IFIP links more than 3500 scientists from academia and industry and has over 100 working groups (WG) and 13 technical committees (TC). It sponsors 100 conferences yearly providing unparalleled coverage from theoretical informatics to the relationship between informatics and society including hardware and software technologies, and networked information systems. IFIP scientific and technological leadership is warranted by working group membership, based solely on individual excellence and asserted by the organization of highest quality international events, and the publication of some 30 new books annually that are distributed worldwide.

The IFIP Working Group (WG 2.14) on Service-Oriented Systems[4] is established with the aim of organizing and promoting the exchange of information on fundamental as well as practical aspects of service-oriented systems. In doing so, the working group considers service-oriented systems from technological and business as well as economic perspectives. It shapes a research community that comprises both academia and industry and aims to become an active, permanent, and international forum on service-oriented systems. Besides the technological underpinnings, the working group addresses the different facets of the discipline. It also targets at organizing current initiatives and research, and proposing suitable and sustainable future research directions. The WG is chaired by

[3] International Federation for Information Processing (IFIP): http://www.ifip.org/

[4] IFIP Working Group (WG 2.14) on Service-Oriented Systems: http://home.dei.polimi.it/baresi/ifip/

Luciano Baresi and Barbara Pernici (Politecnico di Milano - POLIMI, Dipartimento di Elettronica e Informazione) and Winfried Lamersdorf (University of Hamburg – UniHH, FB Informatik).

Given the current level of activities in service orientation, the WG aims at consolidating initiatives instead of proposing new ones, and as such becoming a glue among existing activities, identifying the right synergies among existing initiatives, and acting as catalyst among existing (sub-) communities. The working group also pursues the objective of consolidating fundamental and theoretical aspects, and identifying future research directions in the discipline. This will provide proper and shared means to conduct research in the field to whoever is interested in service-oriented computing and systems. A first foreseen incarnation of these activities is the provision of qualified support to PhD-level research through the creation of dedicated workshops addressed to supervisors of PhD theses in the field. Shared and strong foundations also serve to strengthen the relationships with related fields (e.g., Internet of Things and Cloud Computing) and to base the coordination of efforts with standardization groups.

As a part of its mission of gluing existing undertakings in the field of service-oriented systems, the WG agreed to promote the use of the KM and guarantee its sustainability. This will be accomplished by creating awareness of KM and its artefacts in the research and practitioners community through promotions and furthering its use at supported events and activities including premier conferences (such as ICSOC, ICWS-SCC-Cloud, ECOWS, ServiceWave). As regards to the agreement between WG Chairs and S-Cube partners (many of which have members in the WG), the hosting and technical maintenance of the KM will still be in charge to the S-Cube partner that are currently responsible for these activities. Accordingly, KM will be hosted, maintained and secured for integrity and quality in its current locality and settings by UniDue (as a WG member) and will be directly accessible through the WG's web site under its auspices.

In addition to KM, the WG will also promote and ensure the sustainability of two other long-lasting artefacts produced by S-Cube; namely, the Use Cases Repository and the Virtual Campus, under the same principles of the agreement.

4.3 Collaborations with other EU Projects and External Bodies

4.3.1 HOLA! Initiative

HOLA![5] is an EC initiative to enhance collaboration and promote advancement of future ICT services in Europe. It aims at supporting the EC in the creation of a critical mass of SSAI stakeholders working together in building concepts for services in the Future Internet. To this end, HOLA! implements strategic mechanisms for establishing and upholding long-term collaboration and knowledge management. One of the key instruments employed for this purpose is raising consolidated knowledge from the European Research Projects within the Internet of Service (IoS) area. This is supported by creating a *Digital Library of project deliverables* of these projects. The Digital Library hosts public deliverables of research projects in the IoS area, facilitating technology transfer and knowledge sharing, management, maintenance and creation. These deliverables include technical documents but also presentations, source code archives, etc.

Since October 2010, S-Cube and HOLA! are collaborating[6] for the purpose of using S-Cube KM as a meta-data schema that provides the keywords attached to HOLA! IoS Digital Library[7] contents.

[5] HOLA! Initiative: http://www.holaportal.eu/node/12

[6] HOLA! Contact point: Angelos Yannopoulos, National Technical University of Athens

HOLA! is currently using KM terms to structure the digital library through keywords, which assist classification and searching in the digital library, and allow relationships to be found between researchers (through their competencies) and research outputs. Please refer to HOLA! IoS Digital Library site[7] for video-tutorials presenting how S-Cube KM structure and terms are integrated to HOLA! Digital Library contents.

4.3.2 OMELETTE Project

OMELETTE Project[8] is an FP7 project aiming at defining interoperable service mashups focusing on the Telco domain. It proposes a process of service development based on a mashup-oriented approach, which will enable the development of multimodal services in the Telco domain by assisting end-users with automatic compositions or composition recommendations and by speeding up the work of developers. To this end, OMELETTE will produce a vocabulary to be used as a common reference that will assist in creating mashups. This requires a platform to record the vocabulary and some method of structuring the content. With S-Cube KM offering a rich repository of terms, OMELETTE has decided to use the KM as the basis for their vocabulary and is collaborating[9] with S-Cube for this purpose since April 2011.

OMELETTE has also initiated the extension of S-Cube KM with terms in the Telco domain and in the NEXOF-RA glossary[10]. To ensure the quality, homogeneity, and consistency amongst terms, the KM adopts a governance structure, including a quality assurance process [6]. Special care is taken with entries added or modified by the non-network users, and their content are reviewed and edited accordingly. The process of extending the KM with new terms (by OMELETTE) and their quality assurance has started in December 2011 and is on-going at the time of writing this report.

4.3.3 External Bodies

S-Cube KM has attracted interest also from non-European research institutes and universities. The initial steps have been taken by S-Cube members and Prof. Aditya Ghose (the research leader in the Smart Services CRC for the ‘Strategic Alignment of Services’), who has expressed their interest in referring to S-Cube KM in their research activities and establishing a long-lasting collaboration. Smart Services CRC is headquartered at the Australian Technology Park in Sydney and with research nodes in Brisbane, Melbourne and Sydney. The KM has been also one of the pillars of the on-going collaboration between S-Cube and Tsinghua University (China) through Prof. Chi-Hung Chi, the Director of Internet Content & Service Engineering Laboratory.

[7] HOLA! Digital Library: http://www.holaportal.eu/content/gilvus-euismod-suscipit-euismod-neo-typicus-refoveo

[8] OMELETTE Project: http://www.ict-omelette.eu/home

[9] OMELETTE Contact point: Vadim Chepegin, at TIE Holding RDI, Netherlands

[10] NEXOF-RA Glossary: http://www.nexof-ra.eu/?q=node/187

5 Conclusion

This deliverable summarized the two major outcomes of workpackage IA-1.1 that have been achieved by its members within year 4 of S-Cube. We consider those outcomes a profound contribution to the community:

- First, the **S-Cube Research Roadmap** provides a clear vision of S-Cube and its collaborators on what research issues and challenges will become relevant in 5-10 years.
- Secondly, the **S-Cube Knowledge Model**, which will be maintained even after the end of S-Cube, will provide an extensive reference on terminology and concepts for the field.

Acknowledgments: As editors of this deliverable, we cordially thank all S-Cube members, associate members, visiting scientists and collaborating project members for their contributions.

– *Andreas Metzger & Oktay Turetken*

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[7] Andrikopoulos V., Metzger, A. (Ed.), CD-IA-1.1.2: Separate knowledge models for functional layers, S-Cube Deliverable. Mar.2009.

Appendix A S-Cube's Experience with Wikipedia

A.1 Examples from Previous Efforts

This section details the integration efforts of S-Cube -and KM in particular- with Wikipedia by going through several examples of the content previously added to Wikipedia and the editors' reactions.

Example 1

18 Dec 2009: All hyper-links to S-Cube partner home-pages, all keywords ("Software Services", "Web Services", "Service Networks") and the project logo was removed from the S-Cube Wikipedia page. No explanation given.

Example 2

20 Jan 2010: The following was added to the S-Cube page in Wikipedia:

> *"The [http://www.s-cube-network.eu/km/km-frontpage S-Cube Knowledge Model] is a collection of technical definitions that are used in the S-Cube project. Its intention is to create a living knowledge base for researchers in the field of software services and software systems."*

21 Jan 2010: Returned to Wikipedia to find the text and link had been deleted from page with the explanation: "removing advert section".

