Combining Model-driven and Capability-driven Developments A Case Study of Industrial Symbiosis

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Abstract

This paper reports on a practical case that involved the confluence of an industrial software development platform, based on the model-driven development paradigm and a research methodology and prototype set of tools, based on the notion of capability. The focus of the application is the development of a web-based industrial symbiosis platform. The outcome is an example of a successful alignment of business-facing aspects with those informatics constructs that ensure alignment of between goals and processes of an enterprise with its support IT system.

1 Context of the Case

This paper reports on an industrial case that has been developed using a combination of (a) an existing software development platform based on the Model Driven Architecture (MDD) paradigm[1] and (b) the method and tools that have arisen as a result of a project[2] funded by the European Commission. This industrial case was carried out by CLMS (UK) Ltd, a software technologies company.

The work reported in this paper involved a software service from the area of industrial symbiosis, henceforth referred to as *i-symbiosis*. This is essentially a specialized *capability* that acts as "enabler of web industrial symbiosis".

Industrial symbiosis (IS) is an association between two or more industrial actors in which the wastes or by-products of one become the raw materials for another. This collaboration between two or more companies is called a ***synergy***. Industrial symbiosis brings together companies from different business sectors, with the aim to improve cross-industry resource efficiency through the commercial trading of: waste materials, energy and water, sharing of processes and assets such as logistics and expertise.

As a result, waste across a wide range of industrial activities, including chemicals, plastic, biomass, electronic and plastic, is reduced, and costs in raw materials, waste discharge and energy consumption are saved. Traditionally, experts and consultants, involving highly complex, labor-intensive and error-prone tasks that often lead to problematic and sub-optimal reuse of available resources, performed industrial symbiosis mediation process for the matching between producers and consumers manually.

For the i-symbiosis service we considered such an exchange amongst firms as being organized "virtually" across a broader region, taking into consideration three contextual factors that are key to industrial symbiosis, namely those of *location*, *resources* and *legislation*. The key phases of i-symbiosis are depicted in Figure 1.

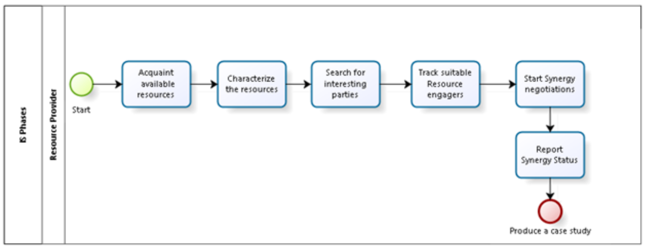


Figure 1 IS Key phases

Waste providers must insert to the platform their available resources and their type along with other resource-details (Phase 1 & Phase 2). In the 3rd phase, the waste provider searches for interesting parties (waste engagers). An industrial symbiosis

[1] This platform is a proprietary platform for the CLMS (UK) Company, known as zAppDev, details of which can be found in http://www.zappdev.com.
[2] Information about this project, known as CaaS (Capability as a Service) can be found in http://caas-project.eu.

platform has to match automatically the provided type of resources to suitable exchange resources and track the available industries, which can act as resource engagers. After the matching process, the waste provider selects one or more of the available matching results to start a synergy. Within the Synergy collaboration, the two interesting parties (waste providers and waste engagers) negotiate about the waste exchange. The last stage in the platform is to report the status of the synergy. Whether successful or not, a report is created which demonstrates the synergy timeline and the arguments supporting either the success or the failure of the synergy. By the end of this industrial symbiosis workflow, the platform creates a “case study” upon the synergy collaboration based on the report.

We considered the provision of service of i-symbiosis as being possible through the capability “enabler of web industrial symbiosis”. This was further analyzed in terms of three capabilities: (a) determining relevance rating, (b) resource description and classification and (c) compliance with regulations. For (a) automated adjustments were considered based on location context; for (b) semi-automated adjustments were considered towards resource monitoring; and finally for (c) manual adjustments were considered for legislation handling.

2 The Business Environment of CLMS

2.1 Introduction of CLMS (UK) Ltd

CLMS (UK) Ltd was established in 1998 with a vision to simplify business change management, with specific focus on IT Systems. CLMS design and produce business-driven IT systems based on an agile methodology and with the ability of maintaining their services and to be constantly aligned with cutting edge technology trends.

