Institute of Architecture of Application Systems

University of Stuttgart
Universitätsstraße 38
D–70569 Stuttgart

Diploma Thesis Nr. 3708

Investigating the Virtual Representation of Human Resources

Mert Canko

Course of Study:	Softwaretechnik
Examiner:	Prof. Dr. Frank Leymann
Supervisor:	M.Sc. C. Timurhan Sungur
Commenced:	January 15, 2015
Completed:	July 21, 2015
CR-Classification:	H.1.2

Abstract

Despite all the advancements of software technologies to increase the productivity of companies, their capabilities to find solutions for certain problem domains are still limited. For the purpose of collaboratively addressing problems, which cannot be solved by algorithms alone, humans as computational units that are connected in a network of hardware and software resources, are therefore becoming increasingly popular.

In this diploma thesis we investigate virtual representations of human resources by analyzing properties of scientific work in the areas of human computation and by examining available sources of information, especially social networks like Facebook, Google+, LinkedIn, XING and GitHub. To comprise both the academic requirements and the offered data from the market products, which according to our comparison substantially differ, we present our concept of a virtual human resource representation. It provides thirteen categories of more than 150 definable attributes to create a basis for the representation of human resources in virtual environments that support collaborative work and business-related processes. Furthermore we show how to access human information using the example of Google+ and how to save this information as a virtual human web ontology instance to be potentially used in web based environments.

Kurzfassung

Trotz aller Fortschritte in den Gebieten der Softwaretechnologie um die Produktivität von Firmen zu steigern, sind diese immer noch begrenzt, um Lösungen für gewisse Problemstellungen zu finden. Für den Zweck kollaborativ Proleme anzugehen, die durch Algorithmen alleine nicht gelöst werden können, werden Menschen, die als Recheneinheiten mit anderen Software- und Hardware-Ressourcen verbunden sind, zunehmend populärer.

In dieser Diplomarbeit untersuchen wir virtuelle Darstellungen von menschlichen Ressourcen durch die Analyse von Eigenschaften aus wissenschaftlichen Arbeiten in den Bereichen der Menschen-basierten Datenverarbeitung und durch die Prüfung verfügbarer Informationsquellen, insbesondere sozialer Netzwerke, wie Facebook, Google+, LinkedIn, XING und GitHub. Um sowohl die akademischen Anforderungen, als auch die angebotenen Daten aus den sozialen Netzwerken zu erfassen, die sich entsprechend unserem Vergleich wesentlich unterscheiden, präsentieren wir unser Konzept der virtuellen Repräsentation einer menschlichen Ressource. Sie bietet dreizehn Kategorien mit mehr als 150 definierbaren Eigenschaften an, um eine Grundlage für die Darstellung von menschlichen Ressourcen in virtuellen Umgebungen zu bilden, welche gemeinsames Arbeiten und unternehmensbezogene Prozesse unterstützen. Außerdem zeigen wir, wie man auf diese menschlichen Daten am Beispiel von Google+ zugreifen kann und wie diese Informationen als virtuelle menschliche Web-Ontologie-Instanzen gespeichert werden können, um möglicherweise in webbasierten Umgebungen eingesetzt zu werden.

Contents

List of Figures

List of Tables

List of Listings

1 Introduction

In a world where traditional computational approaches are rapidly changing by new discoveries of innovative technologies and possibilities, the way we composite components of solution to both simple and complex tasks need to increasingly adapt. To cope with the rising demands of industrial and business processes, marketing analyses, medical and scientific research as well as of private undertakings which utilize hardware and software technologies, more sophisticated mechanisms of accessing and connecting resources with processing and storing capabilities become of prime importance. In the last few decades a new field of application called social computing has emerged, enabling humans to communicate, produce and share socially created information, thus having gained the attention of most diverse industries as a new resource of influence for today's businesses [Sch94]. Increasing amounts of scientific research goes into exploring the potential of processing capabilities of human resources as individuals and collaborating teams and the possibility to access, manage and deploy these resources in cooperation with other hardware and software resources to create a more efficient and effective solution for problems far surpassing the reach of modern IT technologies alone [RTD14].

In this thesis, we will illuminate different properties and capabilities of humans with the focus on accessing them from social networks and providing them as virtual human resources to build a referential foundation upon which the desired solutions of all industries can be built.

1.1 Problem Description

In the year of 1981 a famous IT pioneer foresaw, that humanity will never require more computational memory than 640 kilobytes[1]. As we have witnessed until today including the mistakenly assigned quote to Mr. Gates, processing power and storage capacity have become two main aspects of continuous technological developments for the sole purpose of solving ever more complex problems of our daily lives. Starting from the navigation system that calculates the optimal route, the smart phone that processes and stores text, audio and video messages in real-time, up to the server farms that create the World Wide Web (WWW) and act as a host for all the information exchange, the computational requirements have always been increasing. A

[1] http://quoteinvestigator.com/2011/09/08/640k-enough/

more successful prophecy, being the Moore's Law, has fulfilled itself since 40 years and there seems to be no end in sight for at least another two decades [Moo06].

Despite all the technological development, modern theoretical informatics has proven that some specific problems will never be solvable by the current computational architectures, e.g. the famous halting problem[2] which proves, that it is undecidable whether an algorithm will ever stop. Even though humans are equally incapable of solving these problems, several problem domains of practical relevance have come to our attention, where human "computation" still has significant advantages over modern computers. A natural aspect of our communication, which is spoken and written language, can be easily understood and translated by a human into another language, whereas the current generation of translation algorithms used by our search engines, fail to deliver correct results depending on the translated languages [Dod12].

To distinguish between a computer algorithm and human intelligence, web services have started to use **C**ompletely **A**utomated **P**ublic **T**uring Test To Tell **C**omputers **A**nd **H**umans **A**part (CAPTCHA)[3][4], which are small graphics with embedded characters, that are displayed in such a distorted way, that optical character recognition (OCR) algorithms cannot parse their content, but humans in most cases can.

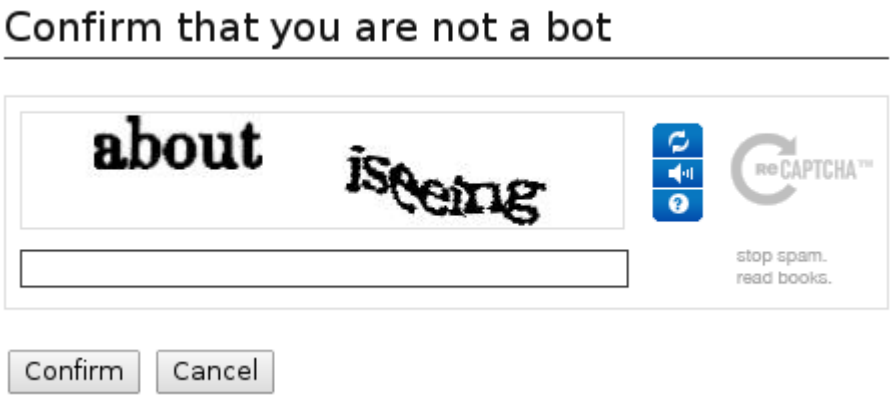


Figure 1.1: A recent example of the free reCAPTCHA[5]-implementation from Google.

The example in Figure 1.1 reveals the second category of problems, namely perception and interpretation of visual information, in which humans still have clear advantages over machines, especially in the accuracy of identifying and differentiating visual content.

Other problem domains are: *deciphering handwriting*, which is a combination of the above mentioned categories [RTD12], *visual pattern matching*, e.g. finding objects or people in a set

[2] http://plato.stanford.edu/entries/turing-machine/
[3] http://www.captcha.net/
[4] http://www.nytimes.com/2002/12/10/science/human-or-computer-take-this-test.html
[5] https://github.com/google/recaptcha

of images, *quality evaluation* of materials [DT12], *common-sense reasoning* [Sah09], which is the ability to draw conclusions based on common-sense knowledge, bug fixing and *incident response management* [MRST+14, RTD12].

For complex problems that cannot be reasonably solved by software alone, various research activities have come to the conclusion that human interference into algorithmic processes is required to provide more efficient and precise solutions [RTD12]. To realize these socially enhanced applications, so called "social computers" need to be invented, allowing human services to be combined with software technologies [TDB12].

Although different approaches to human-software and human-machine collaborations have been proposed by various theses and papers [DB11, DT12, TDB12, RTD12, SJB+13, TSBBL14], either highlighting required human properties and capabilities or the way in which humans can be modeled to work together, clarity about how to practically access available human information to be providable for any of the presented concepts has been missing so far [DT12, TSBBL14].

This diploma thesis will shed light on scientific requirements and market offerings, bringing clarity about these sources of information for the generation of a virtual human resource representation with software processing capabilities, ready to be accessed and applied to solve problems of most diverse domains.

1.2 Motivating Scenario

The popularity of humans as computational units is continuously increasing and a growing number of people leave their digital profile in various web platforms like Facebook and LinkedIn, depending on the network they want to participate in. Even companies start to create their own internal social networks to connect their workers to solve tasks more efficiently. The representation of humans in these virtual environments differ from product to product, are incompatible to one another and are limited to their own networks.

In our motivating scenario we have an online interacting company offering a web platform that allows users from different social networks to log-in with their accounts. The platform automatically generates a uniform representation of that individual and makes it accessible to be discovered, analyzed in regards to its attributes and used, e.g. as a human computing unit, that is capable of forming relationships, working in teams and solving tasks.

Although web services like Amazon Mechanical Turk provide a platform for both online workers and requestors[6], the human representation is limited to that platform and incapable of collaboratively working with other online workers. Additionally it is not possible to log-in

[6] https://www.mturk.com/mturk/

with any social network to automatically derive a virtual representation, nor does the provided platform profile fulfill the rising requirements for human computational units, which still need to be investigated by analyzing related academic research.

Therefore we will inquire into a human representation for virtual environments, that comprises the provided data of social networks and includes the required attributes for creating human computational units in accordance to the analysis of the scientific work, which we will tackle in this diploma thesis.

1.3 Definitions and Conventions

In this section, we list the definitions of abbreviations which are used in this diploma thesis.

API	Application Programming Interface
BPEL	Business Process Execution Language
BPM	Business Process Management
BPMN	Business Process Model and Notation
CAPTCHA	Completely Automated Public Turing Test To Tell Computers And Humans Apart
CLI	Command-line Interface
FMC	Fundamental Modeling Concept
HCE	Human-based Computing Element
HRO	Human Resource Ontology
HRP	Human Resource Provider
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
IRI	Internationalized Resource Identifier
JSON	JavaScript Object Notation
JVM	Java Virtual Machine
KIBP	Knowledge Intensive Business Process
MCE	Machine-based Computing Element
OAUth	Open Standard for Authorization
OCR	Optical Character Recognition
OWL	Web Ontology Language

RDFS	Resource Description Framework Schema
SCU	Social Compute Unit
SMTP	Simple Mail Transfer Protocol
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SU	Service Unit
TCP	Transmission Control Protocol
TOSCA	Topology and Orchestration Specification for Cloud Applications
Turtle	Terse RDF Triple Language
UDP	User Datagram Protocol
UML	Universal Modeling Language
URI	Uniform Resource Identifier
UUID	Universally Unique Identifier
WS-BPEL	Web Services Business Process Execution Language
WSDL	Web Services Description Language
WWW	World Wide Web
XML	eXtensible Markup Language

1.4 Outline

The remaining parts of this thesis are structured as follows:

Chapter 2 – Fundamentals: provides the necessary knowledge into concepts and technologies used in this diploma thesis.

Chapter 3 – Analysis of Human Resources: analyses properties and requirements of human resources.

Chapter 4 – Comparison of Requirements with Existing Sources of Human Information: compares the derived requirements for the virtual representation of a human resource with already existing information resources.

Chapter 5 – Virtual Human Resource Representation: presents the virtual human resource representation concept.

Chapter 6 – Implementation: introduces the implementation that realizes the virtual human resource representation concept.

Chapter 7 – Summary and Outlook summarizes the results of the thesis and gives an outlook for the future.

2 Fundamentals

In this chapter, we will examine the different fundamentals, which have contributed to the investigation of a virtual human resource representation that is presented in this diploma thesis. Due to the vast possibilities of human interactions and an according number of research areas, we will consciously put our main focus onto business-related technologies. Next to various kinds of business process approaches, available sources of human-related information will be analyzed. Being part of a larger field of work in the University of Stuttgart, we will also highlight areas of application in regards to human resource deployment in cloud applications.

2.1 Business Processes

Every business consists of many more or less formal processes that describe how a business works and accomplishes tasks [DM03]. Next to software and hardware resources, that can be modeled to plans, human resources increasingly receive an attention with the newest business process languages like BPEL4People. For humans to be usable in web services to accomplish tasks, the WS-HumanTask specification provides further guidance.

In the following subsections, we will detail three types of business process approaches, known as *activity-oriented*, *knowledge-intensive* and *informal* and inspect BPEL4People for the purpose of highlighting potential areas of human computation.

2.1.1 Activity-Oriented Process Model

In processes which are activity-oriented, ordering these activities by describing possible sequences is the main function to be executed. Those environments, which build upon this approach, are also known as prescriptive process models [Hei90]. These models enact the activities in a controlled order, therefore their description and scheduling prior to their execution is required [AO94]. Activity-oriented business processes have one or several goals, are generally unambiguous, precise and uncomplicated, and provide a positive performance impact [Nur05]. Especially in cases of novice performers, the prescriptive nature of the support model can help the process to remain on track by delivering an accordingly suitable feedback [AO94].

Despite its advantages of executional process clarity, in real industrial situations completely predetermined activities hardly match the required action sequence or even its type. It is unrealistic, that a process engineer can forecast all possible combinations of situations and their solutions. Additionally the possibility of creative expression of a good performer, which may result in better performance or higher quality, is taken away, converging in less flexibility to adapt to unplanned situations.

2.1.2 Knowledge Intensive Business Processes

Business processes which are termed as knowledge-intensive (KIBP) do not yet have a commonly agreed definition. According to Richter-von Hagen et al., the knowledge requirements of the elements participating in the process, primarily need to be fulfilled to create the term's value [HRP05]. Main aspects of KIPS are: knowledge-prevalence, collaboration, predictability, complexity, structure, goal-orientation, event-driven, repeatability, frequency and time [MUM14].

There is a definite knowledge-prevalence, as the required knowledge to execute the process and the amount of its sources is high [KI07]. Collaborations imply multi-user environments with complex coordinations of information exchange processes. How the activities of a KIBP will precisely happen, is in most cases unpredictable [Pan11]. Therefore they are often referred to as unstructured processes [PM03]. To regain some control, goals and milestones are defined and their achievement within the execution process is required [Jon01]. The accuracy of information depends on internal and external events and they may change, requiring flexibility from knowledge applying process elements to reach the intended goals [DJB96]. Because of informational dependency, partly coming from external sources, KIBPs are generally less repeatable than other forms of business processes, require longer execution times and therefore are applied less frequently [MS08, IBM12].