10 Feb 2010: Added the text and link again, which were immediately removed with the following explanation:

> *"The section was removed because it was not sourced to an independent reliable source. All of the information on Wikipedia must be independently verifiable. Please also note that if you have a conflict of interest with a subject, you are highly discouraged from editing its article. TNXMan 16:14, 10 February 2010 (UTC)"*

Example 3:

17 Feb 2010: Added project objectives to S-Cube Wikipedia page and a link to the KM:

Project objectives:

- Establishing an open community of Software Engineering and Service Researchers from both, industry and academia
- Creating a common [http://www.s-cube-network.eu/km/km knowledge-base]
- Developing long term visions and research directions

17 Feb 2010: The project objectives and link were removed from the S-Cube Wikipedia page. No explanation given.

Example 4:

8 Mar 2010: Added a sentence and link from Wikipedia article to Service Choreography term. This has remained but the added value is minimal: the link does not have a context and the relationship to cross-cutting concerns, for example, has been lost.

Latest Attempts:

In September 2011, the members put links to 15 KM terms in Wikipedia. Table 1 lists these terms, their link addresses, the time when they were added and by whom. As can be seen, eight out of 16 terms were removed by Wikipedia without any valid explanation.

Table 1. List of Terms added to Wikipedia

Wikipedia Term	Wikipedia Address	S-Cube KM Term	Who Added	When Added	Removed?
Performance Indicator	http://en.wikipedia.org/wiki/Performance_indicator	http://www.s-cube-network.eu/km/terms/k/key-performance-indicator	Alex Nowak (USTUTT)	22/09/11	Yes
Business Process Modelling	http://en.wikipedia.org/wiki/Business_process_modelling	http://www.s-cube-network.eu/km/terms/b/business-process-modeling	Alex Nowak (USTUTT)	22/09/11	Yes
Business Activity Monitoring	http://en.wikipedia.org/wiki/Business_activity_monitoring	http://www.s-cube-network.eu/km/terms/b/business-activity-monitoring	Alex Nowak (USTUTT)	22/09/11	Yes
Service-oriented Software Engineering	http://en.wikipedia.org/wiki/Service-oriented_software_engineering	http://www.s-cube-network.eu/km/terms/s/service-oriented-software-engineering	Angela Kounkou (City)	30/09/11	Yes
Self Management	http://en.wikipedia.org/wiki/Self-management_(computer_science)#cite_ref-0	http://www.s-cube-network.eu/km/terms/s/self-healing-system	Angela Kounkou (City)	30/09/11	
Web Services Invocation Framework	http://en.wikipedia.org/wiki/Web_Services_Invocation_Framework	http://www.s-cube-network.eu/km/terms/s/service-binding	Angela Kounkou (City)	30/09/11	Yes
Context (computing)	http://en.wikipedia.org/wiki/Context_(computing)#See_also	http://www.s-cube-network.eu/km/terms/c/context	George Baryannis (UoC)	23/09/11	
Service Level Agreement	http://en.wikipedia.org/wiki/Service-level_agreement#See_also	http://www.s-cube-network.eu/km/terms/s/service-level-agreement	George Baryannis (UoC)	23/09/11	
Service Discovery	http://en.wikipedia.org/wiki/Service_discovery#See_also	http://www.s-cube-network.eu/km/terms/s/service-discovery	George Baryannis (UoC)	23/09/11	
Semantic Web Services	http://en.wikipedia.org/wiki/Semantic_Web_Services	http://www.s-cube-network.eu/km/terms/s/semantic-web-services	Dragan Ivanovic (UPM)	26/09/11	Yes
Quality-of-Service	http://en.wikipedia.org/wiki/Quality_of_service	http://www.s-cube-network.eu/km/terms/q/quality-of-service-qos	Dragan Ivanovic (UPM)	26/09/11	Yes
Workflow	http://en.wikipedia.org/wiki/Workflow	http://www.s-cube-network.eu/km/terms/w/workflow	Dragan Ivanovic (UPM)	26/09/11	Yes
Service-Choreography	http://en.wikipedia.org/wiki/Service_choreography#cite_note-0	http://www.s-cube-network.eu/km/terms/s/service-choreography	Martin Trieber (TuW)	NA	

Wikipedia Term	Wikipedia Address	S-Cube KM Term	Who Added	When Added	Removed?
Business-Transaction Management	http://en.wikipedia.org/wiki/Business_transaction_management#cite_note-4	http://www.s-cube-network.eu/km/terms/b/business-transaction	Martin Trieber (TuW)	NA	
Process-Modeling	http://en.wikipedia.org/wiki/Process_modeling#External_links	http://www.s-cube-network.eu/km/terms/b/business-process-modeling	Martin Trieber (TuW)	NA	

A.2 Relating our Experiences with Wikipedia Content Standards

1) As illustrated in the examples, adding our own work to Wikipedia is difficult under Wikipedia's content standards as there is a conflict of interest - defined as:

   "... adding material that appears to promote the interests or visibility of an article's author, its author's family members, employer, associates, or their business or personal interests."

2) Much of the content of the KM has been added from the original research and findings of S-Cube. However, Wikipedia editorial guidelines stress that contributions must be independently verifiable and they should not contain original work.
3) According to Wikipedia policy, the KM could be considered a "self-published source":

   "... self-published media [...] are largely not acceptable. This includes any website whose content is largely user-generated". "Self-published material, whether on paper or online, is generally not regarded as reliable."

4) It is not allowed to add knowledge from "self-published" sources as it is considered "original research" (see also point 2 on independence):

   "... used on Wikipedia to refer to material—such as facts, allegations, ideas, and stories—for which no reliable published source exists".

5) Content "promoting" a piece of work, such as the S-Cube network or its output, is considered "an advertisement" and removed (see examples above). Adding KM items, such as references to deliverables and competencies (a directory of names and institutions), would not be possible.

Research Challenges on Adaptive Software and Services in the Future Internet: Towards an S-Cube Research Road Map *DRAFT*

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***Abstract*—This paper presents relevant research challenges on software services and systems as identified by researchers under the umbrella of the EU FP7 Network of Excellence S-Cube. We discuss the approach to identify and assess those research challenges, as well as how this effort relates to previous and related research road map activities.**

***Keywords*-Service-oriented systems, software services, SOA, Future Internet, monitoring, adaptation, quality prediction, service technology, software life-cycle**

I. Introduction

The rapid evolution of software technology has brought monumental changes to virtually every market sector and has created enormous opportunities for innovation. One such opportunity is developing innovative systems through the composition of software services available over the Internet. Those services have the power to provide utility to users in a much more dynamic and flexible way than is possible with traditional software technology. However, service-oriented systems and their corresponding software services require fundamental changes to the way software is developed, deployed and maintained [1]–[3].

A. Motivation

Software that constitutes a service-oriented system is no longer owned by on single organization but is distributed and shared amongst many organizations. This distributed ownership opens up a whole range of research challenges, including the design, evolution, adaptation and quality assurance of service-oriented systems. The aim of this paper is to identify and assess those challenges, as well as to relate those challenges to related research road map efforts.

Due to the emergence of the Future Internet, those challenges will even be amplified and novel challenges will rise. The Future Internet constitutes the vision of a future ubiquitous, federating and all-encompassing infrastructure that will overcome structural limitations of the current Internet in terms of scalability, mobility, flexibility,security, trustworthiness and robustness. The Future Internet will thus culminate in the convergence of the physical ("Internet of Things") and digital worlds, into a completely new reality, where richer real-time and mobile communication modalities will arise [4]. Future software and service technology and methods thus will need to cope with trends such as the convergence of the Internet of Things and the Internet of Services; novel life-cycle models where the boundary between design and runtime will increasingly blur; online quality assurance and self-adaptation; as well as novel architectural styles for large-scale, long-living service-oriented systems. The research challenges resulting from those trends in the Future Internet will be elaborated below.