All development activities are driven by models that capture business semantics and provide a clear overview of every component of the application. By using models and process logic descriptions, CLMS achieve to offer customized and tailored services. They provide to their clientele a variety of services, including ERPs and cloud-based ecosystem solutions.

The “philosophy” of CLMS is to continuously improve the services they provide through an increased level of their capabilities. At the same time, the knowledge and experiences they gain from the delivery of these enhanced services, directly impacts, informs and evolves their own capabilities. This feedback causality loop is the CLMS meta-capability that it strives to maintain in all of its business activities. It is a continuous capability development and improvement cycle that is facilitated and indeed it is embodied in a specific platform, namely that of the zAppDev platform.

Therefore, by participating in the CaaS project, CLMS strives to enhance their capabilities, specifically those that relate to their core products and services that are embedded in the zAppDev platform.

2.2 Introduction to zAppDev

zAppDev is a cloud-based application development environment. It supports high-level modeling, design validation and code generation in order to automate repetitive tasks and produce consistent applications for multiple platforms. Changes in the design and technology are incorporated fast through an automation engine, using model compiler templates. zAppDev facilitates IT and business teams’ collaboration; applications can be tested immediately after each build. Their clients can test their application from day one and throughout the design and development life cycle.

zAppDev is model driven. It provides a complete integrated approach for modeling business requirements, workflows, business logic, data and web services, and user interfaces, and automatically generates the complete software application from these models. zAppDev is quite different from other application development frameworks (e.g. Ruby on Rails), because it is not tied to a particular programming language, and/or type of application that it can produce.

Because zAppDev is model driven, CLMS is able to provide complete integrated solutions to a large variety of domains. With each domain analysis and implementation, zAppDev can adopt extra features of functionality within it and evolve as a software platform (as mentioned already about the CLMS business capability development).

Consequently, zAppDev itself offers to CLMS the key features of: reusability, customizability, adaptability, and extendibility.

In summary zAppDev offers:

1. Platform independence
2. Incremental instantly-adaptive development
3. Integrated Architecture Governance and Flexible Application Life-Cycle Management

2.3 Introduction to CaaS

The CaaS project proposes a capability-driven approach to business and IT development in order to produce solutions capable of fitting to changing business contexts and at the same time taking the advantage of emerging technology solutions. From the business perspective, we define capability as an ability to continuously deliver business value in dynamically changing circumstances [1]. From the technical perspective, capability delivery requires dynamic utilization of resources and services in dynamically changing contexts.

The overall ethos of the CaaS project is to create an integrated approach consisting of methods, tools and reusable best practices that allow digital enterprises to take advantage of changes in business context and technologies.

The main contribution is a new methodology for joint digital business and information system development referred as the *capability driven development (CDD)*. The CDD provides the means for coping with a variety of business execution alternatives and for adjusting business delivery according to changes in the operating context.

The conceptual elements surrounding capability, are based on the core concepts of Enterprise Modeling e.g. [2, 3] with extensions that offer opportunities for a greater and a more in-depth analysis [4, 5]. Figure 2 depicts the interrelations among *business capability* entity with already known concepts such as *business goals, KPIs, business processes, context, resources* etc.

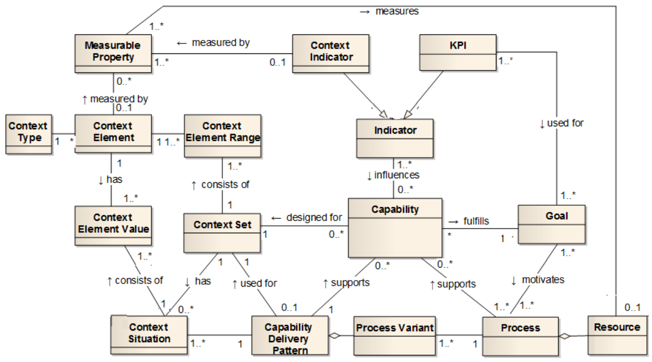


Figure 2 The 'capability' meta-model

A capability development environment is also established. The main components of the environment are[3]:

- **Capability Design Tool (CDT)**: a graphical modelling tool for supporting the creation of models (goal models, process models, concept models, context models, business processes and capability models) according to the capability meta-model.
- **Capability Context Platform (CCP)**: The context platform is a platform for gathering the context information defined in a context model and distributing it to the CNA.
- **Capability Delivery Navigation Application (CNA)**: a web application that imports the capability models defined in the CDT in order to monitor the described context. CNA connects to the context platform to monitor the capability context, informs the capability analyst and business services manager about current KPIs and handles run-time capability adjustments.
- **Capability Delivery Application (CDA)**: A CDA represents the business application or service used to support the capability delivery.