2.1.3 Informal Processes

According to Sungur et al., business processes, also described as work-flows, are mainly used in areas of manufacturing, scientific research and the IT business [SKL14]. They are based on models, predefining execution steps for the enactment of the process, also known as *formal processes*. In contrast, *informal processes* are defined as human-centric, as they are carried out based on the experiences of the performer. The four characteristic properties are: implicit business logic, different relationships among resources, resource participation in multiple informal processes, changing resources [TSBBL14].

Informal processes have no predefined execution logic, as collaborating participants are not only unpredictable in their movements, but also undefinable regarding their amount [Nur08]. An elaborately predefined business logic would add high costs, therefore it is mainly created

during the enactment by decisions from the human participants [SKL14]. To cope with the requirements of more complex tasks, sets of human performers can be formed, who are able to share information related to the process and bring in their unique skills [Non94]. Relationships are not limited to human interaction, but also extend to other resources, like hardware- and software-components [TSBBL14]. Depending on the situational requirements, members of a formed process team can also participate in other teams, with different roles and relationships to one or more resources [MWMY11, MWM+12]. To cover cases of dynamic request changes, requiring new sets of skills to accomplish a task, resources are changeable during the process execution.

2.1.4 BPEL4People and Web Service Human Task

While the Web Services Business Process Execution Language (WS-BPEL) only describes the orchestration of web services, the absence of a human component interacting with these services has become a demanding situation. The solution has been seen in the extension of the execution language by BPEL4People, offering service-enabled human interactions and role-based activities[1]. Users can be assigned generic roles and task ownership can be handed to single persons. This extension builds upon the Web Service Human Task (WS-HumanTask) specification, allowing local and external tasks to be specified regarding a process definition[2]. Tasks and notifications include properties, behavioral aspects and operations to modify human tasks. The lifecycle of a human task, that is service-enabled, can be controlled by a coordination protocol. The focus has been set on portability and interoperability and at the same time on offering an independent syntax.

2.2 Social Computing and Human Resources

As the works of Riveri et. al. have pointed at, there are problems that humans still can solve better than software and therefore their assistance is very much required [RTD12]. Truong et. al. even advocate for social machines that are a combination of human services and software to be able to solve more complex problem cases [TDB12]. According to him, capabilities of humans are difficult to program into applications, like it is possible with software capabilities. Still the topic of human computation and their distributed application has been investigated by Gentry et. al. since the year 2005 [GRS05]. To create human resources that are able to be used in similar ways like their software and hardware counterparts, the retrieval of their identifying and describing information will become an important requirement. For this reason, we will look at possible sources of information in the next section.

[1] https://www.oasis-open.org/committees/bpel4people/charter.php
[2] http://download.boulder.ibm.com/ibmdl/pub/software/dw/specs/ws-bpel4people/BPEL4People_v1.pdf

2.3 Social Networks - Sources of Information

One of the biggest movements of social computing in the last few decades has been the emergence of social networks, offering platforms for humans to create profiles and share text-, audio- and video-based content about themselves and others, with contacts or even with unknown users[3]. Starting with the Bulletin Board System (BBS) in the 1970s[4], that allowed the transfer of messages and data, then continuing with GEnie from General Electric in the 1980s, that had around 350 thousand users playing text-based massively multiplayer games [Tim94]. Continuing with the 90s and the rise of the Craigslist, Yahoo! Geocities and America Online[5] (AOL), big networks with social interactions made their entry into WWW. Late in the 1990s, instant messengers like I Seek You (ICQ) and MSN Messenger started to appear, followed by the blogging site LiveJournal. Coming to the 2000s, platforms which are closer to what we refer as "social networks" did emerge, like Habbo, and Friendster for young people, Myspace for music-oriented and LinkedIn as well as XING for business-oriented people. Beginning in the year 2004, the still very popular Facebook counts more than 1.4 billion users today[6]. To have a piece of the cake, Google has joined the social networks with Google+ in 2011.

Increasing amounts and types of social networks are continuing to emerge, offering most diverse information about users and their activities. By offering access to their network contents via specific APIs, these platforms have become a valuable source of interest. For the potential generation of a virtual human resource representation, we will look at some relevant networks in greater detail in Chapter 3.1.

The next section will highlight one potential area for human resources to be useful, which is orchestrated cloud applications.

2.4 Topology and Orchestration Specification for Cloud Applications

Topology and Orchestration Specification for Cloud Applications (TOSCA) is an OASIS standard defining the structure and management of applications in the cloud, allowing portability and service interoperability among different cloud implementation environments[7]. Application topologies consist of a Service Template, which houses a Topology Template consisting of Node Templates, their relationships and plans for deployment, as can be seen in Figure 2.1.

[3] http://www.webdesignerdepot.com/2009/10/the-history-and-evolution-of-social-media/
[4] http://www.bbsdocumentary.com/software/AAA/AAA/CBBS/memories.txt
[5] http://www.adweek.com/socialtimes/social-networks-timeline/460981
[6] http://www.statista.com/statistics/264810/number-of-monthly-active-facebook-users-worldwide/
[7] https://www.oasis-open.org/committees/tc_home.php

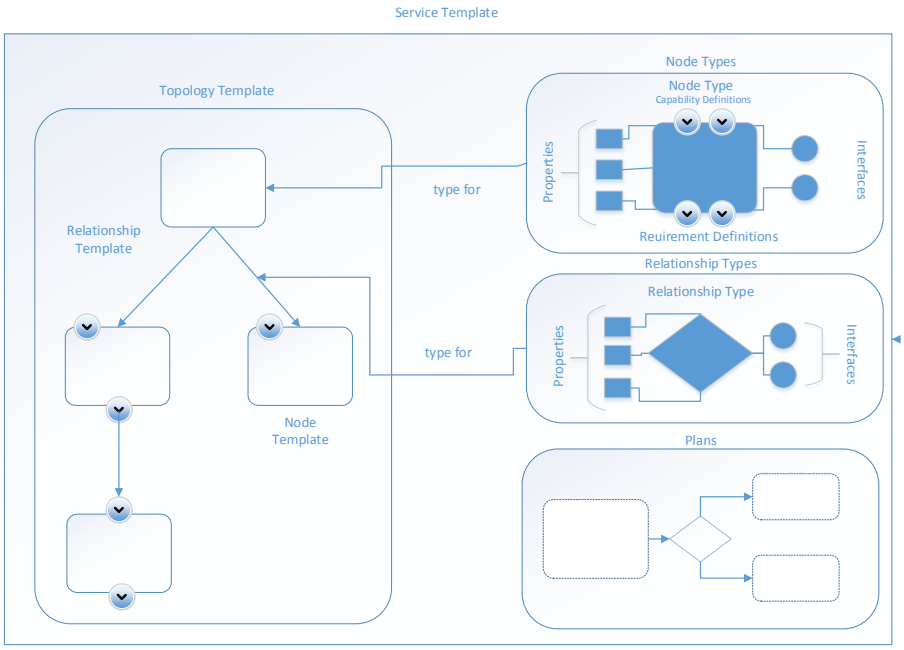


Figure 2.1: A Service Template consisting of nodes, relations and plans[8].

As an example, assuming two Node Templates, one of the Node Type "Webserver" and the other "Webservice", connected by a Relationship Template of the Relationship Type "hostedOn", would constitute a Topology Template. Brought together with a deployment plan detailing their instantiation sequence, the required elements to model a TOSCA Service Template would be complete.

Node Types, like the example "Webserver" consist of properties, like an IP address and interfaces and specific folders for "Webservices" to be hosted on. Build plans, which determine the creation and termination of Node- and Relationship-Templates, rely on already existing business process workflow languages like the Business Process Model and Notation (BPMN) and Business Process Execution Language (BPEL).

In the next chapter, we will analyze the topic of human resources in regards to their properties and capabilities and formulate requirements for the generation of a human resources that are representable in virtual environments.

[8] http://docs.oasis-open.org/tosca/TOSCA/v1.0/os/TOSCA-v1.0-os.html

3 Analysis of Human Resources

In this chapter, we will analyze the various descriptive and operational properties of human resources, especially in regards to their relationships to other human and hardware or software-based resources. In a first step we will outline the different sources that contain properties for human resources and in a second step we will derive proper requirements for the creation of a human resource that can be represented in virtual environments.

3.1 Sources of Information

For the purpose of determining relevant properties of a human resource that is able to be discovered, analyzed and used e.g. to form teams with other human resources and to collaboratively work on tasks, we identified the following areas of information:

- Anthropological works with the focus on digital anthropology including techno-anthropology, digital ethnography, cyber-, virtual- and cyborg-anthropology
- Academical research and related scientific work in the fields of business processes, social computing, topology and cloud orchestration
- Industrial offerings in regards to social computing comprising social networks, online repositories, crowdsourcing platforms, instant messengers and massive multiplayer online games

To determine whether these areas provide relevant materials to inspect and derive human related properties, we conducted a literature discovery in the following databases: ACM, IEEE, INFORMS, ProQuest and Springer. Additionally we looked into journals and publishers like World Scientific, GI, CEUR-WS and IJNGC. To find more relevant information, we used specific keywords to narrow down the immense amount of scientific and industrial work that in some form addresses the topic of social computing and human interaction. Independent of the field of knowledge, the human interface describing its properties and possibilities of interaction received our greatest attention. The used keywords were: *individual compute units (ICU), social compute units (SCU), social machines, human-based-machines, -systems, -computing, human resources, human-provided services (HpS), community-based software development, hybrid services, socially enhanced applications (SEA), collective problem solving, crowdsourcing, virtual humans, human representations, informal processes, human-decision-based processes, flexible human-based*

business processes, human business relationships, collaborative work, human tasks, agent-based and goal-oriented processes, social robots, human/cyborg properties and skills, human/cyborg data.

Due to digital anthropology being a young field of research with relevant data expected to come in the near future[1], we decided to skip it for the time being and continued to focus on the academical works in the fields of social computing and the various market offerings that are already existent. For those we created accounts, applied for developer accesses and manually investigated the provided options by filling information fields with data, testing functionalities like sending messages and by analyzing the various APIs that most of the services offered. Among them: *Facebook, Google+, LinkedIn, XING and GitHub*.

As a result of the scientific literature review covering twenty-three papers, and the industrial analysis including five social networks, we have identified more than 350 properties attributable to a human resource. As most of them can be categorized to some extend, we have chosen categorical property names to more easily derive requirements for the generation of a virtual representation of a human resource, which we will present in Chapter 5.

3.1.1 Scientific Research

In this section, we will first look into the academical works and research papers, which have analyzed the topic of human resources and their application in social business processes. Secondly we will extract useful properties describing a human to acquire an overview of the scientific requirements in this regard.

Informal Processes

In the works of Sungur et al., human resources have been investigated in the context of collaborative business processes, whose business logic is not predefined, but goal-oriented and subject to change depending on various unforeseeable factors, like newly incoming incident requests and the requirement for new human resources within the process flow [TSBBL14, SKL14]. To cope with these requirements, several properties of humans and the processes in which they operate, have been highlighted. To fulfill the demands of the proposed informal process model, human resources require autonomic abilities like pro-activity, reactivity, planning and determining goals. Additionally they must be able to build teams and assign specific roles to the members. Further, the usage of human and non-human resources to reach a goal and the ability to change these resources within the execution time has been mentioned.

[1] http://www.oxfordbibliographies.com/view/document/obo-9780199766567/obo-9780199766567-0087.xml

Human-provided Services

The Human-provided Services Framework presents a service-oriented approach, that allows services, which are provided by humans, to be defined and discovered [STD11]. The interaction is performed by a middle-ware, supporting SOAP and REST access. Requests by a requestor of the service are transmitted either synchronously to the HpS-user, who offers the service, or they are stored in a message repository, readable in an asynchronous way. Interactions, whose rules can be defined by a HpS-user, are analyzed by a specialized algorithm and recorded in a database to offer ranking information, like the performance of task processing, the available time of a HpS and its degree of expertise. The paper further details HpS-user profile data and metrics, categorizing them in hard- and soft-facts. These facts include the employment history, profession, skills and their level of competency and evidence in form of external references to backup the claims.

Socially Enhanced Applications

A Simulation Framework for Socially Enhanced Applications (SEA) describes the necessity of human contributions to solve complex computational problems in a more accurate way [RTD12]. The challenge according to Riveni et al. is to select ideal compositions of human-based services and software-based services and to decide when and how to model them in a business process. The proposed framework for SEA offers a solution with so called mixed resources including their scheduling and performance monitoring. While detailing the required properties of a software-based service the paper also determines important ones for a human-based service. These have been divided into two categories, comprising of static and dynamic properties. Next to the name and price for a human-based service, its availability, skill, competency, workload, reputation, reliability and success rate have been given. By this, the authors put the focus on aspects of a human-based service, that are required in the professional industries to create the mentioned SEAs.

Social Compute Unit

Dustdar and Second have created a fundamental work with *The Social Compute Unit* in the subject of human computation [DB11]. The *social compute unit* (SCU) is a virtual construct that can be instantiated and dissolved in accordance to the task requirements, offering computing power, that is based on socially connected humans. Depending on changing processing demands an SCU can be scaled in its size. Besides its programmability, computing power and scalability, an SCU has a lifecycle including six stages to fulfill an incoming request. For each request with an according problem description, a matching SCU is created. After assimilating the problem domain's requirements, the SCU is virtualized by providing a social-collaborative space for communication and a test environment to solve the problem. In a next step, the

results of the virtual environment are deployed into the physical manifestation. After the task's completion, the SCU is dissolved and rewarded, if the outcome meets the expectations. The paper highlights many aspects of a human resource, which is part of an SCU. As an addition to the mentioned SCU capabilities, a resource ID, its role, expertise and reputation is defined. The available time to be provision-able into an SCU, is given as "time-supply". Furthermore the paper provides the property of connectedness among human resources, incentives, rewards and the context, under which the resources are used.

In the paper *Virtualizing Software and Humans for Elastic Processes in Multiple Clouds - a Service Management Perspective*, Dustdar and Second introduce the words human-based and machine-based computing elements (HCE, MCE) with enhanced focus on their elastic virtualization [DT12]. To create clouds of hybrid services, the paper investigates into individual and team capabilities and relationships among HCEs and MCEs. At the end of its analysis, it offers a very detailed property tree examining several categories like context, quality, payment, incentive, rights, law and jurisdiction. Each property is further refined into e.g. performance and accuracy, pricing and taxation, data and service rights, warranty and compliance rules.

Collective Problem Solving

In the work of Sengupta et al., *Collective Problem Solving Using Social Compute Units*, next to the *social compute unit* definition the problem of incident arrival, management and solution has been investigated [SJB+13]. In a networked server environment, where software- and hardware-problems occur in great amounts for most diverse reasons, a clever incident management has become the requirement of many companies, especially cloud-service providers. For solving incoming problems in a collaborative manner, several essential human properties have been discussed, among them the ability to form and to change SCUs depending on evolving incident situations. Next to individual human skills, collective team capabilities to solve an incident, play an important role. To provide a more precise metric, the computing power of a SCU is defined by its number of members and the individual's skill levels. With the "state of investigation" property, the progress of an incident analysis can be determined.