B. *Contribution of Paper*

This paper summarizes relevant research challenges on software services and systems as identified by researchers under the umbrella of the EU FP7 Network of Excellence S-Cube (http://www.s-cube-network.eu/). By doing so, the paper set the scene for the 2012 ICSE workshop on "European Software Services and Systems Research - Results and Challenges". The workshop served as a springboard to discuss software engineering research challenges for future service-oriented systems, aiming to deliver the *S-Cube Research Roadmap* on adaptive software and services in the Future Internet.

The remainder of the paper is structured as follows. Section II motivates the need for "yet another" research roadmap by scrutinizing existing, related research roadmaps and efforts. Section III describes the process we followed to identify and assess novel and relevant research challenges. Section IV provides a summary description of the research challenges identified together with an assessment of their relevance. Those research challenges are further elaborated in four separate papers along the research areas of "Service life-cycle and software engineering" [5], "Service technology foundations" [6], "Multi-layer and mixed-initiative monitoring and adaptation for service-oriented systems" [7] and "Online service quality prediction for proactive adaptation" [8].

II. Why Yet Another Research Roadmap?

A. *Related Roadmap Activities*

Several related research roadmap activities have been performed. They were done from different points of view, within different communities and with different aims. Below, we discuss the major relevant outcomes of those activities clustered by "communities".

1) *Industrial R&D Efforts:*

2) *Collaborative R&D Efforts:*

3) *Fundamental & Integrative Research Efforts:*

B. *Aims of S-Cube Research Roadmap*

Based on the above analysis, the aims of the S-Cube research roadmap are to

- extend existing understanding from above roadmaps with novel fields / areas for challenges not covered (e.g., novel challenges introduced by cloud computing model),
- refine the often very general problems and better understand their impact / relevance in the setting of SOA ,
- (c) update and extend existing focused roadmaps by taking a broader view across different communities

III. Identifying and Assessing the Research Challenges

Our overall objective was to set out to identify research challenges that may become relevant after and beyond S-Cube. Specifically, we set out to identify challenges that may become relevant in 5–10 years and which have the potential to radically challenge existing thinking (i.e., beyond incremental).

Below we summarize the process that we followed in identifying research challenges and assessing their relevance.

A. *Identifying the Challenges*

Organization of Research Roadmap Workshop (one full day with 40 project members and associate members attending Figure 1 provides the demographic distribution of participants.

As can be seen from the demographic distribution, the identification and assessment of the research challenges thus constituted a joint endeavor and synergy of complementary communities, most notably BPM, SOC, Cloud/Grid and SoftEng.

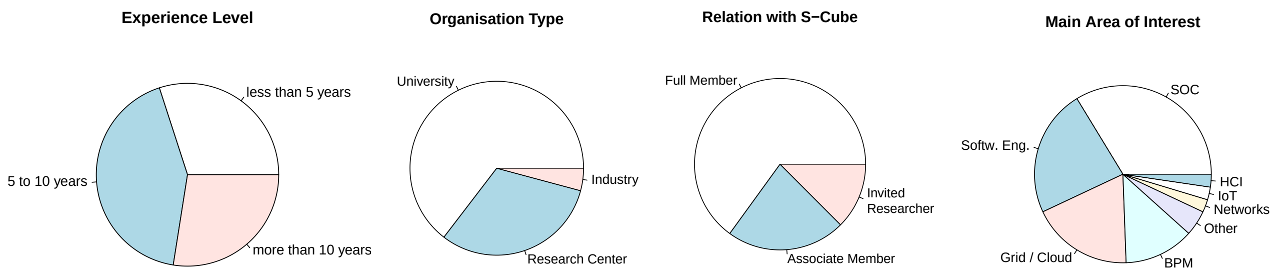

Figure 1. Demographic Distribution

Contributors to the different activities have all more than four years of experience in performing joint research in the realm of S-Cube.

The Research Roadmap Workshop was organized along four topical sessions:

- "Service life-cycle and software engineering"
- "Service technology foundations"
- "Multi-layer and mixed-initiative monitoring and adaptation for service-oriented systems"
- "Online service quality prediction for proactive adaptation".

Each session started with an introduction presentation of the S-Cube "area" leader (either the workpackage or activity leader for that "area"), who introduced the challenges identified within the S-Cube network and the key results already produced in recent years. This was followed by selected position presentations from associate members and invited researchers from outside the S-Cube network. The sessions were organized such as to leave enough room for open discussions and contribution of additional research challenges not feature in presentations. At the end of each session, the research challenges were consolidated and "owners" of those challenges have been identified. After the workshop, "area" leaders together with "owners" of research challenges have elaborated the identified challenges, which are thus presented in greater detail in [5]–[8].

The S-Cube Research Roadmap Workshop was concluded by a session, during which "area" leaders presented a summary of the identified research challenges. Finally, a survey study on the relevance of the identified research challenges has been performed, involving all of the NN participants (see Section III-B for more details).

B. *Assessing the Challenges*

We performed a survey study during the closing session of the S-Cube Research Roadmap Workshop in order to systematically assess the relevance of the identified research challenges. The survey study involved all of the 40 researchers that participated to the workshop. For each of the challenges that were identified in the previous sessions, researchers were asked to quantify (using a questionnaire) the potential relevance and degree of impact, assuming that research achievements addressing those challenges will have been produced [1].

To this end we followed the proposal elaborated by the Australian Technology Network of Universities [9], which differentiates between the following levels of research achievements:

- *Results*: Publications, Patents, Standards; e.g., Publication of new cloud-based e-contracting manager (ECM) for Transport & Logistics (T&L)
- *Transfer*: Engagement with end-users, Licenses, Royalty agreements, Pilots, Trials; e.g., Public-private partnership on prototypical implementation and trial of ECM
- *Outcomes*: New or improved products, Service or processes; e.g., Company builds on transfer results and delivers new T&L ECM services to the market
- *Impacts*: Value-added, time savings, reduced risks / costs, increased productivity, increased competitiveness, reduced consumption of natural resources; e.g., ECM services enable higher transparency of global T&L market, leading to increased market opportunities for SMEs

[1]Researchers aiming to address those challenges may also consider employing the SEQUOIA methodology (http://www.sequoiaproject.eu/) to complement our findings with an assessment of potential socio-economic impact.

It should be noted that, complementary to this survey study exercise, the research challenges that have been

C. Design, Execution and Data Collection

When designing the survey questionnaire, we took into account findings from psychology as reported by Krosnick [10]: Based on the observation that ranking can be very time consuming and that people enjoy ratings more than rankings, we asked participants to rate the individual research challenges. Concerning the answer choices, we did not offer a "no opinion" choice. This was based on the observation that offering a "no opinion" choice, can compromise data quality. Further, we used verbal scale labels, as numeric labels might convey the wrong meaning. Finally, the choices were ordered such as to start with lowest relevance (i.e,. "Results", see anbove), as studies have shown that people tend to select the first option that fits within their range of opinion. By doing so, our study will thus lead to more "conservative" results.

The questionnaire has been pretested by 10 researchers from the institute of the main author. This pretest led to significant improvements for what concerns the understandability of questions and options. Specifically, we have realized that the options concerning research relevance have been perceived as difficult to understand and thus have been augmented with examples.

In the final session of the S-Cube Research Roadmap Workshop, the survey questionnaire and assessment scale has been explained in a short introductory presentation before handing out the questionnaires. We have received 40 responses altogether, i.e., each participant has completed and returned a questionnaire.

D. Validity Threats

We have aimed at ensuring construct validity by careful design of the survey questionnaire as discussed in Section III-C above.

Concerning, internal validity, we aimed to have a "fair" balance between different research areas (each has been devoted an individual session) and to allow everybody to freely contribute to the discussions.

Concerning external validity, results should be carefully generalized taking into account the fact that members from the SOC and Software Engineering community constituted the majority of participants (see Figure 1) and that participants in our survey study have obviously not been selected randomly (cf. [10], [11]).

Concerning repeatability, the questionnaire is available from URL. In fact, the survey has been repeated during the S-Cube workshop at ICSE.

IV. Research Challenges

This section summarizes the research challenges that have been identified as described above. Together with the refined and updated research challenges identified at the beginning of S-Cube (see [1] for a detailed discussion), they form the S-Cube research road map on future software services and systems.

We have clustered the research challenges into four topic areas along the S-Cube research framework (IRF; see Figure 2). This research framework has been developed and used within S-Cube to guide the research activities of the network (see [1], [12]).