A high-level architecture design of how these components are related is shown in Figure 3. It describes interaction between essential components of the system: CDT as design-time tool, CNA and CCP as general runtime support, CDA and custom data providers developed for each use-case.

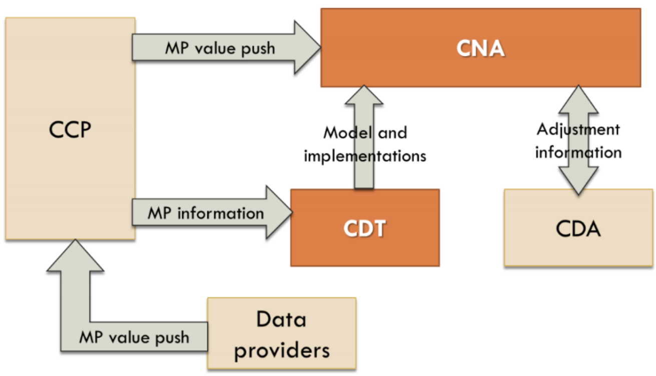


Figure 3 CDD Architecture Design[4]

[3] Described in D5.3: Final Version of CDD Methodology, Deliverable of CaaS Project, 31st of May, 2016

[4] Architecture Design is taken from D6.6: CDD Environment Documentation, Deliverable of CaaS Project, 29th of April, 2016

3 Designing of the I-symbiosis Platform

CLMS aimed to implement an industrial symbiosis platform which would improve industrial symbiosis by automating the process of mixing and matching the interests of different actors in the symbiotic waste resource chain, and would provide knowledge-based support for managing resources and finding compatible ones. The platform should be able to suggest compatible matches to a company and facilitate the creation of Synergies for these matches.

At the core of the platform needs to be the industrial symbiosis semantic repository, which is based on knowledge graphs instead of relational databases. The knowledge management of resources is more efficient due to machine learning architectures and it is increasing the time of response within the system during the matching process while simultaneously the repository of resources will distinctly increase.

Through the industrial symbiosis web portal, users will be able to register to the system, access and enter information about resources, locations, their interests etc. in a user-friendly way, through maps, graphs, and wizards. Concepts and properties from the industrial symbiosis ontology will be used to guide users through the navigation and registration processes, and the information registered through the portal will be stored in the semantic component. Various types of user queries for finding contacts, companies, and resource matches will be supported.

User profiles along with information extracted from the semantic repository will be used by the matchmaker service, which computes intelligent matches between production and demand for industrial waste through a highly sophisticated algorithm. Optimal sets of possible collaborations between businesses will be produced by calculating the similarity between resources and technologies with respect to the distance between these concepts in the domain ontology.

The results calculated by the matchmaker will be presented to the user through appropriate views at the portal. Business users will be able to monitor and manage the established synergies lifecycle, e.g., access other participants' resources and information, or block the progress of a synergy. A number of metrics, such as landfill diversion, water savings, and CO_2 reduction, will be used to evaluate the performance and activity of synergies. These metrics will be available by the participating organizations, and they could be updated during a synergy's lifecycle.

Through a notifications system, industrial symbiosis practitioners will be notified about important changes in the synergies in which they will participate. Aggregated information and statistical reports about the synergies, sites, companies etc. will be also generated by the platform.

A use-case diagram representing the aforementioned description is depicted in Figure 4.

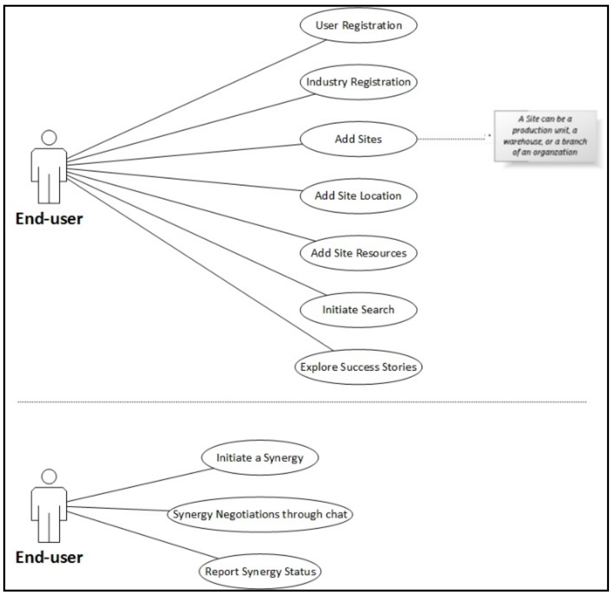


Figure 4 Industrial symbiosis use case diagram (Synergy sub-case)