Provisioning SCUs in the Cloud

In the work of Candra et al., *Provisioning Quality-Aware Social Compute Units in the Cloud* the term of an SCU is further broken down to its atomic elements, which is an individual compute unit (ICU) [CTD13]. Several ICUs collaborating are building an SCU and according to the paper, they could be derived out of social networks like Facebook and LinkedIn by an ICU manager. Other possible sources of human information are crowdsourcing marketplaces like Amazon Mechanical Turk. The proposed provisioning framework receives a consumer request, the ICU manager provides human resources from social networks and a quality-aware algorithm ensures the ideal combination of ICUs depending on their properties to solve the

requested task. At the end, an SCU is formed and deployed for execution. Candra defines four main qualities a human resource must have, namely skill set, response time, cost and social connectedness. The skill set consists of skills and their expertise degree, which may be determined by statistical measurements. Additionally, the paper elaborates on working styles of SCUs, which are defined as: pipeline, parallel, fault-tolerant and shared artifacts. Pipeline stands for the execution of tasks in a sequential order by the ICUs, while parallel allows a splitting of the task, its parallel execution and merging into a solved task. Fault-tolerance copies the same task and the best processing of an ICU is taken as the result. Shared artifacts allow each ICU to process more than one task and each task to be processed by more than one ICU at a time.

All properties that have been derived from research papers, represent the academic side. To get a more complete view, we will also investigate into the market offerings in the following section.

3.1.2 Market and Product Research

The mentioned scientific works define and require more than fifty human resource properties, but the actual market situation may offer completely different resource data. Although researchers like Sengupta et al. or Dustdar and Second investigated into real-world usefulness of social compute units, like server environments, Candra et al. have pointed out the possibility of the extraction of human data from available sources like social networks. For this reason we will analyze several offerings, which have billions of users and are a daily point of attraction and with this a continuously growing source of human-related information.

Facebook

Perhaps being the most famous among all current social networks, Facebook remains a platform of attention for more than 1.4 billion active users on the planet today. With the ongoing development of its service functionalities since its creation in the year 2004, we can assume, that potentially derived properties encompass more aspects of a human, than most people may be even aware of. Having reached such a popularity, the gaming industry started to offer online games like Candy Crush Saga[2], gaining access to the users profiles and by this providing either competitive or cooperative game experiences. For the same reason, great amounts of companies began to analyze the user profiles to generate user specific ads[3]. These ads being Facebook's main financial source, information about humans beyond a useful virtual representation for business-related environments may be available. Still other aspects do cope

[2] https://apps.facebook.com/candycrush/
[3] https://developers.facebook.com/docs/adproviders

with the property requirements of the research papers and even surpass them in regards to their refinement. Due to its big user-base, Facebook is a very interesting source of user information for the generation of human resources. Especially in the context of daily life sharings beyond the scope of professional activities, with the exception of artists, companies and organizations, the platform can be an ideal supplement for more professional networks like LinkedIn and XING, which we will analyze in the coming sections as well.

To access user relevant information, Facebook offers three ways. Either one can create a user profile and inspect all the available data fields, or directly access fillable user information through two REST APIs. The first one, which is in deprecated mode since 2011[4], offers a different set of information than the replacement interface called Graph API[5]. Although both are still functional, we have chosen the latter for the purpose of remaining up-to-date with the current development and to deliver a longer lasting base of relevant information.

Depending on the access-status of Facebook profiles, the amount of accessible information is limited to the public profile or includes the extended properties and permissions. While the public profile only allows insight into the ID, name, link, gender, email, locale and timezone of a user, the extended profiles open up all the remaining information, including personal information like address, biography, birthday, used currencies and devices, favorite athletes and teams, the user's education and work information, installed applications, political and religious orientations, interests, relationship status, shared media content and even security settings.

Having the name "Graph" API, the mentioned information are regarded as vertices, while edges include: achievements, activities, numerous ad-based data, albums, books, movies, music, photos, events, friend lists, groups, likes, inbox and outbox messages.

The complete list of vertice and edge information can be found in the Facebook documentation online[6][7]. Most of the human properties, except the ones available by the public profile, require a review by Facebook after an according application has been registered as a developer.

Google and Google+

Having started as a search engine for the WWW in the year 1998[8], Google has become one of the most influential software companies in the world, offering free of cost web services like YoutTube, Calender, Gmail, Drive, Maps, Translator, Shopping, News, Books and the social network Google+. Due to Google's wide array of APIs, accessing profile information of all

[4] https://developers.facebook.com/blog/post/616/
[5] https://developers.facebook.com/docs/graph-api
[6] https://developers.facebook.com/docs/facebook-login/permissions/v2.3#reference-public_profile
[7] https://developers.facebook.com/docs/graph-api/reference/user
[8] https://www.google.com/about/company/history/

these web services is possible[9]. Depending on the user's public settings, the retrieval of basic data is provided even without the user's authorization. More detailed information are available after the authorization process, where the user logs into his account and gives the asking application his permission to different areas of his profile. This procedure is executed according to the open authorization protocol OAuth2[10] and requires a developer account[11] that has to register the application and specify whether it is a web service, an installed application, or a server-to-server application. Without further examination or approval from Google's side, all user related information become accessible by using the OAuth2-protocol.

Google+ builds upon the Gmail account, that is regarded as the user's base ID, enabling him to access all other services and expand the mail-based profile accordingly. Depending upon the specified scopes in the authorization process, different user related information can be derived out of the Google+ API[12]. It is also possible to extract these data without any authorization from the user's side, if the desired information have been set to be publicly open. Google categorizes all data into: basic information, people, communities, story, work, education, places, contact, links and applications. And these categories contain the ID and name of the user including honorific pre- and suffixes, both a display- and a nickname, the birthday, gender, display language and the url to the user's profile. While Facebook has omitted the profile image access, Google offers several ways to extract it including resizing options. Further information are related to a self-description, the relationship status, a list of url's to other profiles or websites of the user. Enhanced details can be retrieved in regards to the educational and work-related background, which includes the organizational name, the role or title and whether the user is still active in one of them. A tag-line can display a short motto, while the places a user has lived in, are also accessible. To further meet more professional requirements, several e-mail addresses can be defined, spanning from private to work-related ones. As a last, the user can detail his personal skills.

A complete list of Google's plus-user properties including official descriptions can be seen online in the resource representation page[13]. All data can be accessed by an application without any review from Google.

LinkedIn

While Facebook could be regarded as a social network with its main focus on private people and Google+ as a hybrid between personal and some professional data, LinkedIn enters the arena of serious business-related information and possibilities of interaction. It started in

[9] https://developers.google.com/apis-explorer
[10] https://developers.google.com/identity/protocols/OAuth2
[11] https://developers.google.com/+
[12] https://developers.google.com/+/web/api/rest/latest/people#resource
[13] https://developers.google.com/+/web/api/rest/latest/people#resource

the year 2003[14], connecting more than 350 million of professional people for the purpose of displaying a web-wide curriculum vitae with detailed insights into professional capabilities and interests of the users. Because of this orientation, retrieval of information is more difficult than with the former two, requiring several permissions and examinations of the intended application. For most basic information[15] like the user ID, name and the industrial affiliation, a basic-profile access without LinkedIn's review is sufficient. Only after signing into their program, the full-profile is in reach, including even phonetically spelled names, which are correctly formatted for their world wide display. Next to several known properties, which have already been detailed in the previous two social networks, the unique additions from LinkedIn are: detailed job position data, a last-modified time-stamp, publications with title, publisher, authors and summaries, patents with status, inventors and descriptions, languages including proficiency levels from limited to native, skills with IDs, certifications, detailed educational data, courses and volunteering activities and refined recommendation metrics. Other information relate to followings, job-bookmarks, honors and awards, phone numbers and service accounts of other companies like instant messengers and twitter.

Premium features of the platform require a monthly fee, that allow to increase the visual appeal of a user's profile in terms of image size and the twofold prominence in search results. Further advantages include insight into those profiles, which have viewed one's own profile and statistical details about job-related topics[16].

Most of the user data is further refined into minutest details to be able to accurately form an online curriculum vitae (CV) that can be used to apply to job-offerings from other companies and business partners. Due to the functionality of confirmation of the given data, one can assume mostly correct and highly detailed information about real-life persons with work histories and capabilities, delivering a valuable source of information for the creation of human resources. The complete property list including official descriptions can be seen online[17], although special data are only accessible by companies, who are partaking in LinkedIn's partner program[18].

XING

XING is a social network with the same intentions like LinkedIn, offering professional user profiles and contacts to business-oriented people. Despite many similar human properties that this platform offers, some differences exist for reasons of competition. E.g. a user is able to share openly what kind of a job he is looking for and can very detailedly present his private and

[14] https://ourstory.linkedin.com/
[15] https://developer.linkedin.com/docs/fields/basic-profile
[16] https://premium.linkedin.com/jobsearch/features
[17] https://developer.linkedin.com/docs/fields/full-profile
[18] https://developer.linkedin.com/partner-programs

business address to be contactable by interested persons or companies. Missing details of social networks like Facebook and instant messengers like Skype are covered under web-profiles and messaging accounts by directing to them. The offered properties are focused for business information only, which keeps the amount of options comparably low.

To access all these information, a developer account is sufficient and without further investigation from XING, all the private details can be retrieved, if the user gives his authorization to the requesting application. For a complete list of properties, see the developers section online[19].

GitHub

GitHub is a social hosting platform for source-codes of millions of open-source projects, offering a place of collaboratively developing software. It has started in year 2008[20] and connects ten billion people[21]. With the addition of social functionalities, the network may offer other types of human properties which have not been covered by the previous web services. Without further complications, the ID, profile image and the url directing to the profile can be retrieved. Other properties are: followers, subscriptions, organizations, e-mail, blog and even a biography. A difference can be found in the repositories, gists, project related events, the amount of disk usage and project collaborators. A user can display his programming services by mentioning his status as hire-able.

The specialty of the platform lies in the ability to create an organization consisting of collaborating users, the ability to create projects and to manage repositories including commentaries, star ratings and issue handling[22]. An organization, its projects and members can be presented by pages, created manually or with an automatic generator[23]. Depending on the progress, collaborators can be added and deleted. With the Activity API subscriptions, feeds, notifications and repository time-lines can be accessed and monitored[24].

Having increased our insight into the industrial offerings including differently oriented social networks ranging from the private to the professional, in the next section, we will derive properties for human resources that comprise both market products and academic works.

[19] https://dev.xing.com/docs/get/users/me
[20] https://github.com/blog/185-github-turns-one
[21] https://github.com/about/press
[22] https://help.github.com/enterprise/2.2/user/articles/be-social/
[23] https://help.github.com/enterprise/2.2/user/articles/creating-pages-with-the-automatic-generator/
[24] https://developer.github.com/v3/activity/

3.2 Attributes of Human Resources

The following sections will detail six major groups of properties that have been derived out of the sources of information from the previous section and that can be associated to human resources: *describing properties, working in teams, working styles, common operations, custom operations and dynamic operations*.

3.2.1 Describing Properties (P1)

Human beings in the context of usable human resources can be described with various properties to be precisely identified and to get a clear perception about all the attributes and characteristics that define them. All five social networks encompassing Facebook (FB), Google+ (G+), LinkedIn (LI), XING (XG) and GitHub (GH) and the academic works [RTD12, DB11] agree, that the primary property of a human is his ID and name including given-, middle- and last-name that *identifies* him. Google+ even offers the honorific prefixes and suffixes. Furthermore all five social networks provide a unique profile URL and an according image to complete the identification. To *describe* a human, other properties like birthday, gender, a small tag line, an "about me" section, the languages (FB, LI, XG) the human speaks and the preferred application's interface language (G+) are provided by the social networks. Although most of them allow the specification of an e-mail address and a primary address, only XING goes into details with additional home and business addresses. [RTD12] asks for the precise current location of a human, being offered by Facebook and LinkedIn. Next to time zone (FB, XG) and other websites (FB, G+), [STD11] mentions the educational and professional history including the current working position, the second also being demanded by [DB11]. All of them are provided by the social networks, except Facebook in regards to the professional background. Other describing properties are the role [TSBBL14], which can change according to the working requirements and the skills of a human [SJB$^+$13, RTD12, CTD13], which are provided by some of the social networks (G+, LI, XG). To know the degree of proficiency for a given skill, [STD11, SJB$^+$13, DB11] and [CTD13] demand for an according skill level. For a detailed list of *identifying and describing* properties including their sources of derivation, please refer to Table A.1 in the Appendix A.1.

A sub category of describing properties for a human are his *social connections*. Contacts, which include friends and professional ones, are offered by all social networks except GitHub and are regarded as required according to [DB11] and [CTD13]. Besides this demand from the academic works, contact requests, groups, subscribers, interests and activities are mainly contributions from the social networks (FB, G+, LI, XG, GH). LinkedIn also allows for the description of associates and job bookmarks, while XING provides room for special desires of a human. Additionally both (LI, XG) permit accounts and profiles from other social networks to be specified to have further reference to uncovered aspects in their own networks. For an

overview of all properties that relate to *social connections* including their sources, see Table A.2.

In the subcategory of *achievements and qualifications*, we have publications, patents, certifications and courses, all specifiable in LinkedIn's platform. Next to honors and awards (LI, XG), the current career level and the achieved educational degree are additions from XING.

An important aspect of a human that may be used as a resource according to [STD11, RTD12] and [DB11] is his *reputation* and the supporting *evidence*. Especially [STD11] details the number of recommendations, the recommenders and the content of their recommendation, all being provided by LinkedIn. [RTD12] concentrates all factors into a trust-score and names the property success rate.

Coming to *job-related data*, a human requires a context for his work, the provided incentive and reward, as well as the time he has to offer for the work [DB11]. A more precise definition of the reward is mentioned as the cost or price of a human resource [RTD12, DB11, DT12, CTD13], and the amount of taxes that would have to be paid [DT12]. For a detailed listing of the *achievements, qualifications, reputation, evidence* and *job-related* properties and the tracing of their sources, please see Table A.3 to A.5.

Other important describing properties encompass the *quality and performance* of a human's work [DT12]. [SJB+13] and [DB11] refer to the computing power of teams, consisting of humans and their skill levels to solve a given problem, while [RTD12] and [DB11] mention reliability and availability of an individual. Other properties in this subcategory comprise the response time [STD11, DT12, CTD13], throughput, accuracy and completeness [DT12].

To be able to *monitor* a human's online activities in regards to his account and platform interaction, the social networks inform about the date of the account creation (GH), whether it has been verified (FB, G+), how many check-ins the user does (G+) and when the last modification has occurred (LI, GH).

Sometimes it is required to define *security* related properties like the permissions that are granted by the user to an application (FB, G+, Li, XG, GH), or the data and service rights he possess to access information and use functionalities [DT12]. The last source further adds warranties and law enforcement abilities of a human and compliance rules, to which he agrees and must obey. A more detailed list to *security, monitoring, quality* and *performance* related properties and according sources can be found in Table A.6 to A.8.

3.2.2 Working in Teams (P2)

To solve more complex problems that exceed the capabilities of a single human resource, the ability to bond with other human resources and to build a *team* is of primary importance. This is accomplished by defining relationships and *communication* channels, into which we will look separately.