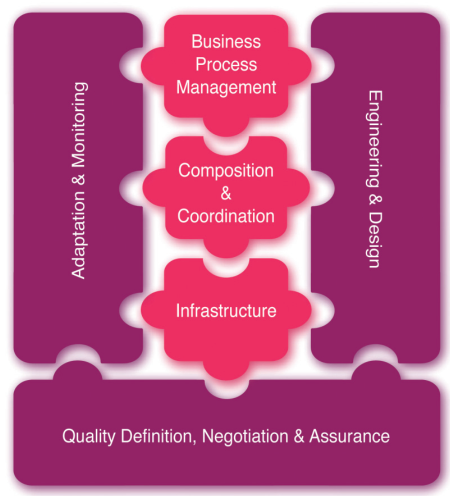

Figure 2. S-Cube Research Framework

- *Service life-cycle and software engineering* (right-hand pillar of IRF) [5]: This includes all challenges related to engineering and design of service-oriented systems, focusing on life-cycle aspects and specific needs for software engineering of services.
- *Service technology foundations* (middle pillar of IRF) [6]: This includes all challenges related to the services technology stack, including service infrastructure (such as Grid and Cloud), service composition & coordination, and business process management & service networks.

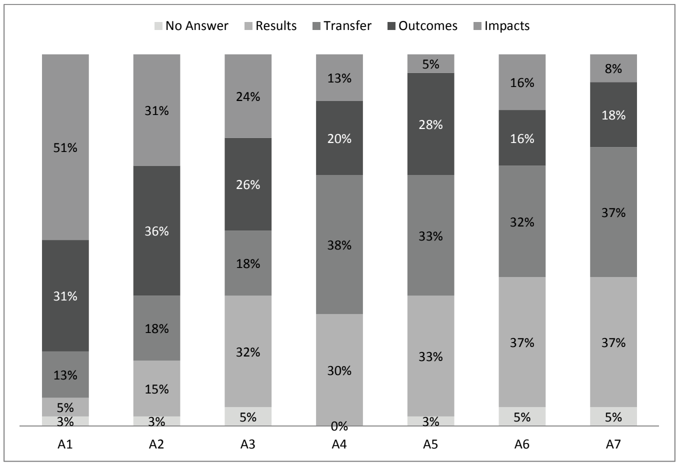

Figure 3. Service life-cycle and software engineering

- *Multi-layer and mixed-initiative monitoring and adaptation for service-oriented systems* (left-hand pillar of IRF) [7]: Adaptation is considered a key capability of service-oriented systems to address the highly dynamic setting in which those systems need to live. This topic area includes challenges related to monitoring and adapting those kinds of systems across the whole technology stack as well as considering context and humans as triggers for adaptation.
- *Online service quality prediction for proactive adaptation* (bottom pillar of IRF) [8]: This includes all challenges related to assessing and predicting service quality during run-time to proactively respond to imminent problems and issues. Due to the highly dynamic nature of services, predicting the quality during design time does not suffice, thus calling for online techniques.

A. *Service life-cycle and software engineering*

1) Techniques and mechanisms for ensuring real-time service provisioning (considering cloud and mobile devices)
2) Techniques to include human services / user-provided services in service compositions
3) Social service models and techniques to support global software engineering
4) Migration of existing service engineering techniques and processes to incorporate design-for-adaptation activities
5) Concepts and techniques for retrieving and updating service descriptions exploiting the notion of linked services
6) Principles and techniques to ensure that design activities remain efficient/effective despite increased design-for-adaptation needs
7) Situational methods and (executable) modelling languages allowing to combine practices (method chunks) for software/service engineering (possibly at run-time)

B. *Service technology foundations*

1) Techniques for adaptable autonomous heterogeneous / social business processes
2) Adaptation patterns for service compositions based on quality attributes
3) Exploiting cloud solutions (IaaS, PaaS, SaaS) for service coordination
4) Formal languages and composition (“orchestration”) approaches
5) Novel architectural styles (beyond SOA & RESTful)
6) Techniques for reasoning about and analyzing properties that emerges due to the interaction of services / organizations
7) Employing nature-inspired computing as unconventional paradigms for service and infrastructure adaptation

C. *Multi-layer and mixed-initiative monitoring and adaptation for service-oriented systems*

1) Decentralized models and techniques to monitor and predict service quality issues
2) Assurances for adaptation

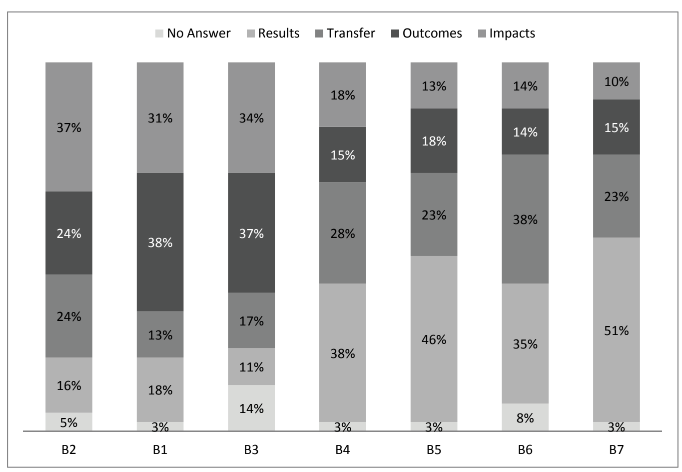

Figure 4. Service technology foundations

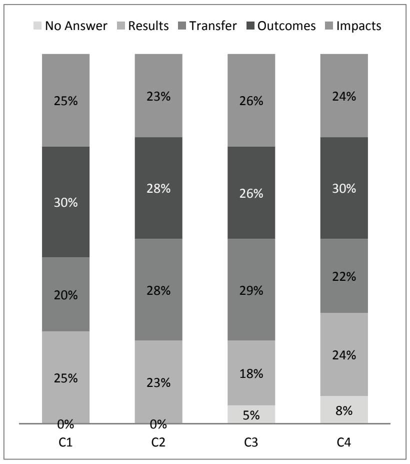

Figure 5. Multi-layer and mixed-initiative monitoring and adaptation for service-oriented systems

3) Approaches for retrieving and analyzing context information to support individuals in performing the right adaptation decisions in user-centric systems
4) Techniques for combining and cross-correlating observations, predictions and events from different sources and provided by different techniques

D. Online service quality prediction for proactive adaptation

1) Leveraging Large Event Streams Towards Prediction
2) Techniques for IaaS performance prediction beyond traditional workload prediction
3) Metrics, techniques and tools for measuring the accuracy of online quality predictions

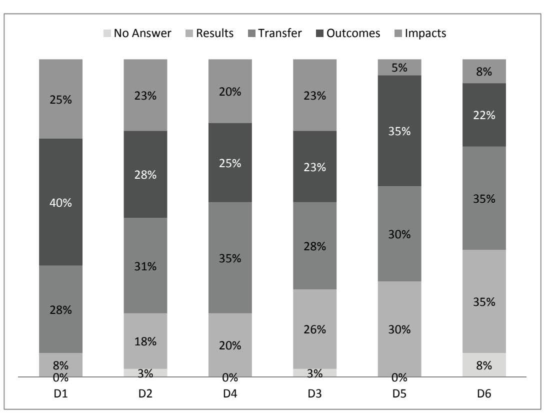

Figure 6. Online service quality prediction for proactive adaptation

4) Concepts, models and algorithms for prediction of quality of heterogeneous (real-world and IT) service-oriented systems
5) Differentiating and correlating short-time predictions (online / adaptation) with long-term predictions (evolution)
6) Concepts and factors relevant for contextualizing accuracy

V. Conclusions

TBD.

Acknowledgment

We extended our deepest gratitude to Jorge Gasos from DG INFSO of the European Commission. In his role as project officer, he was instrumental to the success, smooth execution and sustainable impact of S-Cube.