The user groups of industrial symbiosis platform are the following:

- Waste producer
- Buyer
- Solution provider (Technology provider)

4 Enhancing CLMS Capabilities Thorugh a Confluence of zAppDev and CaaS

4.1 Identify CLMS' capabilities on a business level

Their capabilities are defined as such, because they are the result of the combination of resources, skills and business goals (e.g. Domain Modelling, Cloud Migration etc.). For delivering those capabilities, CLMS as a software house uses state of the art technologies such as Knowledge Models and REST/SOAP services. The collaboration of capabilities with technologies are providing CLMS services to their clientele (e.g. industrial symbiosis ecosystem).

All of these capabilities are met through zAppDev. zAppDev is a cloud-based application development environment. It supports high-level modelling, design validation and code generation in order to automate repetitive tasks and produce consistent applications for multiple platforms.

In these terms, the main business capability of CLMS is the *M_CAP1 Adaptive and Extensible Software Development*. This top business capability can be analyzed in terms of the *sub-capabilities* depicted in Figure 5.

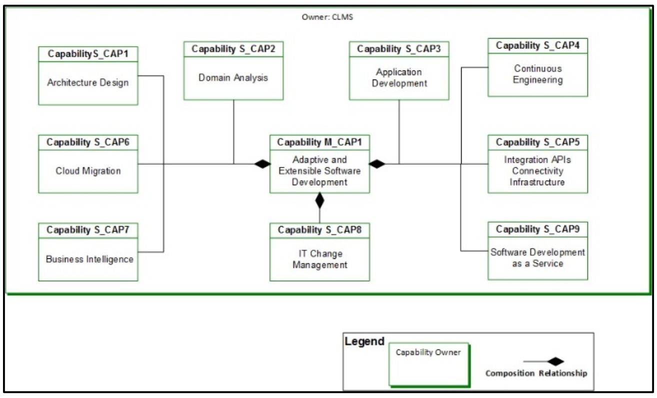


Figure 5 Capability diagram of CLMS

Each sub-capability is responsible for the delivery of one or several business services. An excerpt of that kind of interrelation is presented in TABLE 1.

TABLE 1 Capabilities and Services of CLMS

Services	Capabilities
ERP Solutions	S_CAP1 Architecture Design
	S_CAP2 Domain Analysis
	S_CAP3 Application Development
Industrial Symbiosis Ecosystem	S_CAP3 Application Development
	S_CAP4 Continuous Engineering
Maritime Connectivity Infrastructure	S_CAP4 Continuous Engineering
	S_CAP5 Integration APIs Connectivity Infrastructure
Bank Enterprise	S_CAP8 IT Change Management
	S_CAP9 Software Development as a Service

4.2 I-symbiosis capability driven analysis

For the implementation of industrial symbiosis platform, CLMS makes use of a set of capabilities that is composed of internal and external capabilities as shown in Figure 6. The collaboration of these capabilities, apart from delivering the service of industrial symbiosis, are creating a new capability for CLMS, the "Enabler of web industrial symbiosis", see Figure 6. Because zAppDev is adaptive and it is knowledge dependent, it "absorbs" all the knowledge, which was concluded from the combination of the set of the initial capabilities. The new capability for CLMS can be described as acting as the enabler of industrial symbiosis through a web based platform. This capability will be further analyzed into sub-capabilities.

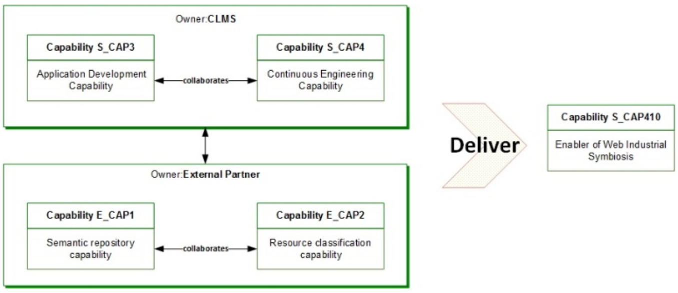


Figure 6 CLMS capabilities used for the industrial symbiosis capability

The goal model presented in Figure 7, is combining high level business goals which represent the philosophy of CLMS and specific use case goals which are setting the framework of implementing the industrial symbiosis platform. Thus, the goal models reflect the desired changes to be performed to improve the platform.

