

**Accessible RDF –
Linked Data as Source of Information for Visually Impaired Users**

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The Semantic Web offers substantial advantages of accessibility of information for both visually impaired and non-visually impaired users. While more and more websites and web services make use of information published as Linked Data, the advantage of data being published in an open format for people requiring assistive technology has not been explored yet. *Accessible RDF* is a website that makes Linked Data available to users in the most accessible manner. It aims at providing access to all information with the publication of the information in Linked Data format as the only requirement. The information becomes independent of the medium. This work explains how the Semantic Web and Linked Data can help make the World Wide Web more accessible and evaluates how users of assistive technology can benefit from it.

Key words and terms: Semantic web, Human factors, Visual impairment, Linked data, Web search, RDF.

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1. Introduction

The World Wide Web has grown into one of the most important media of our time. Thanks to accessibility tools, laws and guidelines how to make websites accessible, the number of users with handicaps who are able to access information online is increasing. However, despite new accessibility tools and techniques, refreshable Braille displays, ergonomic interaction devices and software tools such as screen readers, most sites remain partly or completely inaccessible. While the possibilities and hardware are making advances, physical and cognitive demand are increasing and widening the gap between the connected and unconnected world. The World Wide Web was designed as a visual medium, and it still is. Users with visual impairments and those who otherwise struggle in recognizing the visual dimension of the Web can never be certain that an important information source is accessible by their means. The vast amount of websites and the different technologies they use (*Flash*, *Silverlight*, *JavaScript*, etc.) all have a different target audience and are constantly challenged to offer state-of-the-art services. The special-needs user comes after that.

If the information available on the web was not obstructed by *HTML* structure and hidden within script objects, all users could rely on accessibility by a few rules. One possibility to put this idea into practice would be for all website developers to publish information in pure, clean *HTML*. However, writing clean *HTML* has proven to be a challenge itself.

A step towards a more accessible web may lie in the adoption of the Semantic Web principle. Sir Timothy Berners-Lee, the creator of some of the web's underlying principles such as *HTTP* and *HTML*, writes in a design issue note on the concept of *Linked Data* from 2006 [Berners-Lee, 2006a]:

“The Semantic Web [...] is about making links, so that a person or machine can explore the web of data.”

Berners-Lee's vision is shared by many, and the Semantic Web is growing daily. His concept of *Linked Data* entails publishing data in standardized formats: *“When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL) [Berners-Lee, 2006a].”*

RDF is, like *HTML*, an *SGML*-based markup language. However, *RDF* is not in direct danger of being utilized for visual appearance. One reason is that *RDF* was not designed to be “looked at”: it separates content from presentation. It is a language that allows machines to connect and reason about the information in the data. It does this through data structures that represent real-life objects, characteristics and relationships and a vocabulary that contains and maintains their original meaning. As it is put on the *W3C Semantic Web Activity* website¹:

“There is lots of data we all use every day, and it is not part of the web. I can see my bank statements on the web, and my photographs, and I can see my appointments in a calendar. But can I see my photos in a calendar to see what I was doing when I took them? Can I see bank statement lines in a calendar? Why not? Because we don't have a web of data. Because data is controlled by applications, and each application keeps it to itself.”

The consumption of the published data by human readers is only secondary. It is the reason why the Semantic Web – a vision that encouraged the development of *RDF* – is called the “Web of Things”², as opposed to the World Wide Web as the “Web of Documents”. Therein lies the more important reason why *RDF* is safe from misuse for visual display: *RDF* represents real-world data, not a document structure freely manipulated by the designer. *RDF* is used to connect data in order to find new information and patterns in the structure. For a human user, it is easier to read and understand information in texts and graphics, which *HTML* (*Hypertext Markup Language*) is used for. For automated agents, on the other hand, there is *RDF*.

The strength of Linked Data is also its weakness: since there are no guidelines how to display *RDF* data, the data that exists on the web today is difficult to access. While *HTML* frontends and standalone *RDF* browsers exist, none of them put particular effort into accessibility, especially not for users with visual impairments.