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THE S-CUBE KNOWLEDGE MODEL
*Experiences in Integrating SSME Research Communities**

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Keywords: Knowledge model, knowledge management

Abstract: The field of Service Science, Management & Engineering (SSME), covers a wide range of research topics and has become fragmented due to the necessary specialization such broad area requires. The European Commission's Network of Excellence in Software Services and Systems (S-Cube) is an attempt to bring scientists together to perform joint research in this field that crosses existing research boundaries and, in the process of doing so, to help establish an enduring European network of researchers practicing SSME.
To assist in the consolidation of research and bridge the gaps between disciplines, the S-Cube Knowledge Model (KM) has been developed to provide a method of capturing, managing and refining the knowledge produced by the network and provide a common understanding of research outputs. This paper describes the motivation, requirements and realization of the S-Cube KM, which allows the collection, analysis and management of research within S-Cube and enables the extraction and combination of the explicit, cross-cutting knowledge embedded in collaborative research.

1 Introduction

In response to the fragmentation of software service-based systems research, the Software Services and Systems Network of Excellence (S-Cube NoE[2]) was conceived by the European Commission (EC) to establish and develop an integrated, multi-disciplinary, vibrant European community in Service Science Management & Engineering (SSME). The S-Cube NoE brings together researchers from many different domains, distributed across 16 academic partner institutions, 6 associated industry partners and 17 associate members to collaborate on research topics defined in the S-Cube research framework. A central goal of the S-Cube NoE is to bring these diverse communities together to ensure their joint research is coherent, interdisciplinary and aligned through the cross-fertilization of knowledge. To help achieve this, the S-Cube NoE has developed the *S-Cube Knowledge Model*, or *KM* for short, to capture, organize and refine the knowledge generated by researchers in the network and provide a common understanding at a terminological level of the wide range of knowledge required for SSME research.

The S-Cube KM is made up of a publicly-accessible technology platform, corpus of information and set of quality assurance procedures. It allows researchers in the network to share, in a standard way, key information about them and their work and to position their research and competencies in relation to case studies and other research and researchers. This information can be used to provide a comprehensive understanding of how the network's research efforts and capabilities fit into the larger body of SSME knowledge and, through its analysis, be used to identify relationships between people, institutions and gaps and overlaps in the research of the network.

This paper is a description of the motivation, methodology and implementation of the S-Cube KM and a presentation of our experiences in capturing, curating, managing and refining the knowledge gath-

*The research leading to these results has received funding from the European Community's Seventh Framework Program FP7/2007-2013 under grant agreement 215483 (S-Cube).

[2] `http://www.s-cube-network.eu/`

ered from researchers in the S-Cube NoE. The paper's main contribution is to describe how a large, multi-disciplinary research project went about ensuring a common understanding of research, capabilities and outputs by using a holistic and consistent knowledge management framework and a set of procedures for content validation and quality assurance.

The remainder of this paper is organized as follows: Section 2 provides the motivation for the KM through a brief introduction to the organization of S-Cube and related works; Section 3 briefly discusses the methodology followed for the construction of the KM; Section 4 describes how the methodology was used in the context of S-Cube to build the KM; Section 5 reports on the realization of the KM in terms of technologies used and functions offered; Section 6 presents details on how the contents of the KM has evolved; Section 7 provides a discussion of our experiences and findings; and, finally, Section 8 presents a set of conclusions and a description of future work.

2 Motivation

S-Cube is an EC initiative to bring researchers from different research domains together in an interdisciplinary approach to the study, design, and implementation of *service networks*. Research on service networks encompasses a broad range of academic and practical fields in the areas of Information Systems and Computer Science, such as Business Process Management (BPM), Grid computing and Software Engineering. Thus, research in this domain necessarily requires an interdisciplinary effort. S-Cube attempts to bridge these domains and bring together scientists and practitioners from different areas to perform research into service networks that cuts across traditional disciplines.

To achieve its goals, the S-Cube NoE has a comprehensive research framework that is split into joint research activities and associated tasks to support and promote the integration and dissemination of research (Papazoglou et al., 2010). The scope of S-Cube's Joint Research Activities (JRAs) is designed to cover the areas where future challenges will arise in software service-based systems and applications.

Figure 1 shows the conceptual relationship between the JRAs of S-Cube. Each block represents a JRA and the figure shoes how the research program positions three *service realization mechanisms* as a central 'spine' of research in three functional layers: service infrastructures, service composition and coordination and BPM. Together, these mechanisms cover how service-based applications are built, deployed, composed and organized before being managed as

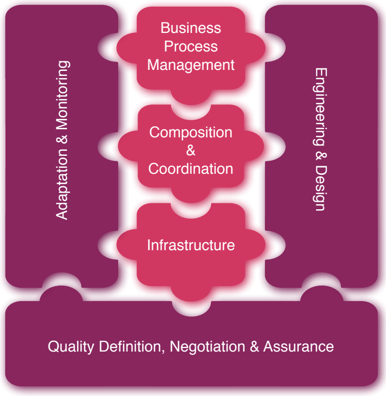

Figure 1: The S-Cube Joint Research Activities (JRAs)

business processes. The spine of service realization mechanisms is surrounded by three *cross-cutting concerns* applicable to each of the mechanisms, i.e., principles and techniques that should be applied in each of the functional layers. For example, each of the functional layers should be concerned with cross-cutting principles regarding how they are designed and engineered and also methods for defining, negotiating and assuring the quality of that layer. Likewise, each functional layer should also be concerned with how they are monitored and adapted (should the quality-of-service drop below an agreed level).

In addition to the research activities, S-Cube also contains a set of integration workpackages to promote interdisciplinary research across the JRAs, ensure the creation of a network of researchers in the field of software services and systems and assess the state and progress of integration. These are grouped into the areas of: spreading of excellence, integrating communities and integrating knowledge.

The S-Cube KM is part of the 'integrating knowledge' group of integration workpackages and was created to provide a common understanding at a terminological level of the wide range of knowledge required for SSME research. This requirement has come about as the same term is often used in different SSME research areas but with a contextual or domain-specific meaning. As a result, the multiple meanings of terms makes it difficult for researchers to communicate across research boundaries and enhances the fragmentation of research.

As we will describe in Section 4, each term is created as a result of the consolidation and reconciliation of conflicting or overlapping definitions of the vocabulary used in each JRA and the KM provides a method of defining associations between concepts, competencies and methodologies to position knowledge in relation to research domains. As a result, it helps achieve the goals of the integration workpackages by providing data through which the integration of research in S-Cube can be assessed.

Therefore, the KM aims to map, integrate and synthesize the diverse concepts and knowledge from the different JRAs and provide a resource that can be used not only as a reference point for teachers, researchers and practitioners but also as a tool to identify a network member's competencies (for mobility, spread of excellence, contact points and sources of information), to help classify research results (which assists in demonstrating research integration) and to illustrate the use of knowledge through associations with common scenarios and use cases.

Related Work

Before continuing with the description of the S-Cube KM, it is important to acknowledge methods of capturing the knowledge generated in other EC ICT research projects. For example, the NEXOF Reference Architecture (NEXOF-RA) project[3] has created a glossary containing a list of terms and definitions for Service Oriented computing (Stricker et al., 2009); the Business Experiments in Grid (BEinGrid) project[4] has developed *Gridipedia* ("the knowledge and toolset repository [...] to preserve and make accessible a whole range of resources on Grid computing and related technologies such as cloud computing and virtualization"); and the INTEROP project has developed a *Knowledge Map (KMap)* of competencies required for research into the interoperability of enterprise applications (Velardi et al., 2007).

However, as described in (Andrikopoulos et al., 2008), these previous efforts fail to meet the requirements of the S-Cube NoE. For example, the NEXOF-RA glossary has a domain-specific scope for terms, focusing on architectural and infrastructural knowledge, and follows a "flat" glossary (dictionary) format. Similarly, Gridipedia only focuses on the Grid and Cloud computing communities. In addition to containing knowledge of Grid computing, Gridipedia also contains downloadable Grid software components and solutions for common business problems. In comparison with this previous work, it was a requirement for the S-Cube KM to be applicable to many communities and the hosting of software components was not required. The S-Cube KM was to provide more dynamic, web- and encyclopedia-based approach that is broader in content coverage, focusing on semantic associations between concepts, approaches and methodologies and capturing associated information about the network, such as competencies and illustrations of how knowledge could be used.

3 Methodology

We now describe the theoretical background for the development of the S-Cube KM. The methodology we used closely follows the activities necessary for the construction of a knowledge model described in (Schreiber and Wielinga, 1998), which illustrates how knowledge model development is decomposed to the sequential steps of knowledge *identification*, *specification* and *refinement*.