In order for CLMS to expand the industrial community regarding the synergies, they intend to introduce a web platform for industrial symbiosis (*CLMS GIS3*) and implement its functionalities with respect to the key concepts and goals of IS theory. In this holistic approach, they desire to face the various contextual factors that will possibly change the flow of i-symbiosis functionality (*CLMS GIS12*). Three goals are supporting the notion of context awareness which are introducing the main context elements of the desired platform: Resources, Location, and Legislation.

CLMS GIS14 is supported by two other goals. The first one refers to the designing of a resource repository (*CLMS GIS17*). In the platform the resource repository is designed with the use of knowledge graphs (*CLMS GIS10*). The use knowledge of graphs allows the platform to be adaptive and extendable in terms of adding new nodes in the existing graphs (resources in our case). The second goal supporting a knowledge graph repository is the use of patterns-templates (*CLMS GIS18*) for resource management. Giving an example, the platform is able to respond and function in different locations with different types of resources which may not be registered to the knowledge graphs. zAppDev already supports the use of existing templates in order to integrate "new knowledge". In this terms, when a new type of resource is inserted, through the use of templates a new node will be imported to the knowledge graph while the matching algorithm will incorporate the new details for managing the new resource. The matching process is based on a machine learning algorithm (*CLMS GIS9*) which will be evaluated against the existing data in the knowledge graph.

The design of the i-symbiosis platform also concerns the enhancement of monitoring the synergies process. The added value to the monitoring will be the enablement, in a more active fashion, of the role of facilitator (*CLMS GIS8*). The facilitator (*i.e.* the platform) is obliged to monitor a synergy from its start and provide continuous guidance to the involved industries. It is also be assigned with the role of handling deadlocks through the synergy collaboration and confirm the end of a synergy either successful or not. These responsibilities are extremely critical during a synergy and CLMS is mostly oriented to not fully automate them. A third party, e.g. the responsible municipality of the two interesting companies may be in charge for executing the activities of the facilitator and the platform will be assisting it.