As part of this thesis, a website has been developed, *Accessible RDF* (in the following referred to as *ARDF*), that allows users to find *RDF* data on the web, which is

¹ <http://www.w3.org/2001/sw/>

² cf. <http://ercim-news.ercim.eu/content/view/343/536/>

then displayed as simple HTML. The aim is to combine the advantages of both HTML and RDF to create an online data source for people with visual impairment. The vast information representable with RDF ought to be accessible through the ubiquitous information technology of our time, accessible for anyone. RDF offers the data structures, HTML enables access, JSP is used to create dynamic content, and SPARQL allows sophisticated information queries (see Chapter 3 for a description of each).

ARDF displays and offers access to RDF data as simple HTML in an effort to create a single, exhaustive information source. It does so by enabling the user to query keywords and data sources, and subsequently displaying it in a simple and intuitive HTML page that stands out through its usability and accessibility. This is achieved by keeping the user interface at a minimum and following accessibility guidelines, first and foremost the *W3C Web Content Accessibility Guidelines (WCAG) 2.0*.

This work is structured as follows. Chapter 2 introduces the topic of web accessibility, focussing on users with visual impairment. It describes the problems users face and tools and techniques how to avoid or circumvent these. In Chapter 3, RDF and the idea of Linked Data is presented. Chapter 4 describes *Accessible RDF* and how visually impaired users can benefit from Linked Data as a source of information. It describes the idea as well as the technical structure of the concept. Chapter 5 evaluates *Accessible RDF* by means of automated accessibility checking tools and an online survey. Chapter 6 and 7 conclude this work by framing the advantages of using *Accessible RDF* and, more generally, Semantic Web technology for web accessibility as it has been shown in this work and as it may be used in the future.

2. Web Accessibility for Visually Impaired Users

Since its advance into workplaces and private households, the World Wide Web has experienced a strong transformation from delivering simply-structured HTML pages to a fully dynamic multimedia-based experience. Although laws exist in many countries that demand accessibility [McLawhorn, 2001] and guidelines how to achieve this have been written [Caldwell, Cooper, Guarino-Reid and Vanderheiden, 2008a], many websites remain partly or completely inaccessible [Sullivan and Matson, 2000]. While HTML and other SGML-based markup languages are easy to browse non-visually in theory, the use of markup languages against standards and definition and modern web technologies such as Adobe Flash and Microsoft Silverlight and make it impossible to process web pages for visually impaired users³. In this chapter, we will look at the issues that arise for visually impaired users while browsing the web. Then we will discuss hardware and software specifically developed for visually impaired users. We will describe their general functionality and what problems arise when using them. Finally, we will discuss guidelines that have been developed to improve web accessibility, their impact on the online landscape, and their shortcomings.

The Web is an increasingly important medium for all people. More information and more services are made available online, and therefore access to these is becoming crucial. Computers and computer networks offer larger possibilities of accessing information than any other medium: multimodal input and output devices.

According to the World Health Organization, 314 million people worldwide are visually impaired, 45 million of them are blind [WHO, 2009]. A survey among US citizens, conducted by Forrester Research in 2003, came to the conclusion that 62% of all adults (age 18 and older) would likely benefit from accessible technology [Stevenson and McQuivey, 2003]. Among the working-age adults in the survey, 27% had reported a visual difficulty performing daily tasks when using computers. While a wave of computer education is going through the population [Forrester Research, 2004], the demand for accessible technology is not likely to decrease. Due to the shift in the population pyramid in Western countries, computer users with disabilities and difficulties will increase. In the EU, the age group 65+ is projected to grow by 27% between 2015 and 2030, while the age groups 0-14 and 15-29 are projected to shrink by

³cf. <http://www.webaim.org/projects/screenreadersurvey2/>

6% and 11%, respectively [Vignon, 2005]. The ratio of population between 15 and 64 to population of 65 years and older is projected to double by 2060 (see Figure 2.1). By 2020, 20% of the working population in the US will be 55 years or older, meaning an increase of 50% over the year 2000 [Stevenson and McQuivey, 2003]. Since most severe disabilities occur after the age of 50, businesses will be forced to maintain and increase productivity of the aging labour force: Approximately 82% of all people who are visually impaired are age 50 and older, although they represent only 19% of the world's population [WHO, 2009].