To provide the necessary basis for *communication* among humans, according to [STD11] we first need to define the messaging systems a human is capable of using, like e-mail (FB, G+, LI), chat and telephone (FB, Li, XG), which most of the social networks offer. Another property defines the messaging type, like being synchronous or asynchronous [STD11]. All five social networks provide notifications to activities, events, incoming messages and tags (FB, G+, LI, XG, GH).

To collaboratively solve tasks, [TSBBL14, SJB+13, DB11] propose the creation of teams, consisting of both human and other resources [TSBBL14], with roles and relationships to both human and software or hardware components [TSBBL14]. GitHub additionally allows to create several teams with precise team sizes and different roles of collaborating users, also being supported by [DB11]. For more details about *communication* and *team-working* properties and their derived sources, see Table A.9 and A.10 in Appendix A.1.

3.2.3 Working Styles (P3)

The ways a human can act and interact to reach a given or self-chosen task, depend upon the agreed business model, which may be restrictive and declarative or flexible and informal. A human resource can be distinguished from a software-based algorithmic resource by its autonomous pro- and reactivity [TSBBL14] and the ability to communicate over different channels like chat, e-mail, phone and multimedia streams (FB, G+, LI, XG). It is able to set sub-goals and improvise depending on the situation [TSBBL14] (GH), or it can create plans and strategically execute them [TSBBL14] (GH). To complete a given task, a human resource may choose to both utilize other human resources and software-/hardware-components [SKL14].

Embedded in a team, human resources can solve a task sequentially, one human resource addressing the problem with its skills after the other [CTD13]. Or they can split the task and execute it in parallel, or approach the problem redundantly with each human resource processing the same object with the best result taken. Tasks may also be shared among human resources [CTD13]. The complete list to *working styles* can be found in the Table A.11.

3.2.4 Common Operations (P4)

Capabilities that may be associated with every human resource, which are non-specific in their nature, are called common operations [SJB+13]. They are shared among all human resources and teams of resources. One of them are state-changing operations, which allow a human resource to start the execution of a task, or to stop it and accordingly to give feedback about its state, like being online, but idle or under load [STD11]. Another category are lifecycle operations that are relevant in the time-span a human resource or a team is built to solve a given task [DB11]. These include the ability to form a team, assimilate the request by analyzing the problem domain, virtualize a possible solution and apply it. After the task's completion, the

formed team or human resource role can be dissolved. [SJB+13] also mentions, that the state of investigation is important to determine the progress of a human resource. For an overview of the *common operations* and their sources, please refer to Table A.12.

3.2.5 Custom Operations (P5)

Custom operations are human resource specific and can be derived out of its skill set [SJB+13, RTD12, CTD13]. A human resource with software engineering capabilities may offer the custom operations: analyze requirements, create a software specification and its architectural design, implement, test and integrate the software component. A language specialist may offer the operation translate. Properties to *custom operations* and their sources can be found in Table A.13 in Appendix A.1.

3.2.6 Dynamic Operations (P6)

To support informal processes in human resource teams and to adapt to changing requirements or situations [SKL14], the abilities to create, dissolve and to change the configuration of a team, are of paramount importance [TSBBL14, SJB+13, DB11]. Changing includes scaling up and down the amount of human and other resources and the type of their relationships [SJB+13]. Additionally it may be necessary to modify properties of a human resource or a team [STD11], like its service definition and interaction rules, or its communication channels to meet changing requirements. Appendix A.1, Table A.14 delivers a list of properties and their sources related to *dynamic operations*.

3.3 Requirements for a Virtual Human Resource Representation

To create a representation of human resources that meets the expectations of our motivating scenario to provide a virtual environment, in which human resources can be discovered, analyzed and applied to any task, we will describe the necessary requirements that have been derived out of the property analysis in the previous sections.

Requirement 1 (R1): *Human Resource Description Definition*.

A human resource is primarily identified and evaluated according to its describing attributes, like name, profession, skills and reputation. If used for a specific task, the definition of its work-related context, role and the payment agreements become a topic. In the motivating scenario the interacting company transforms social network profiles into a uniform representation that can be discovered by other users and analyzed to find matching properties like security restrictions and job-related data to relate to this resource. To encompass all categories of description for a human resource as detailed in the describing properties analysis, like social

connections, achievements, reputation, job-related data, quality, monitoring and security, an according definition is required.

Requirement 2 (R2): *Team-Working Capability Definition*.

For the purpose of creating teams and working together to accomplish more complex goals, a human resource must be primarily able to communicate with others. For this we need to define messaging systems like chat, e-mail, status feeds, notifications and other means, by which any collaborative work can be supported. Other requirements include the capability to create and participate in teams, define roles and relationships between resources to provide the basis for a possible team-work in a virtual environment, like in our motivating scenario.

Requirement 3 (R3): *Working-Style Definition*.

In the process of executing a task, better methods may appear and become more attractive. A restrictive execution approach can limit the flexibility and thus possibly decrease the quality of the resulting work. To support creative ideas, which set apart humans from machines, different working styles like the ability to define new plans, set sub-goals and change working styles from sequential to parallel or shared is required. For this reason and according representation must include options to define the various working-styles that a human resource is capable of.

Requirement 4 (R4): *Common Operation Definition*.

To define whether a platform, in which human resources can act and interact, supports common operations that are available to all users, like changing settings, sending and receiving messages, starting processes, changing their states or assimilating a problem domain to collaboratively find a solution, we need an according definition for the virtual representation.

Requirement 5 (R5): *Custom Operation Definition*.

As every human being has a different set of skills with diverging degrees of expertise, one human resource may be more suitable to translate a text passage, while the other may be more advanced in organizing and providing information to the human resource team-members. To determine the suitability of a human's skills and to offer him the possibility to execute them, a custom operation definition is required.

Requirement 6 (R6): *Dynamic Operation Definition*.

To adapt to changing situations in a virtual environment, the affected human resource or team must be able to create a new configuration with human resources of e.g. different expertise areas. Next to elasticity of teams, the modification of relationships and even resource properties like roles is important, for which dynamic operations of a human resource representation is required.

4 Comparison of Requirements with Existing Sources of Human Information

The properties and requirements for a human resource have been defined in greater detail in Chapter 3. In this chapter, we will investigate into existing pools of human information and compare, if or to which degree they meet the defined requirements derived from the property analysis.

4.1 Requirements Comparison for a Human Resource

For the creation of a human resource that can be identified and which is able to operate by various means as detailed in Chapter 3.3, we will look at sources of information from today's market offerings and determine to which degree they meet the requirements. The contenders are Facebook, Google+, LinkedIn, Xing and Github. Table 4.1 shows the results of our requirements comparison.

Source	**Req. 1**	**Req. 2**	**Req. 3**	**Req. 4**	**Req. 5**	**Req. 6**
Facebook	⊕	⊙	⊖⊖	⊖⊖	⊖⊖	⊖
Google+	⊕	⊙	⊖⊖	⊖⊖	⊖⊖	⊖
LinkedIn	⊕⊕	⊙	⊖⊖	⊖⊖	⊖⊖	⊖
XING	⊙	⊖	⊖⊖	⊖⊖	⊖⊖	⊖
Github	⊖	⊕	⊕⊕	⊙	⊖⊖	⊕

Table 4.1: Requirements comparison with existing sources of information.

Legend:

⊕ ⊕	All or most requirements are met.
⊕	A good amount of requirements are met.
⊙	Requirements are only partially met.
⊖	Requirements are marginally met.
⊖ ⊖	Requirements are not met.

Facebook as a platform especially created for casual social interaction, meets R1 to a good degree by offering relevant information to identify and describe the human resource, but misses professional data, like skills and payment options. In regards to team-working capabilities, Facebook offers an e-mail-service, chat, audio messages and various other means to communicate with other human resources, but it is not possible to specify specific relationships, except in terms of mating-related information and therefore it meets R2 only partially. Neither working-styles, nor executional operations can be defined, therefore R3-R5 are not met. It is possible to form groups, add platform users, but properties and roles cannot be modified, nor can relationships be changed, therefore R6 is only met marginally.

Google+ as a platform created for casual social interaction with some business related information, meets R1 a little more complete than Facebook, by offering refined educational and professional background information and the option to define skills. But details like skill level, reputation, certifications or achievements are out of its scope. R2 is partially met, as Google+ offers similar communication possibilities including a well established mail-system and user circles, but fails to define relationships and roles. R3-R6 are met comparably to Facebook.

LinkedIn as a platform especially created for the professional business market, meets most of the identification and description-based requirements with the greatest amount of details including certifications, publications and awards. Its usefulness to form a human resource is comparably enhanced to the other platforms. Still it lacks dynamic properties like response-time, time-supply for a given task or the definition of access rights to other resources. R2-R6 are comparable to Google+ and Facebook and mostly not met.

XING as a platform with its focus on the business market, meets R1 in a similar way like LinkedIn with the disadvantage of much less detailed non-business-related properties. With the lack of most communication channels, except a forum-like platform for groups and private messages for a premium fee, the platform is more ideal to present a digital CV and to create contacts, but is insufficient for serious team-work and therefore R2 is only marginally met. R3-R6 are identical to Linked, Google+ and Facebook.

GitHub as a platform specialized in collaborative working with repositories, meets R1 only in regards to a user's identification including basic data, but misses most of the professional and private details from the other platforms. By the ability to build teams including relationships through roles and by using different channels of communication, it comes closer to the requirements of R2, than the other platforms. GitHub allows to work freely on software projects with the ability to determine own goals, create forks and address issues in teams sequentially, fault tolerant or in parallel. It is possible to utilize tools and other human resources by using the appropriate communication channels, which meets most of R3 and therefore is regarded as met. R4 is met partially, as all users have the same set of operations available, but are limited to software-development related operations and cannot be defined for other purposes, by which R5 is not met. A human resource can create teams and change its configuration, but is unable to specify and modify team properties, although it comes closer to R6 than LinkedIn, Google+ and Facebook.

As we can clearly see, no source of information alone meets all requirements, but a combination of several social networks could provide enough information to form a virtual human resource that comes closer to the demands of the academic works. In the next chapter, we will present our virtual human resource representation concept that is more complete in determining and providing relevant human resource properties and capabilities in regards to all six requirements.

5 Virtual Human Resource Representation

This chapter will present our *virtual human resource representation* concept, which is an extension of the actor-concept that is based on *Informal Process Essentials* as detailed by Sungur et al. in [TSBBL14]. In his work, resources can either be software, hardware, or human components. The former two components are already known and well operating within business processes, but the latter has not yet been formally and comprehensively defined, for which we will present our own concept for the purpose of creating a human resource representation in virtual environments.

5.1 Virtual Human Resource Representation Concept

To satisfy all six requirements that have been investigated in Chapter 3.3 and derived out of a comprehensive scientific and market research, we introduce our concept of a virtual human resource representation. It encompasses all six property categories of Chapter 3.2 and offers more refined property and operation definitions including the following thirteen sub categories, see Figure 5.1.

Figure 5.1: Properties of the virtual human resource representation.

All sub categories, related properties and capabilities of a virtual human resource representation are described in the following sub-sections.

5.1.1 Identification and Description

The most basic aspects of a virtual human resource representation are its ID, name and profile image to be properly identifiable. Depending on the used or logged-in platforms and applications, several more IDs may be required. Other important properties include gender, birthday, languages and a self-written description. For a complete list of properties and descriptions, see Table A.15 in the Appendix A.2.

Further describing properties include the primary e-mail and living addresses of a human resource, its educational and professional background comprising of organizations, industries and its current position. To have an idea about its capabilities, it can define the skills and their expertise degrees that it owns, see Table A.16.

5.1.2 Social Connections

To keep in touch with other friends, comrades and professional contacts, we have defined a universal contacts property in Table A.17 that includes all types of social connections. A human resource can belong to a group or have associations, be a subscriber to others and be involved in activities. To remain visible to other contacts, it is tag-able and may even possess more profiles on other social networks.

5.1.3 Achievements and Qualifications

Our virtual human resource representation allows for detailed specifications of the various achievements and qualifications of a human resource, including publications, patents, certifications and awards. If it likes, it is able to further detail its career level status and make its school marks visible, see Table A.18.

5.1.4 Reputation and Evidence

Without a good reputation, the chances for the discovery and usage of a human resource are limited, therefore it is able to provide various proofs for its capabilities, see Table A.19, e.g. by delivering statistical data about its success rate or the amount of recommendations it has received.

5.1.5 Job-Related Data

A requestor, who wants to hire a human resource, is interested in knowing the amount of time it offers and the price it expects for its services. Depending on the country, taxations may be handled differently and a reward is not limited to money, but can be anything. For more details, see Table A.20.

5.1.6 Quality and Performance

For the determination of work-related metrics like quality and performance, our virtual human resource representation includes the required properties, see Table A.21. Computing power is related to one or more human resources that are collaborating in teams with specific skill sets and expertise degrees. Some human resources may have a higher throughput in processing a task, while others may provide a greater accuracy and faster response time. Depending on the requirements, any or all properties may be of interest for a requestor or even a software-algorithm that automatically discovers and matches the requirements to available human resources.

5.1.7 Monitoring and Security

As Table A.22 shows, some platforms may provide statistics about the profile usage of a human resource, like the date of its creation and whether it has been verified or not. Other parameters are the number of check-ins and a last-modified time-stamp.

For connecting to a web platform and working in teams, different restrictions are necessary to cover both the platform's and the resource's security requirements. Additional safety for the human resource is provided in Table A.23 by warranty, law enforcement and for the requestor by compliance rules.

5.1.8 Communication and Team-Work

Without communication, team-work is not possible. As Table A.24 shows, our virtual human resource representation is able to define messaging systems and their types. It can provide private and professional e-mails and phone numbers, receive in-platforms messages and notifications. Team-work comprises the creation of teams with IDs and members, the definition of roles and relationships to both human and non-human resources. For more details, see Table A.25.

5.1.9 Working Styles

As Table A.26 shows, our virtual human resource representation allows for different possibilities of executing work, which supports informal processes as well as more classic process languages like BPEL. A human resource is able to create goals and plans, and to use other human resources and software components to reach these goals. Through working in teams, tasks can be processed in pipeline-mode, in parallel, fault-tolerant or shared.

5.1.10 Common, Custom and Dynamic Operations

Common operations are available to all human resources, like giving information about one's own state of being or state of investigation. In the context of creating a human resource or team of human resources to solve a requested task, basic lifecycle abilities are presented in Table A.27 and it is possible to add further common operations to the shared list of capabilities.

Custom operations, like in Table A.28, are specialties of a human resource and derived out of its skills, therefore they need an explicit definition and association with a human resource, for which our virtual human resource representation concept includes the required properties.

Dynamic operations allow the modification of teams in regards to their members and relationships during the execution of a business process for the purpose of dynamically adapting to changing situations or newly incoming requests, see Table A.29.

5.1.11 Other Properties

Just to give an example, that there is no end into potential properties and capabilities, which could be attributed to a virtual human resource representation, we have added two properties in Table 5.1, which have a great significance in software-development environments, where source-code is deposited in repositories and human resources can work on them collaboratively.

Property	**Description**
Repositories	A list of repositories that belongs to the person.
Gists	A list of gists that belongs to the person.

Table 5.1: Other example properties.