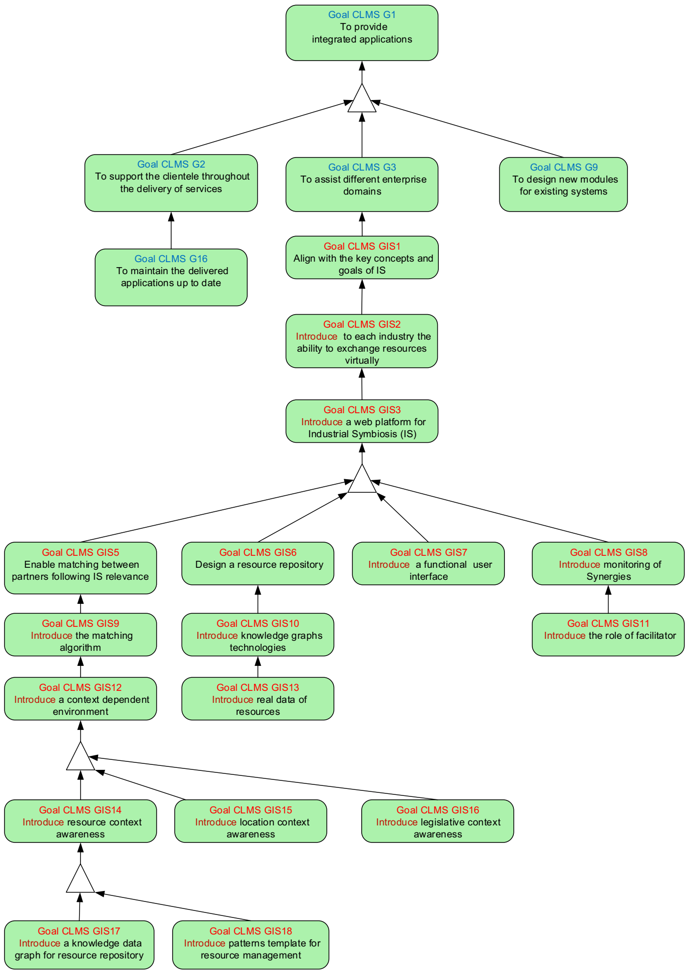


Figure 7 Goal model for i-symbiosis platform

The capability selected for further analysis and improvement where the "Enabler of web industrial symbiosis". This capability encompasses the CLMS capabilities and the capacity of providing a web based platform, the i-symbiosis platform. This is shown schematically in Figure 8. CDA in this application is the i-symbiosis platform, which is developed with zAppDev. CDA is communicating with the CNA application where adjustment information is exchanged. In our case CDA is also functioning as a data provider to CCP by continuously sending data to the context platform.

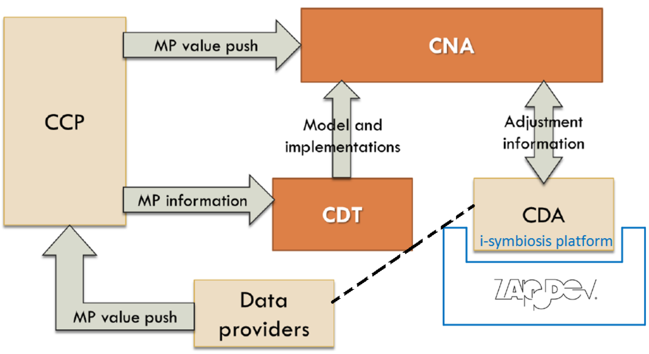


Figure 8 i-symbiosis platform linked to the CDD environment

Based on the three contextual factors that can affect the industrial symbiosis (location, resources, legislation), we analyze three scenarios where the CDD tools should enable the monitoring and enhancement of the existing capabilities. In each scenario, CDD tools will help in three different levels: automated adjustments, semi-automated adjustments and manual adjustments. The three scenarios led to the identification of three sub-capabilities, see Figure 9.

The combination of i-symbiosis platform with the CaaS tools is represented in Figure 10.

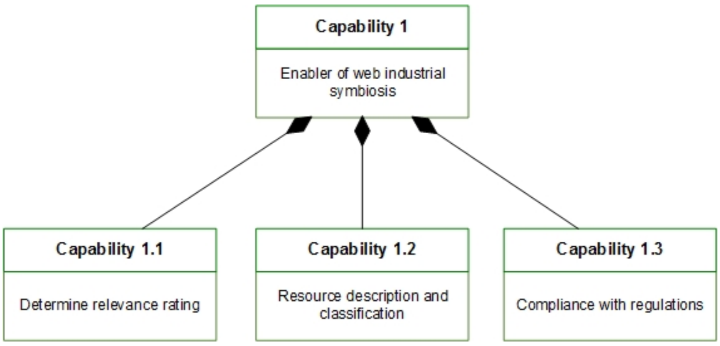


Figure 9 Overview of the four identified capabilites of the i-Symbiosis platform

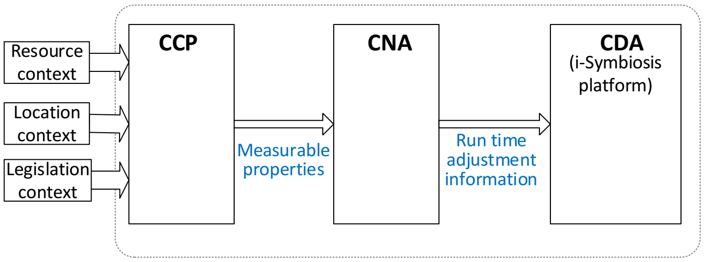


Figure 10 CDD tools and the i-symbiosis platform

4.3 Semi-automated Adjustments towards Resource Monitoring

In this section we will demonstrate one of the three scenarios identified which is about applying semi-automated adjustments towards resource monitoring.

4.3.1 Design and Analysis with the CDD Concepts

The "Resource description and classification" capability enables the detailed description of resources in order to enable a better match between organizations.