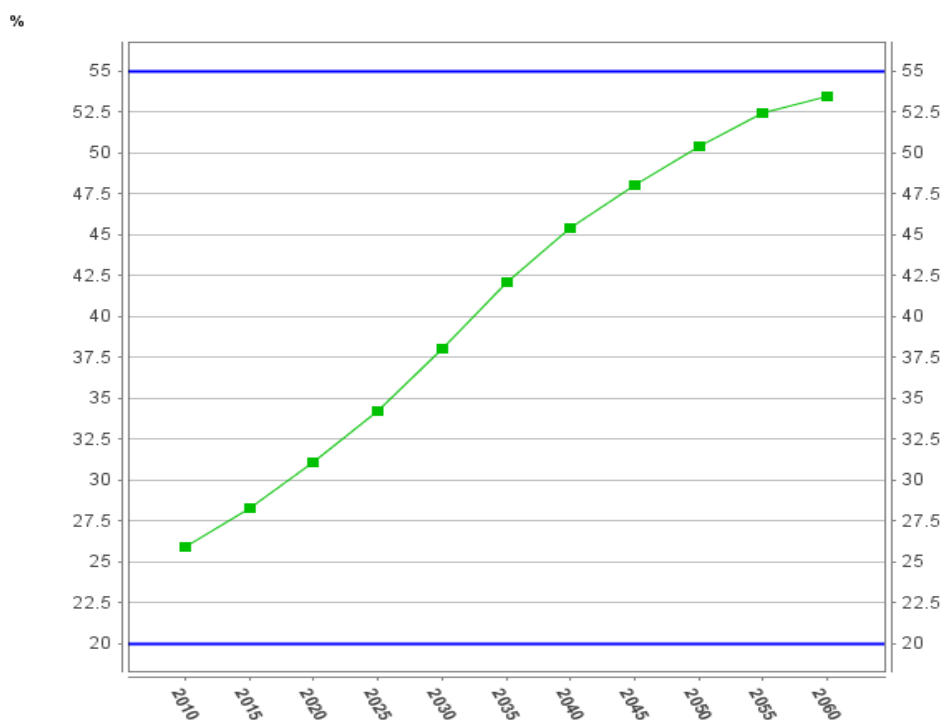


Figure 2.1: Describes the number of people of age 65 and older as percentage of the people between 15 and 64 in 27 EU countries, projected from 2010 to 2060. Source: Eurostat⁴.

If we take a look at how Braille literacy affected education and employment of blind people between the 1960's and 1990's, we might get an understanding for the importance of effective and available accessibility technologies for visually impaired computer users today and in the future. In a study published in the *Journal of Visual Impairment and Blindness* in 1996, Ruby Ryles discovered that congenitally blind people who had made Braille their primary medium had a significantly lower unemployment rate and were significantly more often employed full-time [Ryles, 1996].

⁴ <http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home>

30% of her Braille literate survey participants obtained a graduate degree, as opposed to 13% of the control group. Other surveys produce similar results [Mack, 1984].

A second survey by Forrester Research then showed that computer use is much lower among adults with severe impairments [Forrester Research, 2004]. However, not only the severity of the impairment plays a role in use rates. For example, in households with a yearly income of more than 125.000 US\$, existence and severity of difficulties and impairments does not affect computer use. However, in households with a yearly income of 40.000 US\$ or below 15.000US\$, the difference in computer use rates between those without and those with severe difficulties can be as much as 30%.

The study, “Accessible Technology in Computing – Examining Awareness, Use, and Future Potential”, also showed that, while use rates are higher if the difficulties/impairments are only mild for dexterity, hearing, cognitive and speech impairments, use rates among users with mild and with severe impairments remain the same. This leads us to the conclusion that even mild difficulties in visual perception can have severe consequences on the usability of computers.

2.1. What is Web Accessibility?

Accessibility is the level of inclusion or exclusion to a resource. In the case of web accessibility, the resource is the World Wide Web, and the level of inclusion or exclusion is measured by the difficulty of accessing it. There is no absolute measurement for an abstract concept as this, but it is possible to break the general down into smaller parts and take measurements at smaller scales: difficulty to access an online resource can result from a number of problems, such as bandwidth limitations, availability of technology, or usability of devices.