With this we conclude our virtual human resource representation concept. In the next chapter, we will inquire into the possibility of creating a prototypic implementation to demonstrate, how such a virtual human resource representation could be utilized to generate virtual human resources out of a social network and to provide them to be usable in collaborative platforms and business processes to reach individual and collective goals.

6 Implementation

In this chapter, we will present our implementation based on the virtual human resource representation concept from Chapter 5. In the first section, we will give an overview of the *Human Resource Provider* (HRP) and first discuss, then specify and design the components required for its creation. In the following sections, we will present a *Human Resource Ontology* (HRO) for providing a virtual human resource representation template and choose an appropriate data-source for the extraction of human resource information.

6.1 Human Resource Provider

The *Human Resource Provider*, which is the name of our prototype, is a proof of concept regarding the extraction of human resource information and providing virtual human resources based on a modeled ontology, which acts as a virtual human resource representation template. There are several possible ways to design the implementation, based upon the chosen components, the required libraries and the possibilities and limitations that come with them. The future intention is to generate virtual human resources that are applicable within a cloud environment in an orchestrated and managed way, being able to interact with other human, hardware and software resources for the purpose of fulfilling the requirements of informal processes as detailed in the works of Sungur et al. [TSBBL14, SKL14].

6.1.1 Requirements Analysis

The required core features to realize a Human Resource Provider are as follows:

- The ability to extract human user data from a chosen source of information, e.g. a social network
- The ability to map retrieved user information on a virtual human resource representation template
- The ability to store virtual human resources out of the created virtual human resource representation
- A loosely coupled architecture through the usage of interfaces to provide

  - the possibility to add other sources of information
  - the possibility to add other implementations of creating virtual human resource representation templates and to store virtual human resources
- Compatibility with web standards, languages and environments
- Compatibility with required libraries
- Easy integrability into web environments used by the OpenTOSCA ecosystem

6.1.2 Specification

To realize the requirements for the Human Resource Provider, we have investigated and specified the following components for its implementation:

- **Java** as the programming language
- **Maven** as its build tool
- **Google+** as the source of human resource information retrieval
- **Google+ API v1.0** to access user information
- **Google+ OAuth2 libraries** for the user-authentication-process
- **Google+ DataStore and storedCredential libraries** to store access tokens
- **OWL2** as the ontology language
- **Protégé** for modeling a human resource ontology to form a virtual human resource representation template
- **OWL-API v4.4** to access and apply the human resource ontology

6.1.3 Design and Architecture

Figure 6.1 gives an overview of the Human Resource Provider architecture as an FMC-diagram, which constitutes of an HRP-core that can be accessed by any requestor.

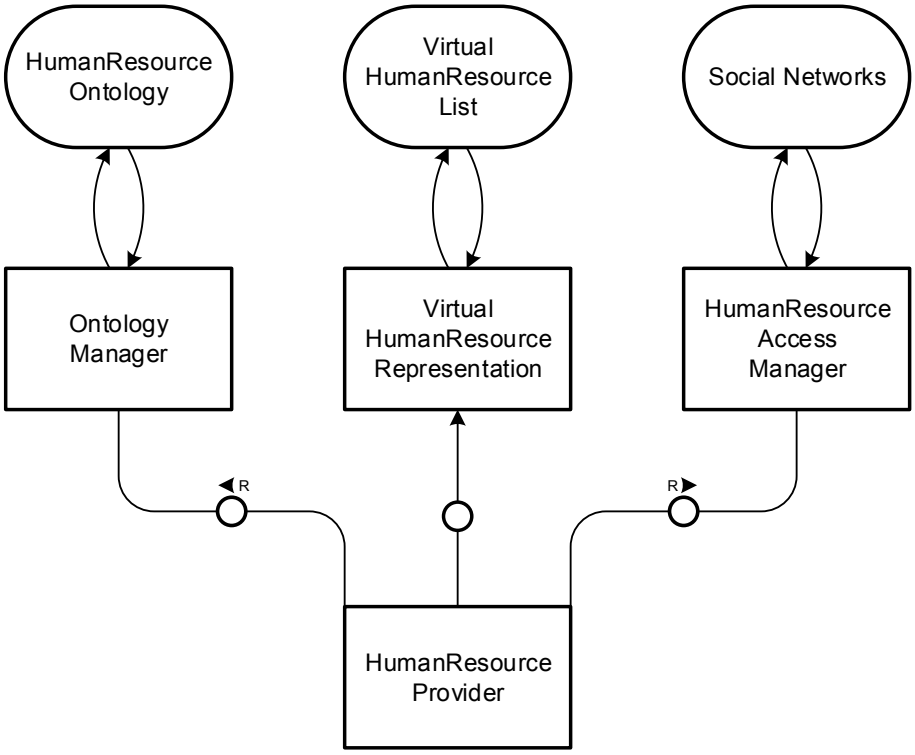


Figure 6.1: Overview of the HRP-architecture as an FMC-diagram.

The HumanResourceProvider component is connected to three components: the OntologyManager, the HumanResourceAccessManager and the VirtualHumanResourceRepresentation. Depending on the called function, the HumanResourceProvider will ask the HumanResourceAcessManager to retrieve user information from a social network, in our case Google+, and build a VirtualHumanResourceRepresentation out of it, which is stored in a VirtualHumanResourceList. If enough user accounts have been transformed to VirtualHumanResourceRepresentations and collected in this way, the requestor can call a second function to obtain a HumanResourceOntology instance that is derived by the HumanResourceOntology through the OntologyManager. This HumanResourceOntology instance contains all user-related information extracted from the social network and is a collection of virtual human resources, ready to be further processed.

6.1.4 Implementation

Figure 6.2 shows UML-classes of the Human Resource Provider, consisting of the main interface and implementation, which allows to add virtual human resources out of the virtual human resource representation, list a specific or all available resources as a HRO-instance that is saved in the OWL-XML-format and return them as a byte array.

Figure 6.2: HRP architecture as an UML class-diagram.

The HumanResource-interface provides the HRP-core with according resources by using the specified social network, in our case Google+. Other platforms like XING or GitHub can be added in this way without disturbing the implemented Google+ solution. The HumanResource-Converter, which is currently transforming virtual human resources into HRO-instances, is also able to call implementations with other instance-representations and to store the created virtual human resources out of their representation. To implement both interfaces, different technologies and libraries are required, enabling the corresponding interface-call to first direct the web-browser to the log-in screen of a user's social network to authorize the HRP-application and to extract his data via the network's REST API. Secondly to store his access-tokens together

with his name in a global credentialStore and thirdly to create a virtual human resource representation, that is stored in a global virtual human resource list. To return this list in a format that can be further processed and used in web-based environments, we decided to create a Human Resource Ontology that is capable of modeling our virtual human resource representation and storing information in the OWL-XML-format. More details to both sides of the implementation are presented in the next sections, followed by a validation of the HRP-prototype.

6.2 Human Resource Ontology

To manifest the presented virtual human resource representation from Chapter 5 as a usable template for the creation of virtual human resources, we decided to model an ontology based on the Web Ontology Language 2 (OWL2) to be compatible with standards that are accepted in web applications and to provide a basis that can be easily modified and expanded to suit the requirements of future developments in regards to virtual human resource representations. Our Human Resource Ontology is an extension of the Informal Process Ontology that is part of the works of Sungur et. al., and represents the actor, which is a human resource in contrast to other non-human resources [SKL14].

For the purpose of providing a virtual human resource representation template to map extracted user information, which is available in an existing social network, we limited the amount of properties and capabilities to relevant information of our chosen source-network. As can be seen in Chapter 3.3, requirement one, which includes describing properties like the ID, name and skills were partially present in most social networks that we investigated. The capability to communicate and therefore to build a base for the second requirement, which consists of team-working properties, like exchanging messages and building relationships, was also partially available for a logged-in user of that platform. But looking at the available APIs, most of them do not allow a remote access to important user-related functionalities, like sending a message in behalf of a user. Instead, the APIs are more focused on retrieving information of already exchanged messages. Except of GitHub, most of the other requirements, like working styles and the definition and execution of operations, are not met by the social networks, see Chapter 4. Therefore we regard our modeled Human Resource Ontology as a basic manifestation of the Virtual Human Resource Representation that has been optimized for describing properties with the addition of the most important aspects of creating and working in teams including the definition of common, custom, and dynamic operations.

Figure 6.3 shows a miniature drawing of the Human Resource Ontology we used to represent the virtual human resource representation concept for the implemented prototype. In Appendix A.3, it can also be viewed in full size.

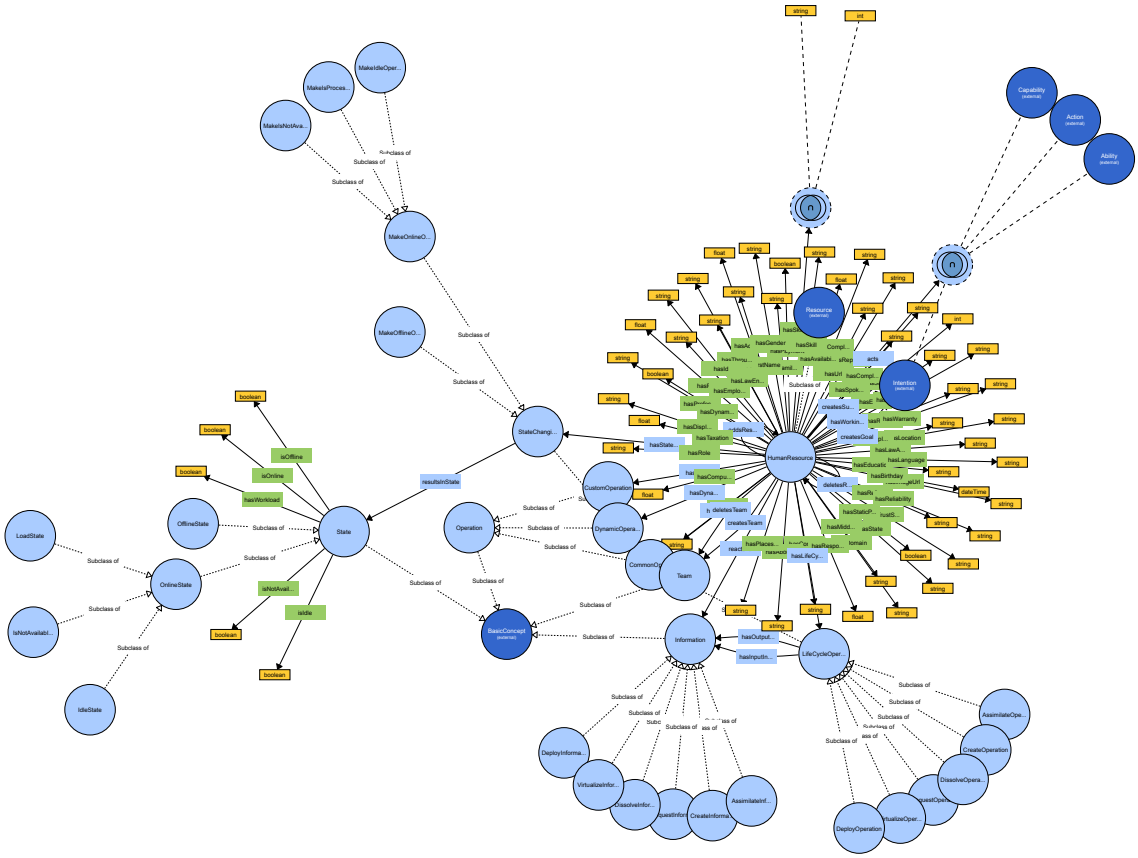


Figure 6.3: Human Resource Ontology.

In the center of the green encirclement of rectangles, we have a bright blue circle, which is an OWL2 Class, representing our human resource, that is a sub-class of the dark blue Resource circle. All dark blue circles are classes from the Informal Process Ontology, including Basic Concept on the bottom left, Intention, Ability, Capability and Action on the top right of the graph.

A human resource has various describing properties, like ID, name, gender, birthday, education and skill. Among the dynamic properties, a human resource can have a context, current location, role and state, all together encompassing 54 describing properties, also known as Data Properties (green rectangles). The yellow rectangles define the type of each property, like string, float or boolean.

The bright blue rectangles are known as Object Properties and are related to what a human resource can do, like creating teams, goals and adding resources to collaboratively work together. The remaining blue circles are various operations, like state-changing operations at the left side of the yellow encirclement, which is further arced into online- and offline-making operations. From an online-state, one can further change into an idle, not-available or under-load state, as can be seen in the circles at the bottom left. In similar ways there are lifecycle

related operations at the bottom right, allowing the assimilation, virtualization, deployment and dissolution of the human resource, depending on the information that is received and transmitted in each phase, see circles at the mid bottom.

6.2.1 Protégé

Protégé is a modeling tool from the Stanford University, offering a graphical user interface for the Protégé API that is based on the OWL2 API[1]. It allows the creation of OWL2-compatible ontologies and to save them in various formats, like Resource Description Framework Schema (RDFS), OWL or Terse RDF Triple Language (Turtle). Figure 6.3 and Appendix A.3 are graphs that are based on the Human Resource Ontology, which we have modeled by using this tool. The presented Human Resource Ontology can easily be expanded with this tool and the OWL2 API to adapt to changing requirements of the available information, that can be associated with a human resource.

6.2.2 OWL2 API

The official OWL2 API allows the creation and modification of web ontologies. By being available as a Java-library and for the reason that it is also used by the modeling tool Protégé, we have decided to utilize it for the purpose of creating our Human Resource Ontology and to save virtual human resources in our prototype as HRO-instances, called Individuals. The required library dependency to be set in Maven to access its functionalities is specified by the entry "owlapi-osgidistribution".

6.2.3 Individuals

Ontology instances are known as Individuals, which represent a virtual human resource that is generated out of the virtual human resource representation template, which is our modeled Human Resource Ontology. These individuals can be added to the ontology and saved with it, or it is possible to create a new ontology including only the individuals with a link to the source ontologies to be automatically imported with the opening of such an Individual-ontology. In the first case, the whole complexity of the Human Resource Ontology, which already imports the Informal Process Ontology, is further increased with the addition of Individuals. While in the second case, only the Individuals are visible and the required source ontologies are contained as links to either an ontology-web-address or to an ontology-file. For reasons of clarity, we have decided to create and save virtual human resources as a new Individual-ontology, that imports its sources.

[1] http://protege.stanford.edu/

6.3 Google+ Resources

Among all the different sources of information that are available to produce a virtual human resource representation, we have chosen Google+ for various reasons. Initially LinkedIn seemed to be the ideal contender, as it provides the most detailed data of a human in regards to business topics, but after being confronted with its API restrictions (Section 3.1.2), we have looked for an alternative. XING, being similarly ideal without the limitations of LinkedIn, did not offer enough general data. As Facebook is more focused on social fun and does not contain user skills or other business related properties, Google+ seemed the have the best balance of both worlds. With the addition of a free access to all user information, even to the degree of not requiring any user authentication by setting the information to be publicly open, Google+ became our choice for the HRP-prototype. The retrievable information of a Google+ resource can be seen online[2].