Figure 2 shows how the three stages proceed from the initiation of the KM and how the final stage of knowledge refinement is an ongoing, iterative task to integrate systematically different bodies of already codified knowledge in a formal, systematic manner. As we will describe in detail in the following sections, the effect of these three stages is to perform the *combination* of explicit knowledge contained in *deliverables*. Deliverables are project documents that either aggregate published/submitted papers and/or include original work, i.e. capture the knowledge produced by the network (see also Section 4). In this sense, deliverables perform the *externalization* of knowledge in Nonaka and Takeuchi's Four Modes of Knowledge Conversion model (Nonaka and Takeuchi, 1995). The *internalization* of explicit knowledge contained in the KM is carried out as the knowledge is internalized into a KM user's tacit knowledge-base, for example through applying the knowledge to their own work. The remainder of this section describes each of the steps from Figure 2 in more detail:

Knowledge Identification In this phase the *information sources* to be used for knowledge modeling, such as glossaries, summaries and scenarios, are identified. In addition, existing model *components*, e.g., domain or task-related artifacts, are also found and evaluated for reuse during the modeling task.

Knowledge Specification In the specification phase, a common representation of this information is developed. This is achieved through taking the model components identified in the previous phase and then "filling the holes" between components using the information sources.

Knowledge Refinement The final phase of KM construction has the purpose of validating the knowledge model, refining the knowledge it contains and completing the knowledge base (to the extent that it is possible). As shown in Figure 2, the knowledge refinement phase is an iterative process. This fits with previous experiences of architecting knowledge, such

[3] http://www.nexof-ra.eu

[4] http://www.beingrid.eu/

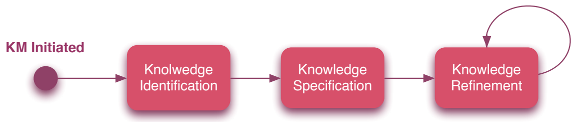

Figure 2: The KM Development Methodology

as (Boer et al., 2007), which described how architects commonly perform their activities (analysis, synthesis and evaluation) in an iterative fashion.

4 Building the KM

This section contains a description of how the phases of the general methodology from Section 3 were applied to the construction of the S-Cube KM, with each phase or sub-phase containing a description of the lesson (or lessons) learnt in completing it.

4.1 Knowledge Identification

For the initial stage of the KM development in S-Cube we identified:

Information sources: In the initial phase of the network, each JRA completed an extensive literature survey that accumulated a significant amount of state-of-the-art knowledge in each area, some of which have subsequently been published as journal articles or book chapters. The results of these surveys acted as the initial, primary information source for the KM. In addition, research expertise of specific people and institutions within the network was identified.

Components: The design of the research framework and the outputs of the integration activities were the basic components for the KM. For example, the model of the structure and relationships between research domains defined in the contractual description of work and by the integration activities, provided a framework for the collection, description and publication of use cases that provides a context for knowledge items.

4.2 Knowledge Specification

For the S-Cube KM, this phase is translated into the following three steps:

4.2.1 Initial Version

The first step in compiling the KM was to ask each JRA to compile a short document describing the research performed in their area. This description had to contain a number of terms (keywords) considered important for the area, together with a separate, self-contained definition for each term. We also asked that when a definition was drawn from an existing source the source to be identified, or, in the case where no widely accepted definition existed, for an explicit original definition. After these terms and definitions were collected, we bootstraped the KM by organizing the information in a simple table format, described in (Andrikopoulos et al., 2008). This initial version of the KM was essentially a type of a dictionary. The competencies of each partner institution were added directly to each term, so as to connect it with one or more experts and/or institutions in the network.

For this first version a commercial spreadsheet software was used to collect and collate the knowledge from the JRAs. After the information was checked and edited where necessary by each JRA leader, it was incorporated in the S-Cube web portal as a set of static web pages. At this stage the KM was only accessible to the network participants and EC project officers responsible for overseeing and reviewing the project.

Lessons Learnt: Creating an initial version of the KM and assessing its strengths and weaknesses allowed us to derive the requirements for the 'final' KM format. It also allowed us to reduce the risk in moving to this format, as it allowed us think about what information each term should contain and refactor the knowledge accordingly (described in later lessons learnt).

4.2.2 KM Templating

While compiling the initial version of the KM we became aware of two major problems with the dictionary-style approach. Firstly, the same term may have different definitions in each research domain. For example, the term 'adaptation' has a different meaning in the context of Service Composition & Coordination — it refers to modifying a previously configured service composition — than the one used in the Adaptation & Monitoring JRA, where it applies to service-based applications in general.

Secondly, the dictionary failed to capture if/when a definition was either *domain-specific* or *context-specific*. A domain-specific definition is defined as an item of relevant knowledge that applies across all of the service realization mechanisms or all of the cross-cutting concerns for that term, whilst a context-specific definition applies across two JRAs. In the previous example, 'adaptation' has both a domain-specific definition (in the Adaptation & Monitoring JRA) and a context-specific definition (in the juncture of the Service Composition & Coordination and Adaptation & Monitoring JRAs) which supersedes the former one in the context of service compositions.

As the initial version of the KM provided terms as simple documents, it could not express these properties or relationships.

Therefore, to record these different definitions and capture the relationships between domain- and context-specific knowledge we re-thought our approach and designed a grid-like template for terms, shown in Table 1. The grid is arranged with *service realization mechanisms* on the vertical axis and *cross-cutting concerns* on the horizontal axis; the position of a definition within this grid indicates its relationship to each JRA of the research framework. The arrangement of the JRAs like this allows us to capture multiple definitions and both domain- and context-specific information. For example, a definition for a term that is contextual between BPM and Engineering & Design (e.g., a methodology for designing business processes) is recorded in the top left cell of the grid. If a definition is domain-specific to Engineering & Design, it applies across all service realization mechanisms and the definition is placed in the bottom cell of the first column (in the Generic row) to indicate this. The right-most lower cell in the template, where the Generic row and column intersect, is used for terms whose definition is applicable across all JRAs areas; e.g., 'software service'. In addition, placeholders where competencies, validation scenarios and references to publications/deliverables can be recorded were attached to each term template.

Lessons Learnt: We found that definitions from different research domains differ not necessarily because of ambiguity of meaning but because they may address different contexts. In ontology engineering, differences in definitions usually indicate ambiguities and a lack of cross-fertilization of knowledge and their removal is encouraged (Shvaiko and Euzenat, 2008). In our case we preserve the differences in definitions to capture domain *and* contextual information, and the term definitions are codified across these two dimensions.

4.2.3 Public Release

Once this template had been evaluated and agreed by the members of S-Cube, we proceeded to migrate the set of terms from the initial version of the KM to the template, reviewing and adding definitions to them where appropriate. At the same time, while we were completing this process, each of S-Cube's JRAs was asked to revisit the state-of-the-art reports already produced to determine further knowledge that could be added to the KM. These reports, together with other first-year project deliverables, were processed by the domain experts within the network, isolating and defining important terms and attaching partner competencies to them. The initial conceptualization of the S-Cube KM was concluded with its release on the network's web portal and was the first publicly accessible version of the KM. This was done in May 2009, following a successful review of the project by the EC.

Lessons Learnt: Having knowledge sources (i.e., state-of-the-art reports) immediately at-hand accelerated the bootstrapping of the KM, despite the element of duplication that was introduced as knowledge was recorded in the state-of-the-art reports and again in the KM.