Accessibility is merely a subset of a larger category of problems: usability. Designing usable user interfaces includes considerations of effectiveness, learnability, memorability, efficiency and satisfaction of the interaction [Thatcher, Bohman, Burks, Henry, Regan, Swierenga, Urban and Waddell, 2002]. These factors also play a role when approaching accessibility, with the exception that satisfaction is merely a side issue compared to what obstacles many users face today. Unfortunately, while usability is a growing factor and industry, accessibility is still often regarded a “necessary evil”. At best, web designers and developers make no distinction between usability and

accessibility. Especially accessibility guidelines for users with learning disabilities or cognitive impairments largely fall into the range of usability.

2.2. Accessibility Issues

The internet has increased communication and collection of information from anywhere in the world at great speed. People with disabilities often benefit in more ways from this development than the average user, because all the information that might otherwise not be available can be presented in different modes and media to suit individual needs with relatively little effort. For example, before the age of computers and internet, people with visual impairments had to find and purchase books printed in Braille or find a spoken version on cassette to read a book. Nowadays, we can find free books on the web and have a speech synthesizer read it to us at variable speed or have it printed line by line on a refreshable Braille display.

At the same time, compatibility of soft- and hardware with the ever-growing demand of new technologies is often left behind, excluding users dependent on accessibility tools. Although these users represent a significant percentage of internet users [Kaye, 2000], the incentive apparently does not exceed the effort required for many web developers. The following sections (2.4, 2.5) list some of the issues that arise for users of accessibility tools through both technical limitations and improvident design. While technical limitations require substantial effort to overcome, many accessibility issues are in fact avoidable and only emanate from faulty software and uninformed design.

While the lack of accessibility in newly designed tools is a well-known problem, solutions and ideas towards its prevention are rare and inconclusive. Some guidelines are implemented already in design tools, creating accessible code without extra effort for the developer. The separation of data and presentation is turning into an omnipresent model (cf. HTML and CSS). However, most accessibility problems cannot be determined programmatically, and therefore cannot be solved programmatically.

2.3. How do visually impaired users access the Web?

Of all disabilities, visual impairment affects use of computers the most. The primary reasons are obvious: the first and foremost medium of feedback a device gives us is through a display. Few or no devices such as computers, mobile phones, PDAs or pagers are not equipped with a display. Furthermore, operating a technical device has developed towards manipulation of on-screen objects since the dawn of windows managers. Besides, any input device requires at least some spatial hand coordination and is therefore harder to learn for blind users.

It is common for visually impaired users to reach out to alternative devices for input. According to a survey among US citizens, more than 69% of all computer users with visual impairment use some accessible technology. This is reasonable as commonly available devices pose a large obstacle. Thanks to haptically enhanced keyboards and learning software, it is reasonably easy for visually impaired users to learn the layout of a keyboard. However, even when familiar with the standard keyboard layout, there are still problems. Keyboard models differ in the alignment of keys, have different layouts in different areas of the world, differ in haptic feedback and may not give feedback on their status (e.g. *Caps Lock*).

Due to the lack of prevalence of alternative input devices, visually impaired users are often excluded from device set-ups outside their own. For example, users might have a Braille display connected to the USB port of their computer. But lack of portability and widespread support of these devices make it hard to use their functionality in other places. The lack of standardized accessibility options exclude any user who is not capable of using standard devices as can be found in workplaces and public places.

2.4. Accessibility Software

The easiest way to increase web accessibility for users with visual impairment is to install software that converts the information that is otherwise hard to access into a different format. In this case, “format” may refer to any characteristic of the underlying media. For example, screen magnifiers enlarge anything that falls within the focus of the program; screen readers convert whatever textual information is available to audio

output; other tools may change colours to increase contrast or change behaviour of control elements. Some popular solutions are presented below.

2.4.1. Screen Readers

In the days of *DOS (Disc Operating System)*, screen reader software would literally read the 25 lines of 80 characters on the display. With the advent of graphical user interfaces, information became less linear, and screen readers had to become more elaborate.

Most screen readers create an off-screen model of all elements on the screen. Algorithms calculating how to represent graphical information and graphical structures differ largely, and are dependent on the developer's efforts. The same holds for web page readers.