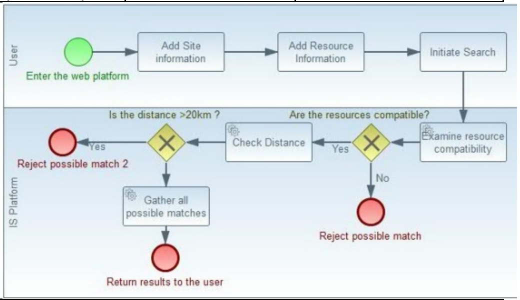
The CDA of i-symbiosis according to the industrial symbiosis process is checking the compatibility of resources during the match making procedure. The successful resource compatibility is essential for every possible synergy between two organizations. The description of resources to exchange can impact the number of possible synergies (matches). If the quality of the resource descriptions is low, there will (eventually) be difficulty to perform matching/create synergies. This in turn will eventually lead to the loss of the capability. The effect of using CDD in resource monitoring would be the early detection of loss in matching power.

The context, in terms of resource description and number of successful matches, can be monitored (using CCP and CNA). This could trigger a *manual* procedure for capability re-design if the values are below a certain level. For example, the attributes for describing the resource may need to be changed manually.

Similar to the first scenario, TABLE 2 describes the basic CDD concepts for this resource monitoring scenario.

TABLE 2 CDD concepts for the 2nd Scenario

CDD Concepts	**Use Case**		
Capability	Capability 1:Enabler of Web Industrial Symbiosis		
	Capability 1.2: Resource description and classification		
Goal	Create and support a network for Industrial Symbiosis (Capability 1)		
	Hava a high quality of the resource descriptions (Capability 1.2)		
KPIs	Number of matches per entered resource		
	Number of attributes used per resource matching		
Context	**Context element range**	**Context elements**	**Measurable Properties**
	Poor (0-	Matching health	Relative amount of

CDD Concepts	Use Case		
	20%), Stable (20-50%), Good (50-65%), Very Good (65-100%)		successful matches
Process			
Process Variants	P1) Unchanged process (see above) P2) Introduce a manual design process to improve the resource description. This process could be triggered by a poor matching health.		

4.3.2 *Implementation with the CaaS Tools*

For the i-symbiosis platform, the initial concept is to be able to check the compatibility of resources during the match making procedure. The successful resource compatibility is essential for possible synergy between two organizations.

The description of resources to exchange can impact the number of possible synergies (matches). If the quality of the resource descriptions is low, there will (eventually) be difficult to perform matching/create synergies. This in turn will eventually lead to the loss of the capability. The effect of using CDD in resource monitoring would be the early detection of loss in matching power.

By using the CDD approach the context, in terms of resource description and number of successful matches, is monitored (using CCP and CNA). This triggers a manual procedure for capability re-design if the values are below a certain level. For example, the attributes for describing the resource may need to be changed manually.

Figure 11 shows the proposed technical implementation for this scenario.

In the architecture, the following interactions occurs:

- The *CDA* continuously send information about the number of successful matches to the CCP. This is done through a *data provider*.
- The *CCP* send the context information further to the *CNA*.
- The *CCP* send the context information to the *CNA*.
- The *CNA* can, based on the context information, calculate if the information deviates from a certain set threshold. For this implementation an *adjustment calculation* will be implemented in the CNA. This is done to use the CNA adjustment features.
- A *manager* can use the *CNA* to monitor indicators related to the matching information. This is done to ensure that the system is running according to the set business goals.

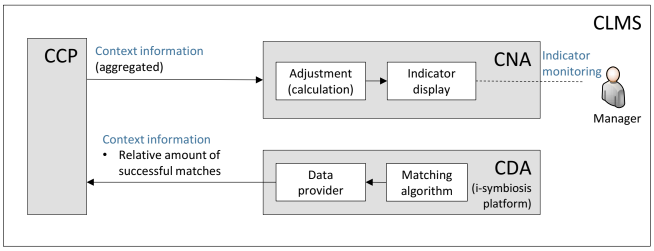


Figure 11 Overview of the technical architecture for resource description

The calculation of the relative amount of successful matches was implemented using a data provider in the CDA. CDA (i-symbiosis platform) has an implemented API REST service that sends, with interval time set to 1 day, the percentage of successful matches achieved. The threshold for monitoring this amount was 25%. Therefore the context element range for our context element *CE2: Amount of successful matches* was set in 25-100%. If the amount is within the specific range the status of capability in the CNA is shown as "working". Otherwise a red indication is shown where the status is represented as "not working" (see in Figure 12).