4.3 Knowledge Refinement

Since the first public release of the KM, we have performed two major refinement cycles, each resulting in a new version of the KM with one more expected by the end of the project. The motivation for carrying out these cycles is not only to add content to the KM with new knowledge produced by the network, but also to ensure the *quality* of the KM terms. Furthermore, as described earlier, a major goal for the KM is the identification of gaps and overlaps in knowledge produced by different domains, which provides feedback about the status of research in the network and ensures KM *consistency*. Since the KM is an evolving resource, we recognized the need for a clear set of repeatable processes to ensure the continuous growth, quality and consistency of the KM. To this end we defined and implemented three major actions that are carried out at regular intervals:

The KM Update Process To ensure its quality, each deliverable is reviewed both internally by different project members and externally by reviewers assigned by the EC. An approved/accepted deliverable contains new or updated terms and definitions that need to be recorded in the KM. The same procedure as before is used to extract knowledge from a deliverable and enter it into the KM, with the only difference being that the person contributing to the KM should check for existing terms and definitions before adding them. As each JRA produces deliverables in a different periodic cycle, this complicates the application of this process. For this reason we decoupled it completely from the production of deliverables and the process is triggered at regular intervals independent of the JRAs deliverable cycle. However, this approach introduces an element of reproduction as knowledge is first captured in the deliverable and then again in the KM. Unfortunately, this is a direct result of EC reporting requirements that mandate the

Research Theme		Technology Principles, Techniques & Methodologies			
		Engineering & Design (ED)	Adaptation & Monitoring (AM)	Quality Definition Negotiation & Assurance (QA)	Generic or Domain-specific
Service Technologies	Business Process Management (BPM)				
	Service Composition & Coordination (SC)				
	Service Infrastructure (SI)				
	Generic or Domain-specific				

Table 1: S-Cube Knowledge Model Template

presentation of knowledge in deliverable (i.e., document) format.

Lessons Learnt: The completion of terms was helped by two factors: when deliverables contained a *glossary of terms*, the entry of definitions was speeded up as it was easy for the person entering the data to copy-and-paste the definitions into the KM; and, as the deliverables used as knowledge sources had already been reviewed both in the internal authoring process and externally by the EC, the quality of the knowledge being added to the KM was already assured, which also helped the person creating or completing a term. Regarding the coordination of who entered which terms and definitions, we found letting people self-organize themselves within the JRAs to process deliverables was preferable to telling them what should be done and when. This 'bottom-up' approach provided a *sense of ownership* of terms, research domains and the KM in general, as contributors essentially became stakeholders.

Quality Assurance (QA) Process – Format The manual addition of definitions to terms and additional information for associated competencies, validation scenarios and references to publications/deliverables, led to mistakes in the formatting of some terms. We found the most common problems to be:

- Typos, grammatical and expression mistakes.
- Misuse of the term template, such as entering information outside of the grid/template.
- Definitions that were copy-pasted directly from a deliverable sometimes only made sense in the context of the deliverable it was taken from.
- References to deliverables or publications that contain the definitions provided were missing.

We addressed these issues by designing a straightforward QA procedure that was applied by manually checking each page: following the completion of the data-entry stage of the process, each term in the KM was assigned to a contributor (not the person who entered or modified the term during the KM update process) who checked the term for these problems and modified it if necessary. To distribute the terms between S-Cube partners fairly, we developed a simple algorithm that automatically and randomly assigns a proportional number of terms to each partner for checking based on the amount of stated effort the partner is willing to put into the QA process.

Lessons Learnt: Manual addition and editing of the KM content generates mistakes and requires a manual QA process. As this process was carried out after each round of KM update, terms were checked and quality-assured in a regular cycle and formatting mistakes were not long-lasting. Errors due to manual editing were mitigated by iterative QA, as well as by codifying the knowledge structure (in our case through templates). Also, as contributors became familiar with how the template should be used we found that the number of these errors has decreased with each entry cycle.

Quality Assurance Process – Content The second aspect to QA is checking the accuracy of the knowledge entered in the KM. We observed early in the

KM's lifecycle that too many domain-specific terms were being entered at the expense of context-specific terms. This was reflected by a dense concentration of definitions in the shaded area of Table 1. The origin of this problem was found to be a result of the design of the research framework around focused research domains, which meant researchers were unsure of how their contribution applied to other domains. In particular, while questioning contributors to the KM they stated that they were uncomfortable adding a context-specific definition to a term except if they were an expert in both domains. In our opinion, this is a more general problem concerning how people behave in large groups of experts and is a larger issue outside the scope of our analysis.

Therefore, to ensure an even distribution of knowledge in the KM, we designed a process which normalizes and rationalizes the distribution of definitions within the terms, 'landscaping' the recorded knowledge. To do this, we classified each S-Cube partner as specializing in either service realization techniques (rows in Table 1) or cross-cutting concerns (columns in Table 1). We then classified terms as being either domain-specific to service realization techniques or cross-cutting concerns depending on their definitions. Domain-specific terms in service realization techniques were assigned to partners who specialized in cross-cutting concerns and vice-versa to ensure as much as possible that 'new eyes' viewed the term. As in the case of the format-focused QA process above, we assigned the terms to partners based on each partner's intended effort (in person months) to determine the proportion of terms they should 'landscape'. Once a partner received their set of terms to validate, we asked them to determine for each term if each domain-specific definition could be replaced with a context-specific definition. If it could be, we asked them to modify the term accordingly.

Lessons Learnt: After we assigned terms to institutions for checking we found further evidence of self-organization. Terms were swapped between institutions so the right expert could address a particular definition. This also supports our finding that people were uncomfortable editing terms that they did not feel to be an expert in. Furthermore, delegation of responsibility to empowered teams per institution allowed them to autonomously forward KM terms to the 'right' peers. This practice requires that teams know who knows what, a known best practice in knowledge sharing (Clerc et al., 2007).

We initially applied the QA processes for formatting and content to all the terms in the KM. However, as the number of terms in the KM grew, the workload on members of S-Cube carrying out the QA processes increased. To reduce the effort required we prioritized the checking of terms modified since they were last subjected to QA (i.e., terms not modified since the last round of QA were not re-checked) and those which had only domain-specific definitions. We determined which terms to check and which to leave out of the process by developing a set of tools to 'crawl' the KM, find simple formatting errors and determine the distribution of definitions within the term. These tools, and the implementation of the KM, are described as part of the next section.

5 Implementation

5.1 Platform

For the implementation and publication of the S-Cube KM we used the Plone content management system (CMS) (McKay, 2009). Plone is a versatile free and open source CMS oriented towards web page publishing but also supporting document publishing and groupware applications. Four reasons led us to using Plone as the platform for the KM:

1. There was a heavy investment in implementing the project's web portal using Plone. In contrast, there was no provision in the budget of the project for separate infrastructure for the KM.
2. Other knowledge management solutions, such as the Simple Knowledge Organization System (SKOS), were immature at the time we were seeking a KM platform. A separate platform would also require integration with the main project portal, which would require additional effort.
3. Plone offers wiki-like capabilities like collaborative editing and versioning that were deemed to fulfill our purposes.
4. The use of a CMS like Plone for the KM means that data input and editing is done through the browser. No familiarization effort with a particular tool (further of the one for learning the template) is therefore necessary and the learning curve is shallow and short.

Lessons Learnt: Using an out-of-the-box CMS system was cheaper in terms of time and money than developing a new application with database schema, persistence methods, middleware and presentation layer. As the KM was implemented in the same CMS as the network's web portal, there was no overhead for integrating the KM with a primary dissemination channel of S-Cube. This increased the *visibility* of the KM and in time the KM became synonymous with the S-Cube NoE. Regarding the adoption of the platform, partners within the network were more than happy to contribute their knowledge using Plone and this ensured the steady accumulation of knowledge and growth in the total number of items. We feel that this success was mainly a result of the KM being implemented using a standard, what-you-see-is-what-you-get CMS that had the same 'look-and-feel' as the project's web portal.

5.2 Functions

The implementation of the KM based on Plone provides to the KM users and contributors with the following standard functions, which are accessible in a tab-based view:

View displays the actual content, along with page creation information. Also allows for direct editing of the term by double-clicking on the page.

Edit allows the editing of the term.

Sharing provides the option to make the term visible to and editable by particular users.

History shows a description of changes to the term per user and date, allowing for differencing between versions and offering roll-back to a previous version.

These functions are available only to registered users of the S-Cube Web portal, allowing us with a better control over the KM modifications. Unregistered users of the KM Web page are offered only the view function.

5.3 Applying the KM Template

In order to apply the KM Template discussed in the previous section, a standard page was created containing an empty KM term template. Each new KM term was (and still is) created by copying this template page, completing the term-specific details and saving as a new page. Each term is represented in a single web page and has a unique URL, allowing for indexing, bookmarking and sharing of the URL. A subdomain in the web portal was created to contain these pages, publicly accessible at `http://www.s-cube-network.eu/km`.