6.3.1 Google+ API

To access user information from Google's social-network, the application-bound secret key and the Google+ API is required. It is both possible to add the library manually to a project, or to let it be automatically fetched by the use of a build tool, in our case Maven[3]. The required settings for a correct integration of all relevant library packages are defined in the Project Object Model (POM) pom.xml - file by specifying the entries "google-api-client" and "google-api-services-plus". The secret key is automatically generated in the process of registering an application in the developer console and is a prerequisite for all access-requests that happen via the OAuth2 protocol, as explained in the next section.

6.3.2 Authorization Process

The application that wants to access a Google-user's information and act on behalf of him, is called a consumer. Via the Open Standard for Authorization (OAuth) 2 protocol the consumer is able to authenticate with the Google service provider without the need of a user to reveal his user name or password to the accessing application, in this case the HRP-prototype. The permission that is given in the authorization process can be revoked by the user at any time in the Google Accounts settings. The authentication process between the consumer, which is the HRP, and the service provider, in this case the Google+ servers, happens in several steps and is called "three-legged authentication", see Figure 6.4.

[2] https://developers.google.com/+/web/api/rest/latest/people#resource
[3] https://developers.google.com/api-client-library/java/google-api-java-client/setup#maven

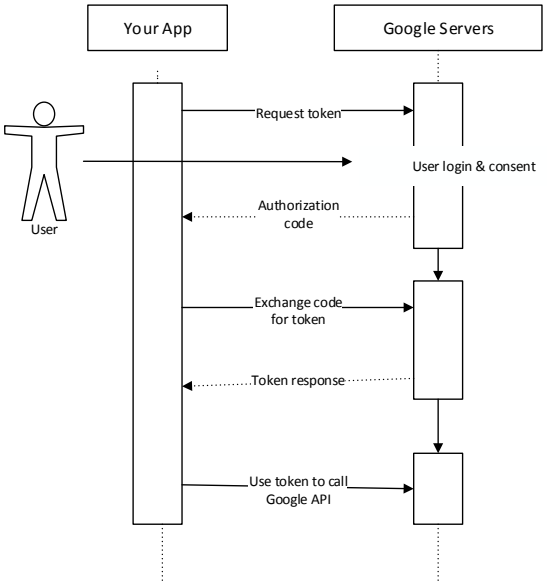


Figure 6.4: OAuth2 authentication process in three major steps[4].

The Human Resource Provider calls the web service endpoint for Google+ access to get a temporary request token, which can only be used for the authentication process. The user together with this token is directed in his browser to the Google Accounts authorization URL, enabling him to sign in with his credentials and by this informing Google Accounts that the Human Resource Provider is authorized by a code to access the service provider, see Figure 6.5. Afterwards the user is redirected back to the HRP at the URL that was provided with the acquirement of the request token at the beginning. A web service endpoint is then called by the consumer to receive an access token in exchange for the request token with the authorization code. By using the access token the Human Resource Provider can call Google+'s own web service endpoints directly.

[4] https://developers.google.com/identity/protocols/OAuth2WebServer

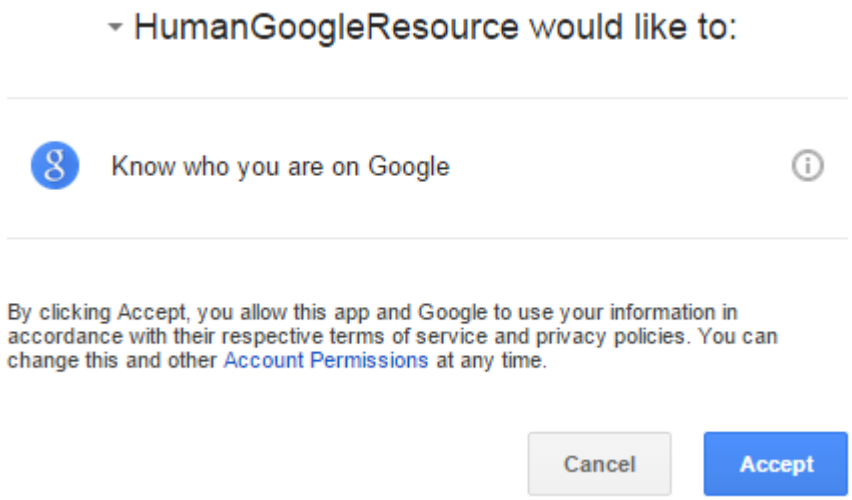


Figure 6.5: The HumanGoogleResource-component of the HRP is asking the user to give his access permissions.

To be able to use the OAuth 2.0 protocol for accessing user related information, special OAuth 2.0 credentials are required and can be obtained from the Google Developers Console, after having attained the developer status.

OAuth endpoints

The HRP uses a set of standard web service endpoints to perform OAuth2-related actions. Depending on the domain it is operating, e.g. www.humanresourceprovider.com, the endpoints for the OAuth protocol would be www.humanresourceprovider.com/_ah/OAuth. Google itself offers specific domains for the deployment of a web service, like appspot.com, but any URL path can be used. The only restriction is that the application, which is using one domain and acquiring an access token, cannot use this token with an application on another domain, in other words the requested tokens are bound to the requesting application and its domain.

The authorization process in greater detail:

1. Obtaining a request token, the Human Resource Provider calls the following endpoint: _ah/OAuthGetRequestToken to obtain a request token, which is needed to handle the other steps of the authorization process. This token has a limited validity of 10 minutes.

2. After acquiring the request token, the HRP must obtain an access token by redirecting the user to a sign in page, where he can log in via his Google account and by this authorize the Human Resource Provider to access the Google service provider. The endpoint is: _ah/OAuthAuthorizeToken. This authorization is granted by the Google Authorization Server. Depending on the “scope” parameters that have been sent with the access-request, the Human Resource Provider can get access to different information.

3. The HRP calls the service provider, after it has been authorized, to get the access token by the following endpoint path: _ah/OAuthGetAccessToken. The access token's lifespan is limited to one hour and needs to be refreshed in specific intervals.

4. Sending the access token to the Google+ API happens by an HTTP authorization header and depending upon the scope different user information can be extracted. To get a long-lived refresh token, "access_type=offline" can be used as a parameter during the authorization code flow.

The alternative way is to persist the credential's access token, either by an own implementation of the DataStoreFactory[5] and DataStore[6] with StoredCredential[7] or by using libraries, like JDODataStoreFactory, AppEngineDataStoreFactory, MemoryDataStoreFactory, FileDataStoreFactory[8].

6.3.3 Storage of User Credentials

By using the Google+ API libraries, which are very much recommended by Google, as they are thread-safe and well-tested, the dependency upon the DataStore becomes inevitable. It is designed to offer user credentials for accessing their profiles by storing both the access and the refresh tokens in StoredCredentials, which have been derived from the OAuth2 authorization process as described in section 6.3.2. Depending upon the intention, there are four possible ways of implementing the DataStore into the application by using one of the following Google libraries:

- **JdoDataStoreFactory** persists the user credentials using JDO
- **AppEngineDataStoreFactory** stores the user credentials in Google AppEngine
- **FileDataStoreFactory** stores the user credentials locally in a specified file
- **MemoryDataStore** stores the user credentials within the application's system memory

As the AppEngine is Google's own environment for deploying web applications and due to its incompatibility with Tomcat[9] that is used as a web server for the OpenTOSCA ecosystem, this option has been dismissed early on. Storing the credentials in a local file is a viable option, but has the limitation that the folder paths have to be uniquely named for the DataStore to accept

[5] https://developers.google.com/api-client-library/java/google-http-java-client/reference/1.20.0/com/google/api/client/util/store/DataStoreFactory.html
[6] https://developers.google.com/api-client-library/java/google-http-java-client/reference/1.20.0/com/google/api/client/util/store/DataStore.html
[7] https://developers.google.com/api-client-library/java/google-oauth-java-client/reference/1.20.0/com/google/api/client/auth/oauth2/StoredCredential.html
[8] https://developers.google.com/api-client-library/java/google-api-java-client/oauth2
[9] https://stackoverflow.com/questions/18138668/google-app-engines-web-application-server-and-apache-tomcat

the credentials-file that is embedded in that path. Additionally in cases of web deployment, storing files locally into a virtual server or web-environment is limited to the local cache of the web application or the temporary files of the server. To have the flexibility of storing the tokens in any way, keeping them within the memory as Java objects and processing the content as the application-environment requires, seemed to be the most sensible approach.

For this reason a global DataStore credentials list has been created that keeps account of all authorized users by storing both the specified userName and its tokens as a storedCedential-object. Before accessing user information, the global list is scanned for entries of the userName and with the help of the refresh token an access token is received, by which the Google+ API grants the retrieval of profile data. In case the userName does not contain any credentials, the user is redirected to the log-in screen by the OAuth2 process, resulting in the response of the access and refresh token, which again are stored in the storedCredential-object with the userName in the global DataStore-list.

6.4 Validation of the Prototype

For the purpose of validating the Human Resource Provider, we have created several user accounts on Google+ and filled them with information, to be first transformed into a virtual human resource representation and added to a list of virtual human resources, and secondly to become an according manifestation by being saved and returned as a HRO-instance. The following two listings show the output generated by the interface-command "listResources()" in the OWL-XML-format.

The beginning of the output in Listing 6.1 contains our ontology-base which is equal to the ontology's Internationalized Resource Identifier (IRI) for the creation of the Individuals, defined as /google+-indiviuduals/#. In lines 10 to 11 both source-ontologies are loaded into the Individual-ontology and the class HumanResource with its various properties is defined.

Listing 6.2 shows how OWL2 associates a created Individual with its parental class, see lines 3 to 8. Both John Doe and Jane Doe are members of Google+ and have been created as dummy profiles for the purpose of testing and validating the prototype. All properties are an addition to the IRI-base, making a human resource visible to web applications, if the created HRO-instance is saved on an appropriate web server. The remaining lines give an idea of the retrieved information from these human resources to be further used in identifying, analyzing and using them in e.g. web environments.

Listing 6.1 Example of virtual human resources that are saved as a Google+ HRO-instance in the OWL-format.

```
<?xml version="1.0"?>
<Ontology xmlns="http://www.w3.org/2002/07/owl#"
      xml:base="http://www.iaas.uni-stuttgart.de/ipsm/informal-process/
                                    human-resources/google+-indiviuduals/#"
      xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
      ontologyIRI="http://www.iaas.uni-stuttgart.de/ipsm/informal-process/
                                    human-resources/google+-indiviuduals/#">
      <Prefix name="owl" IRI="http://www.w3.org/2002/07/owl#"/>
      <Prefix name="xsd" IRI="http://www.w3.org/2001/XMLSchema#"/>
      <Import>file://HumanResourceProvider/human-resources.owl</Import>
      <Import>file://HumanResourceProvider/informal-processes.owl</Import>
      <Declaration>
            <Class IRI="HumanResource"/>
      </Declaration>
      <Declaration>
            <DataProperty IRI="hasGender"/>
      </Declaration>
      <Declaration>
            <DataProperty IRI="hasBirthday"/>
      </Declaration>
      <Declaration>
            <DataProperty IRI="hasSkill"/>
      </Declaration>
      <Declaration>
            <DataProperty IRI="hasGivenName"/>
      </Declaration>
      <Declaration>
            <NamedIndividual IRI="JohnDoe"/>
      </Declaration>
      <Declaration>
            <NamedIndividual IRI="JaneDoe"/>
      </Declaration>
      <Declaration>
            <DataProperty IRI="hasImageUrl"/>
      </Declaration>
      <Declaration>
            <DataProperty IRI="hasId"/>
      </Declaration>
      <Declaration>
            <DataProperty IRI="hasFamilyName"/>
      </Declaration>
      <Declaration>
            <DataProperty IRI="hasUrl"/>
      </Declaration>
      ..
```

Listing 6.2 The second part of the created Google+ HRO-instance.

```
1       ..
2       <ClassAssertion>
3             <Class IRI="HumanResource"/>
4             <NamedIndividual IRI="JaneDoe"/>
5       </ClassAssertion>
6       <ClassAssertion>
7             <Class IRI="HumanResource"/>
8             <NamedIndividual IRI="JohnDoe"/>
9       </ClassAssertion>
10      <DataPropertyAssertion>
11            <DataProperty IRI="hasGender"/>
12            <NamedIndividual IRI="JaneDoe"/>
13            <Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string">female</Literal>
14      </DataPropertyAssertion>
15      <DataPropertyAssertion>
16            <DataProperty IRI="hasGivenName"/>
17            <NamedIndividual IRI="JaneDoe"/>
18            <Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string">Jane</Literal>
19      </DataPropertyAssertion>
20      <DataPropertyAssertion>
21            <DataProperty IRI="hasId"/>
22            <NamedIndividual IRI="JaneDoe"/>
23            <Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string">1006..0159</Literal>
24      </DataPropertyAssertion>
25      <DataPropertyAssertion>
26            <DataProperty IRI="hasUrl"/>
27            <NamedIndividual IRI="JaneDoe"/>
28            <Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string">
29                  https://plus.google.com/100629606288466440159</Literal>
30      </DataPropertyAssertion>
31      <DataPropertyAssertion>
32                  <DataProperty IRI="hasFamilyName"/>
33            <NamedIndividual IRI="JohnDoe"/>
34            <Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string">Doe</Literal>
35      </DataPropertyAssertion>
36            <DataPropertyAssertion>
37            <DataProperty IRI="hasSkill"/>
38            <NamedIndividual IRI="JohnDoe"/>
39            <Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string">Supervising</Literal>
40      </DataPropertyAssertion>
41  </Ontology>
42  <!-- Generated by the OWL API (version 4.0.2.20150714-1728) http://owlapi.sourceforge.net -->
```

In the next chapter, we will summarize the contributions of this diploma thesis to the topic of human resources by the investigation into a virtual human resource representation and provide an outlook for the countless possibilities of its application.

7 Summary and Outlook

In this diploma thesis, we have investigated into the subject of creating a Virtual Human Resource Representation by first introducing the topic of social computing and the discrepancy between software and human capabilities in solving complex problems. Secondly, we described a motivating scenario in showing the potential of a platform into which users can log-in with their favorite social network accounts to become discoverable, analyzable and usable for further applications, e.g. the modeling of business plans including human and non-human resources. In Chapter 2, we gave insight into informal business processes encompassing situation specific procedure changes during the execution time and went into the topic of social computing while introducing the term human resource. Mentioning available sources of information like social networks, we also looked into cloud applications and supporting languages for a potential area of human resource application. In Chapter 3, we analyzed properties and capabilities of human resources, which were derived out of both academic work and actual existing web services, like Facebook, Google+, LinkedIn, XING and GitHub. After deriving proper requirements for the creation of a virtual human resource representation, we compared them with the mentioned social networks and investigated into their commonalities and differences. Not being satisfied with the result, as no existing solution met all requirements, we presented our concept of a virtual human resource representation in Chapter 5. After offering more than 150 properties in thirteen categories for the definition of attributes and capabilities of a human resource, we introduced our implementation of a virtual human resource representation prototype. The Human Resource Provider extracts information from the Google+ platform and creates web ontology instances of our modeled Human Resource Ontology that is a manifestation of the virtual human resource representation concept. These so called Individuals are embedded in the OWL-XML-format, providing IRIs for their discovery, query, analysis to find matching candidates and for the possibility of their deployment in supporting web based environments.