In the beginning, HTML pages were linear collections of a limited number of elements. Converting a web page into text and speech was a straightforward practice. Today, HTML allows embedding of a large number of non-linear elements, including *JavaScript* and *Flash* elements. Therefore, all accessibility tools nowadays rely on accessing and retrieving HTML data and structure through the document's *Object Model (DOM)*.

Excursus: Document Object Model (DOM)

The *Document Object Model* is an interface for programs to access the content, structure and style of a document [W3C, 2005a]. It is defined and maintained by the *World Wide Web Consortium*. DOM contains “a standard set of objects for representing *HTML* and *XML* documents, a standard model of how these objects can be combined, and a standard interface for accessing and manipulating them” [Wood, Le Hors, Apparao, Byrne, Champion, et al., 2000], or, simply, a programmatic interface for HTML and XML.

The *DOM* specification consists of three levels. Level 1 specifies the *DOM Core* and *DOM HTML*. Both are extended in Level 2, but since *ARDF* uses HTML only, we will focus on Level 1 here. The *DOM Core* provides an interface that can represent any structured document. *DOM HTML* provides higher-level interfaces for a more convenient access to HTML documents.

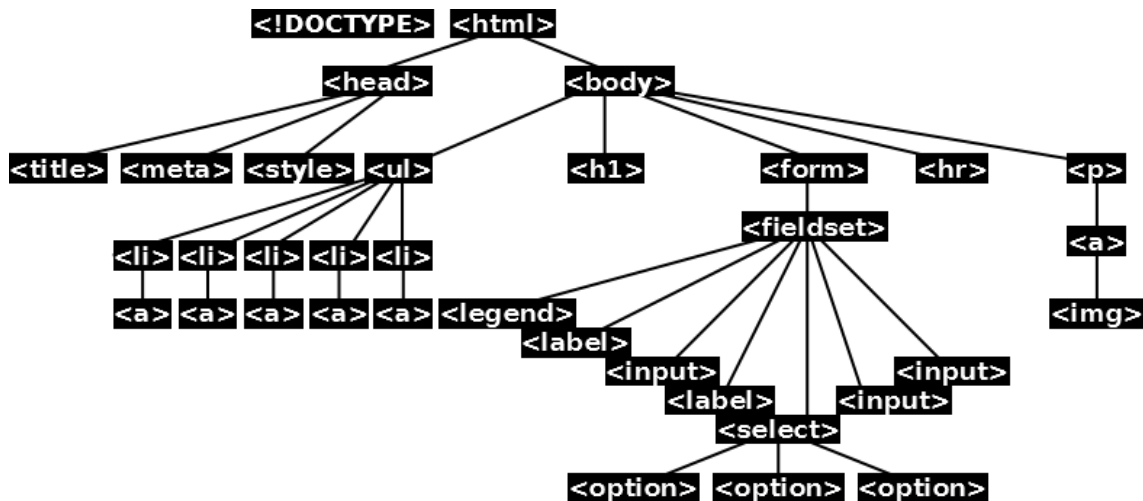


Figure 2.2: DOM model of ARDF's index.jsp

Specifically, the *DOM Core* defines a Document interface and the *HTML DOM* defines a `HTMLDocument` interface specifically for operations and queries on a HTML document. The same holds for the `Element` and `HTMLElement` interfaces. Every interface in the *DOM* contains methods to retrieve the properties of a specific HTML element. For example, the `HTMLTitleElement` contains the attribute `text`, which represents the title of the page as declared in the `<title>` tag. `HTMLAnchorElement` contains properties such as `accessKey` (cf. Section 4.3.1), `href` and `charset` and the methods `blur()` (to remove focus from element) and `focus()` (to give focus to this element) [Wood, Le Hors, Apparao, Byrne, Champion, et al., 2000]. Screen readers use these methods to access the parts of a document to read it to the user, as opposed to the pre-*DOM* method of reading the HTML file line by line.

Due to the availability of audio output devices and great advancements in speech synthesis in the past years, screen readers are nowadays one of the most common solutions to accessibility problems on computers and mobile devices⁵. Several commercial solutions are available, such as *Job Access With Speech (JAWS)* or *WindowEyes*. However, free screen readers are available (*Non Visual Desktop Access (NVDA)*, *Orca*), and many operating systems now include a screen reader by default (*VoiceOver*, *Narrator*).