Lessons Learnt: The copy-and-paste of text from various sources to the CMS behaved differently depending on which browser is used by inserting hidden characters in the pasted text. These characters are not directly a problem since they are simply not rendered to KM viewers. However, they become important when we use automated tools (discussed below) to extract the information they contain for data analysis and reporting.

5.4 Tool Support

As part of the KM development and QA processes, we created a set of command-line scripts to check the format and content of the KM and ensure its general consistency. As the KM is deployed within the S-Cube web portal and access to the main Plone database is restricted, the tools were developed to 'crawl' the KM by following the hyperlinks found in the KM term index and retrieve each web page representing a term, parse the HTML and create a local in-memory representation. Using this representation allows the formatting and content analysis of the KM terms and the automatic report generation that support the management of knowledge in the KM. They have also allowed us to perform the transformation of the KM into different formats, e.g., XML dialects such as GraphML, which was used in an attempted visualization of the relationships between concepts.

Lessons Learnt: Although 'screen-scraping' is often seen as an archaic method of gathering data, this approach has worked well for us: building tools in a programming language known for its speed of development (i.e., Ruby (Flanagan and Matsumoto, 2008)) allowed us to spend a minimum amount of time on developing supporting tools for the KM. The standard structure of each term meant that once the main body of code for retrieving and processing web pages was written it only needed to be extended to generate new reports.

6 Evolution

In principle, the evolution of the KM is driven by the progress of the network, i.e., the more knowledge produced by the partners, the more content (terms, definitions, competencies and references, etc.) is added to the KM. The development of the KM content over time is summarized by Figure 3. Measurements are shown at 7 different points in the network's lifespan that coincide with deliverable releases, project reviews and contractual milestones, where Month 1 of the network corresponds to March 2008. There are two major growth periods in Figure 3, around month 13 and month 33, marking the production of two major versions of the KM (the first public release and the *consolidated* version, respectively).

The latest version of the KM (month 39 of the project) contained 688 definitions across 419 terms with 215 recorded competencies. Due to the nature of the processes discussed in Section 4, there were very few removals of terms from the KM, with the emphasis being on reconciliating and landscaping problematic terms — which also partially contributes to

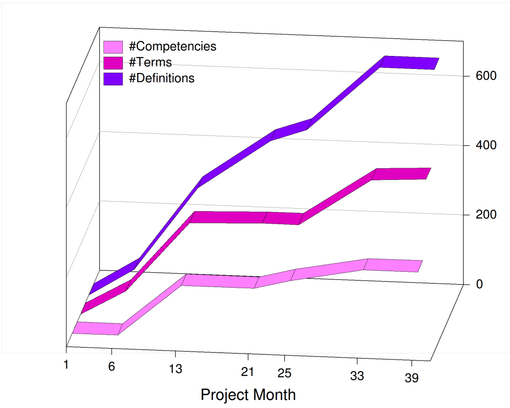

Figure 3: Evolution of the KM

the continuous growth of the KM shown in Figure 3. Overall, Figure 3 reflects the periodical nature of the activity in the KM on behalf of its contributors where short periods of intense activity and growth are followed by longer periods of smaller activity and corrective actions. This is to be expected since the evolution of the KM is aligned with the network's timeline, defined by the deliverable schedule and important milestones at specific intervals (e.g., annual reviews).

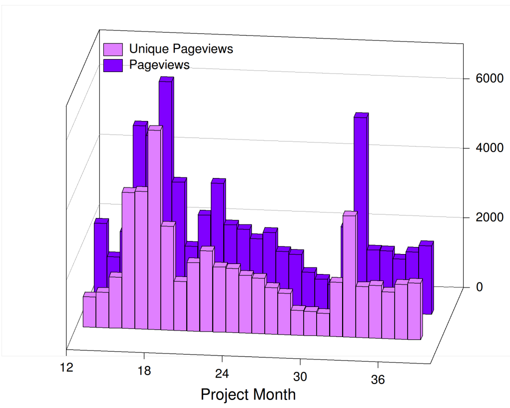

Figure 4: KM Visits – Source: Google Analytics™

In terms of public visibility of the KM, Figure 4 shows the number of visits to the KM subdomain of the S-Cube Web portal as reported by Google Analytics. The KM receives on average approximately 2500 page views and 2000 unique page views (i.e., number of visits during which one or more of the KM pages were viewed) per month since going public. The KM is visited from users in more than 100 countries, with USA, India, Philippines and Canada in the top 10. Note that the support tools discussed in Section 5 access the KM via an external HTTP connection and do not effect the data gathered by the Google Analytics service used to provide metrics of the KMs use and popularity.

Lessons Learnt: In most months, the difference between page views and unique page views is relatively small, meaning that KM visitors view just a few pages per visit, as shown in Figure 4. This can be explained by the lack of *direct links* between terms in the KM, which discourages viewers from navigating between them, as one would when browsing Wikipedia. We are planning to address this deficiency of the KM by adding (hyper)links between terms as part of the final version.

7 Further Lessons Learnt

Generally, we have found the development of the S-Cube KM to be remarkably smooth: conflicts between researchers, such as those regularly observed between Wikipedia authors fighting to have 'their' knowledge accepted, were minimized due to several factors (listed in no particular order):

- The grid structure of each term allowed multiple definitions to co-exist within the same term.
- The production of the state-of-the-art reports in the initial phase of the network gave S-Cube researchers the opportunity to understand their partners research strengths, weaknesses and perspectives and use them in later stages of the project.
- Most discussions over the finer points of terminology had already taken place as the deliverables were being produced so by the time they entered the KM most ambiguities, discrepancies and controversies had already been removed.
- The network's emphasis on regular face-to-face meetings to encourage joint research allowed researchers to start 'speaking the same language' more quickly than if their relationships had been remote. In terms of impact to the KM, the shared understanding of the objectives of S-Cube created by these meetings facilitated the KM construction.

We feel the success of the KM can be also demonstrated in examples of how the KM has been and is currently being used as:

A point of reference: for example, the terms and definitions from the S-Cube KM were used as a commonly accepted glossary in (Dustdar and Li, 2011).

A teaching aid: the KM has been used in the S-Cube Virtual Campus[5] to tag course material so they can be re-used by lecturers and students across teaching modules.

An accepted knowledge source: as discussed in Section 6, the KM has been accessed by researchers from

[5] `http://vc.infosys.tuwien.ac.at/`

many countries seeking an accepted definition for a term. In this sense, the KM has provided publicly-available reference material for researchers in SSME and helped to align research across domains.

A hub for other EC knowledge-related activities: the S-Cube KM has been adopted by other EC-funded projects, e.g., the Hola! co-ordination activity[6] intends to build a repository of structured knowledge using KM terms from projects in the SSME area.

8 Conclusion & Future Work

This paper presents our experiences in developing a Knowledge Model (KM) for S-Cube, a large, pan-European research network that brings together scientists and practitioners from different areas to carry out fundamental interdisciplinary research in SSME. The KM aims to map, integrate and synthesize various concepts from different research areas, facilitates research by consolidating and reconciling overlapping definitions used by each research area and provides a resource that can be used as a reference point, teaching aid and a hub for project activity.

The variety of communities involved and the differences in how they use terminology led us to design a template to capture knowledge that allows the positioning of knowledge within a domain and context. We implemented this template using the content management system (CMS) used to provide the network's web portal and developed an iterative methodology to accumulate knowledge captured in project deliverables (documents that aggregate existing knowledge and/or contain existing work) in the template. To address issues with mistakes due to manual editing and uneven distribution of knowledge across the KM we developed and applied appropriate QA processes at regular intervals.

By observing the KM's evolution over many months we can conclude that network members were happy to contribute their knowledge to the KM, resulting in a successful product. The number of accesses to the (publicly available) S-Cube KM from all over the world is evidence of this success. During the different phases of the KM construction we had to take a number of design and management decisions. It is our intuition that some of the lessons learnt in these decisions are more applicable/useful for large communities (like S-Cube) and distributed/virtual ones (as in the case of Wikipedia) than others (e.g., enterprises). Further investigation of our findings are necessary to provide empirical evidence of this intuition. In addition, we plan to investigate visualization techniques for the KM that will make it more accessible to users.

[6] http://best149.best-center.external.hp.com/eu/node/12

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