Future Work and Outlook

With the universality of the created human resource ontology instance that have been derived out of a social network like Google+ and the provided Internationalized Resource Identifiers, each human resource is uniquely identifiable and suitable for the integration into various web platforms. In Chapter 2.2, we have mentioned OASIS TOSCA as a topology and cloud specification that allows the definition of Node Types and Relationship Types including a

business plan for their instantiation and deployment on a server environment. By applying the concept of a virtual human resource representation to define an according Node Type and by mapping the information of human resource ontology instances to Node Templates, which are instances of Node Types, it would be possible to create topology plans with both human and non-human resources. With the addition of relationships and a business plan, they could be deployed on a chosen web platform like OpenTOSCA.

Gartner has identified four trends in the IT industry and predicts that next to cloud technologies, social computing will have the greatest impact on how businesses will function in our world. Moving away from predefined processes that are still dominating organizations, the support of flexible approaches to accomplish complex tasks by individual decision-makings in dependence of the changing situational requirements, will according to him "*unleash yet to be realized prductivity growth*".

Our presented virtual human resource representation is a distillation of today's academic requirements and market offerings, providing a universal basis for the representation and application of human resources. Emerging research fields like digital anthropology are starting to acknowledge the growing inseparability of our physical world and social digital technologies and therefore may provide more insight into how a virtual human resource representation could be regarded and used to enrich our lives in the near future. Online gaming communities like World of Warcraft have created web platforms, offering millions of virtual characters a digital world to interact with each other. These game characters also have skills with various degrees of capability and they are able to build and manage teams similar to the proposed virtual human resource representation concept. In regards to collaboratively executing business processes, there is room to learn from such massively multiplayer online role-playing games, which posses long-term experiences and provide proven methodologies of communication, gaining experience and acquiring ratings to display one's own expertise level to other users.

Speech recognition and translation algorithms that are offered with Microsoft Cortana and Google's Web Speed API, as well as virtual and augmented reality technologies like Facebook's Oculus Rift and Microsoft's HoloLens show the possibilities of our future in regards to communication and interaction. They may well profit from the proposed concept to also enter the arena of professional and business-related collaboration platforms with an accordingly capable virtual human resource representation.

A Appendix

A.1 Property Analysis and Derived Sources

The following tables (A.1-A.14) contain properties and their derived sources, including Facebook (FB), Google+ (G+), LinkedIn (LI), XING (XG), GitHub (GH), Informal Process Essentials by Sungur et al. (IPE) [TSBBL14], The Human-provided Services Framework by Schall et al.(HpS) [STD11], Collective Problem Solving Using Social Compute Units by Sengupta et al. (CPS) [SJB+13], A Simulation Framework for Socially Enhanced Applications by Riveni et al. (SEA) [RTD12], The Social Compute Unit by Dustdar and Second (SCU) [DB11], Supporting Informal Processes by Sungur et al. (SIP) [SKL14], Virtualizing Software and Humans for Elastic Processes in Multiple Clouds by Dustdar and Second (EP) [DT12] and Provisioning Quality-Aware Social Compute Units in the Cloud by Candra et al.(QA) [CTD13].

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
ID Unique		⊕								⊕			
ID Applications	⊕	⊕	⊕	⊕	⊕								
Kind		⊕											
First Name	⊕	⊕	⊕	⊕					⊕	⊕			
Middle Name	⊕	⊕							⊕	⊕			
Last Name	⊕	⊕	⊕	⊕					⊕	⊕			
Full Name	⊕	⊕							⊕	⊕			
Formatted Name	⊕		⊕										
Display Name		⊕		⊕									
Honorific Prefix Name		⊕											
Honorific Suffix Name		⊕											
Profile URL	⊕	⊕	⊕	⊕	⊕								
Profile Image	⊕	⊕	⊕	⊕	⊕								
Birthday	⊕	⊕	⊕	⊕									
Gender	⊕	⊕		⊕									
Tag Line													
About Me	⊕	⊕											
Languages	⊕		⊕	⊕									
Display Language		⊕											
E-Mail Primary	⊕	⊕	⊕	⊕	⊕								
Address Primary	⊕		⊕	⊕									
Address Private				⊕									
Address Business				⊕									
Location	⊕		⊕						⊕				
Timezone	⊕			⊕									
Website	⊕	⊕											
Educational History	⊕	⊕	⊕	⊕			⊕						
Educational Summary			⊕										
Professional History		⊕	⊕	⊕			⊕			⊕			
Professional Summary			⊕										
Profession							⊕						
Industry			⊕	⊕									
Current Position		⊕	⊕	⊕		⊕	⊕			⊕			
Skills		⊕	⊕	⊕				⊕	⊕				⊕
Skill Level							⊕	⊕		⊕			⊕

Table A.1: Identifying and describing properties and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Contacts	⊕	⊕	⊕	⊕						⊕			⊕
Contact Requests	⊕	⊕	⊕	⊕									
Groups	⊕	⊕	⊕	⊕									
Associations			⊕										
Subscribers	⊕	⊕	⊕	⊕	⊕								
Subscribed To	⊕	⊕	⊕	⊕	⊕								
Interests and Likes	⊕	⊕	⊕	⊕									
Job Bookmarks			⊕										
Desires				⊕									
Activities	⊕	⊕	⊕	⊕	⊕								
Tagged Places	⊕	⊕											
Web Accounts			⊕	⊕									

Table A.2: Social connections, activities and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Publications			⊕										
Patents			⊕										
Certifications			⊕										
Courses			⊕										
Honors and Awards			⊕	⊕									
Career Level				⊕									
Educational Degree				⊕									

Table A.3: Achievements, qualifications and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Evidence							⊕		⊕	⊕			
Recommendation Number			⊕				⊕						
Recommendations			⊕				⊕						
Recommenders			⊕				⊕						
Trust-score									⊕				
Success Rate									⊕				

Table A.4: Reputation, evidence and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Context										⊕			
Time Supply										⊕			
Payment									⊕	⊕		⊕	⊕
Taxation												⊕	
Incentive										⊕			
Reward										⊕			

Table A.5: Work, request related data and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Computing Power								⊕		⊕			
Performance												⊕	
Reliability									⊕			⊕	
Availability									⊕			⊕	
Throughput												⊕	
Response Time							⊕					⊕	⊕
Accuracy												⊕	
Completeness												⊕	
Quality of Data												⊕	
Overall Quality												⊕	

Table A.6: Quality, performance and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Account Created At					⊕								
Account Verified	⊕	⊕											
Check-ins	⊕												
Last Modified			⊕		⊕								

Table A.7: Monitoring properties and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Permissions	⊕	⊕	⊕	⊕	⊕								
Data Rights												⊕	
Service rights												⊕	
Warranty												⊕	
Law Enforcement												⊕	
Compliance Rule												⊕	

Table A.8: Security related properties and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Messaging Systems							⊕						
Messaging Type							⊕						
E-Mails		⊕		⊕									
Phone Numbers	⊕		⊕	⊕									
Status	⊕												
Feed	⊕												
Inbox	⊕	⊕	⊕										
Outbox	⊕	⊕	⊕										
Notifications	⊕	⊕	⊕	⊕	⊕								

Table A.9: Communication related properties and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
ID Teams					⊕								
Team-Members	⊕	⊕	⊕	⊕	⊕	⊕		⊕		⊕			
Team Size	⊕	⊕	⊕		⊕								
Create Team	⊕	⊕	⊕	⊕	⊕	⊕		⊕		⊕			
Define Role					⊕	⊕				⊕			
Create Relationship						⊕							
Relationships Human Resources						⊕							
Relationships Non-Human Resources						⊕							
Delete Relationship								⊕					

Table A.10: Team-working properties and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Create Goal					⊕	⊕							
Create Plan					⊕	⊕							
Working Style													⊕
Process in Pipeline													⊕
Process In Parallel													⊕
Process Fault-Tolerant													⊕
Share Tasks													⊕
Use Human Resources											⊕		
Use Non-Human Resources											⊕		
Change Non-Human Resources											⊕		

Table A.11: The different working styles and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Add Common Operation To List								⊕					
Common Operation List								⊕					
Lifecycle-ability										⊕			
Define State							⊕						
Define Investigation State								⊕					

Table A.12: Common operations and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Add Custom Operation To List								⊕					
Custom Operation List								⊕					
Associate Custom Operation with Resource or Team								⊕					

Table A.13: Custom operations and their sources.

Properties	FB	G+	LI	XG	GH	IPE	HpS	CPS	SEA	SCU	SIP	EP	QA
Add Dynamic Operation To List								⊕					
Dynamic Operation List								⊕					
Modify Relationships								⊕					
Modify Relationships In Teams								⊕					
Modify Members In Teams					⊕	⊕		⊕		⊕	⊕		
Change Resource Properties							⊕						

Table A.14: Dynamic operations and their sources.

A.2 Virtual Human Resource Representation Properties

Property	Description
ID Unique	The unchanging unique ID of this person.
ID Applications	A list of IDs unique to each application the person has logged into.
Kind	Identifies this person as a human resource and distinguishes him from other types of resources, like bot identities.
First Name	The person's first name.
Middle Name	The person's middle name.
Last Name	The person's last name.
Full Name	The person's complete name, including middle name, pre- and suffixes.
Formatted Name	The person's name in different formats, like Chinese or Japanese including a correct ordering.
Display Name	The first and last name of the person to be displayed.
Honorific Prefix Name	The honorific prefixes like "Mr." or "Dr." for this person.
Honorific Suffix Name	The honorific suffixes like "Jr." for this person.
Profile URL	The profile URL of this person.
Profile Image	The person's profile image, which can either be the image-file itself or an URL.
Birthday	The birthday of this person.
Gender	The gender of a person can be "male2, "female" or "other".
Tag Line	A brief description, tag line or motto of the person.
About Me	A self-description of the person.
Languages	Contains the languages a person speaks with selectable degrees of expertise, like "elementary", "limited"- or "professional work" and "native".
Display Language	The person's preferred rendering language for viewed content.

Table A.15: Identifying and describing properties.

Property	Description
E-Mail Primary	The primary e-mail address of the person, which can be both used for private and professional messaging.
Address Primary	The primary address of the person consists of the "street", "city", "ZIP code", "province" and "country".
Address Private	The person's private address.
Address Business	The person's business address.
Location	The current location of the person, either self-set or determined by the application.
Timezone	The person's current timezone offset from UTC.
Website	The person's private or professional website.
Educational History	The person's educational history contains a list of school and university names including title, start-, end-date and whether it is the current one.
Educational Summary	The summary of the person's educational history.
Professional History	The person's professional history contains a list of companies and organization names including "title", "start"-, "end-date" and whether it is the "current one".
Professional Summary	The summary of the person's professional history.
Profession	The profession of the person.
Industry	The industry to which the person belongs.
Current Position	The person's current position in a company or role in a team.
Skills	Contains a list of the person's skills.
Skill Level	Determines the degree of expertise of a given skill, based on the observed activities of the user. Can either be a value in between a value-range, like 7 out of 10, or an ordering of skills from best to least.

Table A.16: Describing properties second part.

Property	Description
Contacts	The contacts of a person include the types private, professional and other.
Contact Requests	A person's pending contact requests.
Groups	The groups the person belongs to.
Associations	Private, professional and other associations the person is a part of.
Subscribers	Contacts and other profiles that are following this person.
Subscribed To	The contacts and other profiles that this person is following.
Interests and Likes	The interests and likes of the person.
Job Bookmarks	Jobs the person is interested in and has bookmarked.
Desires	Private and professional desires of the person, like a new job or a contact in a specific country.
Activities	The current activities of this person.
Tagged Places	List of tagged places this person has been in.
Web Accounts	Accounts and profiles, that the person owns from other companies, like LinkedIn, GitHub, Twitter and Skype.

Table A.17: Social connections and activities.

Property	Description
Publications	The publications that are associated with the person.
Patents	The patents that are associated with the person.
Certifications	The certifications that are associated with the person.
Courses	The courses the person has taken.
Honors and Awards	The honors and awards the person has received.
Career Level	The achieved career level of the person.
Educational Degree	Achieved educational degree of the person.

Table A.18: Achievements and qualifications.

Property	Description
Evidence	External sources being a reference to the person's qualifications.
Recommendations Amount	The amount of recommendations that the person has.
Recommendations	A list of recommendations describing the person.
Recommenders	A list of recommenders that formulated the recommendations.
Trust-score	Determines the degree of trust customers, consumers and requesters have towards this person.
Success Rate	Is a rating for the amount of successfully finished jobs and tasks, e.g. 9 out of 10 or 97%.

Table A.19: Reputation and evidence.

Property	Description
Context	The context in which the person is operating, e.g. in response to an incident correction request.
Time Supply	The amount of time this person offers for a given task.
Payment	The person's payment conditions, e.g. 100 dollars per hour.
Taxation	The amount of taxes paid for the person in percentage or a specified value.
Incentive	Motivating objects or contexts for the person to perform a specific task.
Reward	Next to the payment of the person, a reward can be anything motivational based on the outcome quality of a requested task, e.g. a better ranking.

Table A.20: Work and request related data.

Property	Description
Computing Power	A value, based on the amount of team members in relation to their skill levels to accomplish a task. E.g. three expert translators for one short document would indicate a higher computing power, than the same task executed by two novice translators.
Performance	Consists of "response time", "availability", "reliability" and "throughput".
Reliability	The continuity of performance the person delivers over the requested time.
Availability	The time span the person is available over the requested time, given in %, e.g. 95%.
Throughput	The amount of processed tasks within a given time, e.g. translation of 500 words per hour.
Response Time	The time-span the person specifies for responding to incoming messages.
Accuracy	Determines the degree of accuracy with which a task has been processed, e.g. 98 words out of 100 are correctly translated. Or the requested task and nothing else has been processed.
Completeness	The completeness of processing a given task, e.g. 10 out of 10 papers translated.
Quality of Data	A value derived out of accuracy and completeness.
Overall Quality	The overall process quality is determined by its performance and data quality.

Table A.21: Quality and performance.

Property	Description
Account Created At	The person's account creation date.
Account Verified	Indicates the account's verification from the platform.
Check-Ins	The number of check-ins the person has made to the platform.
Last Modified	A time-stamp of the person's last profile editing.

Table A.22: Monitoring properties.

Property	Description
Permissions	The permissions that the person has granted to the application.
Data Rights	The permissions the person has to access or modify a data resource.
Service rights	The permissions the person has to access or modify a service resource.
Warranty	The contractual warranty under which this person is hired, e.g. guaranteed employment time of 5 months.
Law Enforcement	The jurisdictional rights this person has to enforce a law.
Compliance Rule	The rules this person must obey for a given task.

Table A.23: Security related properties.