⁵ cf. <http://www.webaim.org/projects/screenreadersurvey/>

Screen readers rely on structural and textual information provided by the operating system and running programs. Guidelines exist that help programmers maintain maximum accessibility for screen readers (e.g. *W3C User Agent Accessibility Guidelines* [Schwerdtfeger, Poehlman, Lacy, Jacobs, Hansen, Allan, Anson, Bingham and Gunderson, 2002]). Maintaining these guidelines and a meaningful structure became the main issue of web accessibility: HTML was misused for visual design; logical structure (as every XML-based language is built around) and therein appropriate browsing techniques for visually impaired users were lost.

Not all information is equally suitable to convert to speech. The main reason is that human visual perception allows parallel and deep hierarchical processing of information, while the user of a screen reader is bound to listening to one voice uttering one word at a time. In other words, the bandwidth of visual perception of web pages is larger than the bandwidth of auditory perception. Instead of precise control over the presentation of an element through size, colour or indentation, screen readers offer only one dimension to sort elements: time. If the program or web page does not have a clear hierarchy and the user no instrument to browse this hierarchy, the user is bound to listen to all content linearly, one item after another. As we will see later, guidelines exist that help programmers and designers develop a layout that is usable for all users.

The availability of audio output on almost all devices makes the screen reader a popular choice among accessibility tools. Another advantage of screen readers is the relatively high speed with which information can be processed. Experienced users can understand synthesized speech at a rate higher than 18 syllables per second [Trouvain, 2007], or 1300 morae⁶ per minute [Asakawa, Takagi, Ino and Ifukube, 2003], thereby far exceeding the reading and recognition rates of Braille displays [Ramstein, 1996; Legge, Madison and Mansfield, 1999]. Progress in speech synthesis research also increased comprehensibility and usability of screen readers [van Santen, 1997].

2.4.2. Screen Magnifiers

While blind users are dependent on screen readers and Braille keyboards, partially sighted users can make use of techniques that enhance the visual display so as to suit

⁶ While the definition of "mora" remains a matter of discussion, many sources describe it according to James D. McCawley's " *The Phonological Component of a Grammar of Japanese* ": "Something of which a long syllable consists of two and a short syllable consists of one [McCawley, 1968]." For a discussion of the term, see [Clark, Yallop and Fletcher, 2007; Auer, 1989].

their needs. Screen magnifiers are the software equivalent of a magnifier, giving the user the possibility to enlarge parts of the screen. Often, they are combined with screen readers that read aloud what currently is in focus, or alternative colour schemes that increase readability. Most GUI-based operating systems already include a screen magnifier.

2.4.3. Other Accessibility Tools

Beside the aforementioned techniques, most operating systems offer a wide variety of small tools or options that ease the use of devices. For example, videos and still images are often supported by alternative texts or subtitle. These are either maintained manually, or can be determined programmatically with computer vision and speech recognition algorithms.

All popular operating systems and window managers come equipped with a pre-defined high-contrast and large-font desktop theme to ease access for users with low vision.

Users with motor impairments, struggling with standard interaction devices such as computer mice and keyboards can make use of speech recognition software. This software listens to the user's voice and interprets spoken text as commands.

Sticky Keys is a feature of keyboards to allow simultaneous keystrokes to be serialized. This enables users to access functionality accessible only through a modifier key ("Alt", "Control", etc.) without the need to actually press two or more buttons simultaneously.

2.5. Accessibility Hardware

Additionally to software, users with visual impairment can also resort to devices specifically designed to ease access to information technology. While most users are capable of learning how to operate a computer or mobile phone through a physical keyboard (and a screen reader/text-to-speech converter), the standard input and output devices are not designed with visually impaired users in mind. Therefore, a large potential to increase usability and accessibility remains, and the following devices set out to do so.