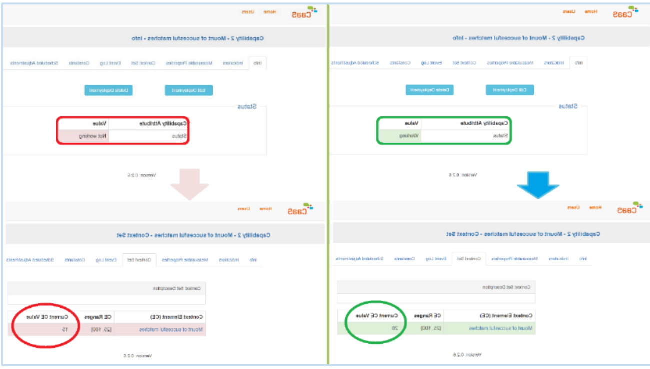


Figure 12 CNA context element for monitoring matches

The CNA indicator display for the specific context element "Amount of successful matches" is shown in the figure below (Figure 13).

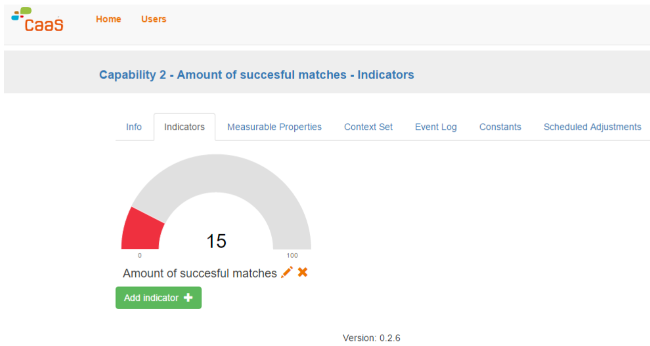


Figure 13 CNA dashboard display amount of successful matches

5 Lessons Learned

This paper presents the analysis and initial capability designs of the industrial symbiosis (i-symbiosis) application at CLMS. The i-symbiosis business application is realized by the zAppDev Model Driven Development tool that CLMS owns and uses for collaborative information system development for its customers. The use case at CLMS hence exemplifies a business scenario when an organizational capability (industrial symbiosis) needs to be supported by a custom-made capability delivery application (i-symbiosis platform).

The analysis and implementation presented in this paper lead to interesting points for discussion.

The capability driven analysis of CLMS on a business level defined their strengths and 'possessions' in terms of resources, setting of business goals and identification of business processes. The declaration of their capabilities and the kinds of technologies that are currently using led into how those capabilities turn into a business output for them. The business analysis was also useful for identifying how the available technologies can be combined and how flexible their software development environment is, to adopt new ones.

We realized that the setting of business capabilities can be further analyzed to the sub capabilities of each use case or business output served by CLMS.

The selection of i-symbiosis platform as the exemplary work was not selected by chance. CLMS intended to create the platform in a way that the context aspect of the industrial symbiosis theory is included to the design and implementation phase. CDD methodology and the tools provided within the CaaS project, takes into consideration the context awareness.

During the analysis of i-symbiosis use case, the CDD methodology contributed to the definition and evaluation of the assets, capacities and abilities that CLMS possess in general. The thorough description of their business capabilities brought to the forefront the unique elements and features that their software development tool, zAppDev, has to offer. zAppDev is an innovative web-based software development tool for developing integrated and complete software solutions and applications The fact that it is an MDD tool made the analysis even more interesting, since zAppDev already embraces various elements of this particular methodology regarding the CDD phase.

Model driven environments share common ground with the CDD concepts since they are both aligned with various modelling concepts. It is only logical to further examine their interrelationships and any correspondence of concepts in order to combine their individual characteristics into an integrated approach. However, the models used in CDD have a focus on describing capabilities, their contexts, goals etc., while models developed according to the MDD principles focus on components of software systems, such as, data objects, information management procedures, user interface components etc. CDD does not include specific methods and tools for the detailed creation of information systems. Thus, combining the CDD approach with MDD gives the possibility to have support for capability analysis and monitoring (provided by CDD) and the detailed implementation of information system (provided by MDD).

The overall aim of using zAppDev or similar MDD tools in congruence with CDD is to support its applicability to enterprises that require capability designs but lack software to achieve context dependent capability delivery. To address dynamic requirements of today's business environments, one should go beyond static design of services that are aligned to organizational objectives and business requirements. It is our premise that the confluence of MDD and CDD offers many advantages to the alignment of businesses and IT solutions.

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