Property	Description
Messaging Systems	A list of messaging systems the person accepts for communication, like e-mail and chat.
Messaging Type	Comprises synchronous and asynchronous messaging.
E-Mails	Contains a list of e-mail addresses of this person, which have a type like "private", "professional" and are open to according contact groups or other specific purposes.
Phone Numbers	The various phone numbers of a person including their type, like "private", "work" and "other".
Status	The current status of the person, e.g. available for work, or task finished by 90%.
Feed	The feed of posts and links this person has published.
Inbox	A person's message inbox.
Outbox	A person's message outbox.
Notifications	The unread notifications that a person has.

Table A.24: Communication related properties.

Property	Description
ID Teams	A list of IDs unique to each team the person belongs to as a human resource.
Team-Members	The ID and names of the team-members.
Team Size	The amount of members in a team.
Create Team	The ability to form teams by inviting human resources to join a team, determining roles and relationships, including relationships to non-human resources, like software- and hardware-components.
Define Role	The ability to define a role in dependence of the task requirement, e.g. team-leader, co-worker, consultant.
Create Relationship	Creates a relationship to a human or non-human resource, e.g. communicate with or collaborate to.
Relationships Human Resources	The list of relationships with one or more human resources.
Relationships Non-Human Resources	The list of relationships with one or more non-human resources, like software- and hardware-components..
Delete Relationship	Deletes existing relationships with human or non-human resources.

Table A.25: Team-working properties.

Property	Description
Create Goal	Creates a goal or sub-goal to accomplish a task.
Create Plan	Creates a plan to accomplish a task, including required resources, their relationships, goals and sub-goals and in which order these goals by which resources should be reached.
Working Style	The different working styles a single or a group of human resources accept to accomplish a task, like "pipeline", "parallel", "fault-tolerant" and "shared tasks".
Process in Pipeline	A task is processed sequentially, one human resource after the other.
Process In Parallel	A task is processed in parallel by splitting and executing the splits through human resources, then merging them into the solution.
Process Fault-Tolerant	A task is processed redundantly by two or more human resources. The best result is taken.
Share Tasks	Shares tasks among human resources, enabling the person to process more than one task and also share a task process with other human resources.
Use Human Resources	Uses one or more human resources to accomplish task.
Use Non-Human Resources	Use one or more non-human resources to accomplish task.
Change Non-Human Resources	Changes software- and hardware-components during the business process execution.

Table A.26: The different working styles.

Property	Description
Add Common Operation To List	Creates a self-defined operation, like "begin execution" and adds it to the common operation list.
Common Operation List	A list of all available common operations.
Lifecycle-ability	The person's ability to form a team, assimilate request information, virtualize and deploy the solution and dissolve the team after the task completion.
Define State	Defines the state of the person, e.g. online, active, offline.
Define Investigation State	Defines the investigation state of a task, e.g. component one is corrected, component two is awaiting correction.

Table A.27: Common operations.

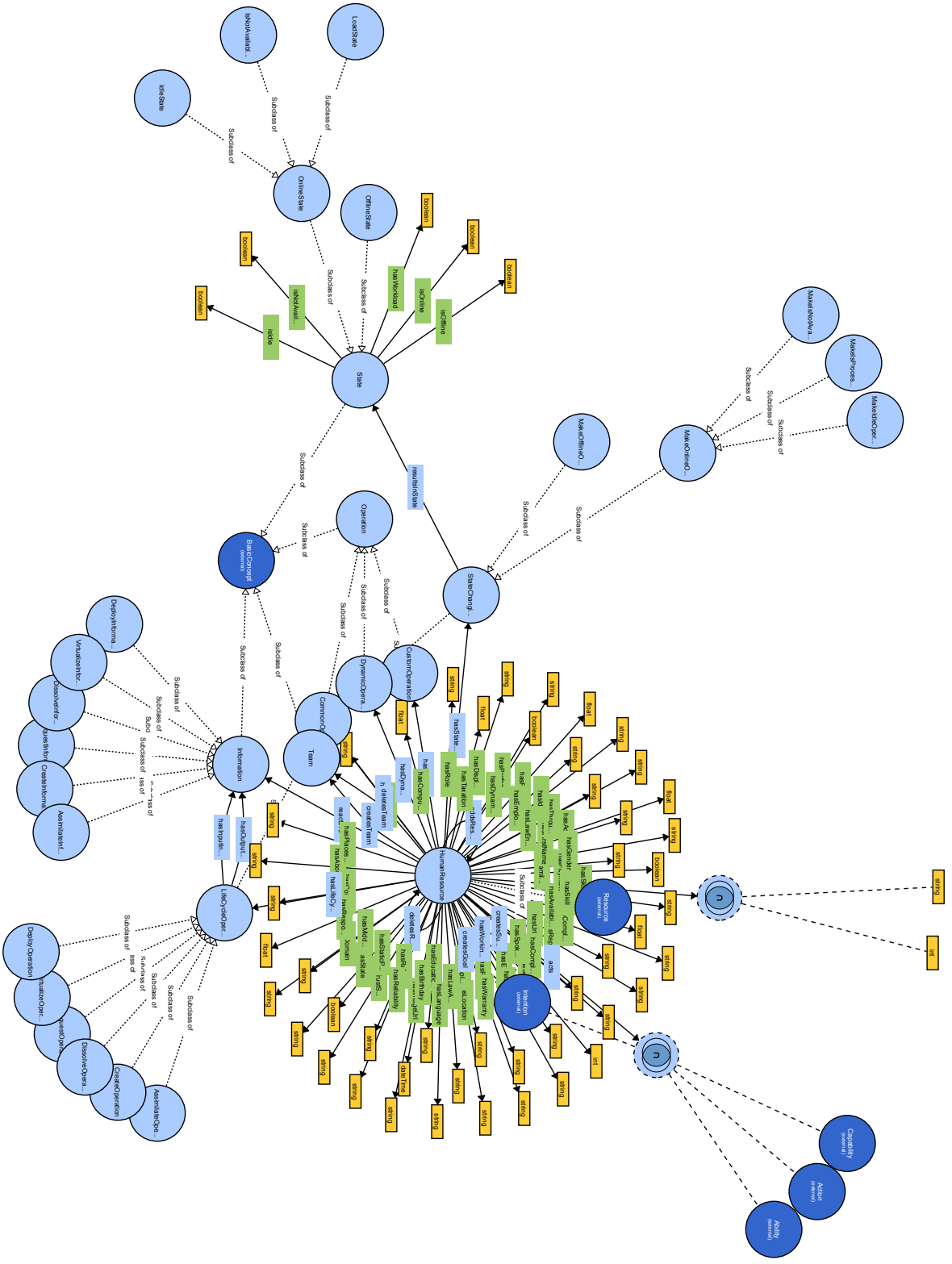
Property	Description
Add Custom Operation To List	Creates a self-defined operation, like translate to language and adds it to the custom operation list.
Custom Operation List	A list of all available custom operations.
Associate Custom Operation with Resource or Team	Associates a custom operation with a human or non-human-resource, or a team like (human resource team one, translate).

Table A.28: Custom operations.

Property	Description
Add Dynamic Operation To List	Creates a self-defined operation, like modify web service properties and adds it to the dynamic operation list.
Dynamic Operation List	A list of all available dynamic operations.
Modify Relationships	Modifies relationships with human or non-human resources.
Modify Relationships In Teams	Modifies relationships of resources in a team.
Modify Members In Teams	The ability to add new resources to a team, or to remove them, during the execution of a business process.
Change Resource Properties	Changes human properties during the execution of a business process, like role and response-time.

Table A.29: Dynamic operations.

A.3 Human Resource Ontology



Bibliography

[AO94] S. Arbaoui, F. Oquendo. Goal oriented vs. activity oriented process modelling and enactment: Issues and perspectives. In *Software Process Technology*, pp. 171–176. Springer, 1994. (Cited on page 17)

[CTD13] M. Z. Candra, H.-L. Truong, S. Dustdar. Provisioning Quality-Aware Social Compute Units in the Cloud. *11th International Conference on Service Oriented Computing*, 2013. (Cited on pages 26, 32, 33, 34, 35 and 63)

[DB11] S. Dustdar, K. Bhattacharya. The Social Compute Unit. *IEEE Internet Computing*, 15(3):64–69, 2011. (Cited on pages 13, 25, 32, 33, 34, 35 and 63)

[DJB96] T. H. Davenport, S. L. Jarvenpaa, M. C. Beers. Improving Knowledge Work Processes. *Sloan Management Review*, 37(4):53–66, 1996. (Cited on page 18)

[DM03] T. Dufresne, J. Martin. Process modeling for e-business. *Information Systems Department, George Mason University, L. Kerschberg (ed)*, 2003. (Cited on page 17)

[Dod12] A. R. Dodita. Limitations of Automatic Translations: Google Translate (Arabic into Romanian), 2012. (Cited on page 12)

[DT12] S. Dustdar, H.-L. Truong. Virtualizing Software and Humans for Elastic Processes in Multiple Clouds - a Service Management Perspective. *International Journal of Next-Generation Computing (IJNGC)*, 2012. (Cited on pages 13, 26, 33 and 63)

[GRS05] C. Gentry, Z. Ramzan, S. Stubblebine. Secure Distributed Human Computation. In *Proceedings of the 6th ACM conference on Electronic commerce*, pp. 155–164. ACM, 2005. (Cited on page 19)

[Hei90] D. Heimbigner. Proscription versus Prescription in Process-Centered Environments. In *Software Process Workshop, 1990. 'Support for the Software Process'., Proceedings of the 6th International*, pp. 99–102. IEEE, 1990. (Cited on page 17)

[HRP05] C. Richter-von Hagen, D. Ratz, R. Povalej. Towards Self-Organizing Knowledge Intensive Processes. *Journal of Universal Knowledge Management*, 2:148–169, 2005. (Cited on page 18)

[IBM12] O. Isik, J. Van den Bergh, W. Mertens. Knowledge Intensive Business Processes: An Exploratory Study. In *System Science (HICSS), 2012 45th Hawaii International Conference on*, pp. 3817–3826. IEEE, 2012. (Cited on page 18)

[Jon01] P. M. Jones. Collaborative Knowledge Management, Social Networks, and Organizational Learning. *Systems, Social and Internationalization Design Aspects of Human-Computer Interaction*, 2:306–309, 2001. (Cited on page 18)

[KI07] U. Kulkarni, M. Ipe. Decision Support for Knowledge Intensive Business Processes. In *Proceedings of the ADPSI Conference*. 2007. (Cited on page 18)

[Moo06] G. E. Moore. Cramming more components onto integrated circuits, Reprinted from Electronics, volume 38, number 8, April 19, 1965, pp.114 ff. *IEEE Solid-State Circuits Newsletter*, 20(3):33–35, 2006. (Cited on page 12)

[MRST+14] D. Murray-Rust, O. Scekic, H.-L. Truong, D. Robertson, S. Dustdar. A Collaboration Model for Community-Based Software Development with Social Machines. In *Collababorative Computing: Networking, Applications and Worksharing, 2014 International Conference on*, pp. 84–93. IEEE, 2014. (Cited on page 13)

[MS08] O. Marjanovic, R. Seethamraju. Understanding Knowledge-Intensive, Practice-Oriented Business Processes. In *Hawaii International Conference on System Sciences, Proceedings of the 41st Annual*, pp. 373–373. IEEE, 2008. (Cited on page 18)

[MUM14] H. L. Malte Unger, J. Mendling. How much Flexibility is good for Knowledge Intensive Business Processes: A Study of the Effects of Informal Work Practices. HICSS, 2014. (Cited on page 18)

[MWM+12] T. Matthews, S. Whittaker, T. P. Moran, S. Y. Helsley, T. K. Judge. Productive Interrelationships between Collaborative Groups Ease the Challenges of Dynamic and Multi-Teaming. *Computer Supported Cooperative Work (CSCW)*, 21(4-5):371–396, 2012. (Cited on page 19)

[MWMY11] T. Matthews, S. Whittaker, T. Moran, S. Yuen. Collaboration personas: A new approach to designing workplace collaboration tools. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 2247–2256. ACM, 2011. (Cited on page 19)

[Non94] I. Nonaka. A Dynamic Theory of Organizational Knowledge Creation. *Organization Science*, 5(1):14–37, 1994. (Cited on page 19)

[Nur05] K. Nurcan, Etien. A strategy driven business process modelling approach. pp. 628–649. BPMJ, 2005. (Cited on page 17)

[Nur08] S. Nurcan. A Survey on the Flexibility Requirements Related to Business Processes and Modeling Artifacts. In *Hawaii International Conference on System Sciences, Proceedings of the 41st Annual*, pp. 378–378. IEEE, 2008. (Cited on page 18)

[Pan11] Z. Panian. A Promising Approach to Supporting Knowledge-Intensive Business Processes: Business Case Management. *World Academy of Science, Engineering and Technology*, 5:642–648, 2011. (Cited on page 18)

[PM03] G. Papavassiliou, G. Mentzas. Knowledge modelling in weakly-structured business processes. *Journal of Knowledge Management*, 7(2):18–33, 2003. (Cited on page 18)

[RTD12] M. Riveni, H.-L. Truong, S. Dustdar. A Simulation Framework for Socially Enhanced Applications. *1st International Workshop on Socially Intelligent Computing (SINCOM 2012)*, 2012. (Cited on pages 12, 13, 19, 25, 32, 33, 35 and 63)

[RTD14] M. Riveni, H.-L. Truong, S. Dustdar. On the Elasticity of Social Compute Units. In *Advanced Information Systems Engineering*, pp. 364–378. Springer, 2014. (Cited on page 11)

[Sah09] A. K. Saha. Review of Commonsense Reasoning, 2009. (Cited on page 13)

[Sch94] D. Schuler. Social Computing. *Communications of the ACM*, 37(1):28–29, 1994. (Cited on page 11)

[SJB+13] B. Sengupta, A. Jain, K. Bhattacharya, H.-L. Truong, S. Dustdar. Collective Problem Solving using Social Compute Units. *International Journal of Cooperative Information Systems*, 22(04), 2013. (Cited on pages 13, 26, 32, 33, 34, 35 and 63)

[SKL14] C. T. Sungur, O. Kopp, F. Leymann. Supporting Informal Processes. In *The 6th Central European Workshop on Services and their Composition (ZEUS 2014)*, pp. 56–63. CEUR-WS.org, Potsdam, 2014. (Cited on pages 18, 19, 24, 34, 35, 47, 51 and 63)

[STD11] D. Schall, H.-L. Truong, S. Dustdar. *The Human-Provided Services Framework*. Springer, 2011. (Cited on pages 25, 32, 33, 34, 35 and 63)

[TDB12] H.-L. Truong, S. Dustdar, K. Bhattacharya. Programming Hybrid Services in the Cloud. *10th International Conference on Service-oriented Computing*, 2012. (Cited on pages 13 and 19)

[Tim94] T. N. Y. Times. A Boom for On-Line Services, 1994. (Cited on page 20)

[TSBBL14] C. Timurhan Sungur, T. Binz, U. Breitenbucher, F. Leymann. Informal Process Essentials. In *Proceedings of the 18th IEEE Enterprise Distributed Object Conference (EDOC 2014)*, pp. 200–209. IEEE Computer Society, Ulm, 2014. (Cited on pages 13, 18, 19, 24, 32, 34, 35, 41, 47 and 63)

All links were last followed on July 21, 2015.

Declaration

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

---

place, date, signature