2.5.1. Braille Displays

Before the rise of personal computers and screen readers, Braille was the preferred method of reading for people with visual impairment. Although Braille literacy and use of Braille in general significantly decreased in the past years [Ryles, 1996], many use a Braille display in situations where a screen reader is impractical, such as in noisy environments, or as an alternative, supplementary output device. A survey among the users of *Web Accessibility in Mind*⁷ revealed that less than 30% of screen reader users had access to a Braille output device [WebAIM, 2009a].

Apart from declining Braille literacy, the technical feasibility of refreshable Braille cells – especially in large numbers, so as to display a line or page of text – prevents them from gaining large popularity. Figure (a) in Table 2.1 shows a refreshable Braille display, which commonly cost between several hundred and 10.000 Euros. Considering that each dot of each Braille cell is driven by a separate actuator, it becomes obvious why most devices are bulky and expensive. Small and mobile devices exist, such as single cell displays (e.g. *Samsung Touch Messenger*), and software solutions to present Braille dots consecutively (e.g. *Nokia Braille Reader*). However, they have not yet gained much popularity or market share.



Table 2.1: a) Top view of an eight dot Braille display (Source: http://commons.wikimedia.org/wiki/File:Refreshable_Braille_display.jpg). b) Samsung Touch Messenger mobile phone (Source: <http://www.idsa.org/content/content1/touch-messenger>). c) Nokia Braille Reader running on a Nokia 5800 Xpress Music mobile phone (Source: <http://noknok.tv/2009/09/21/nokia-braille-reader-released/>).

2.6. Accessibility Laws and Guidelines

The idea that the World Wide Web is a basic necessity and access to it should be a basic right grew in the late 20th century. While at first the Web had little to offer to the

⁷ <http://www.webaim.org>

average person, guidelines how to guarantee access to specific resources soon became necessary. In the following, we will introduce some of the most influential laws and guidelines. Many other have been proposed and implemented; many are based on the ones presented here.

2.6.1. Web Content Accessibility Guidelines

The Web Content Accessibility Guidelines (*WCAG*) is a collection of documents about recommendations for making web content more accessible. They are published by the *Web Content Accessibility Guidelines Working Group (WAI)* under the *Web Accessibility Initiative* of the *World Wide Web Consortium (W3C)*. Thanks to the impartial role of the *WAI* and open development, the *WCAG* became the unofficial standard for accessibility guidelines. It was and is incorporated in many laws and counts as the basis for the recent amendments to Section 508, the US American Rehabilitation Act for accessibility of information from federal agencies [Thompson, 2005], among others.

At the heart of *WCAG* are four principles: information and user interfaces must be *perceivable*, meaning that they should be presented in a way that any user can perceive. User interface components must be *operable*, meaning that any functionality should be universally accessible, navigable and unobtrusive. The user must also be able to *understand* all content and functionality. This includes predictability of design and functionality, as well as supporting in critical situations. Lastly, any content should be *robust*, referring to compatibility to current and future demands on online resources. From these four principles are 12 guidelines derived, some of which (those which play an important role in *ARDF*) will be discussed in detail in Section 4.3.

WCAG covers guidelines for accessibility for limited devices such as mobile phones, and for people with many disabilities, including “blindness and low vision, deafness and hearing loss, learning disabilities, cognitive limitations, limited movement, speech disabilities, photosensitivity and combinations of these.” Therefore, not all guidelines apply equally to the *Accessible RDF* website. However, all guidelines are implemented as far as they apply to the architecture. Section 4.3.1 lists some of the guidelines and success criteria from *WCAG* that are particularly important in our design.

The WAI has been successful in promoting web accessibility since 1997. Beside the WCAG, WAI also published and further develops the *User Agent Accessibility Guidelines (UAAG)* and the *Authoring Tools Accessibility Guidelines (ATAG)*. UAAG is written for developers of user agent software such as web browsers, media players and assistive technologies. ATAG is aimed at developers of authoring tools, such as HTML and XML editors, content management systems, blogs, wikis and social networking sites. The idea behind the architecture of the three guidelines is that they form an “implementation cycle” [W3C, 2005b] around the content and if only one of the components is missing a feature, there is little motivation for the other components to implement it, as it still would not result in an accessible interface.

The first version of WCAG was published on May 5th, 1999 [Chisholm, Vanderheiden and Jacobs, 1999a]. Although WCAG is widely accepted, W3C received much criticism after the release of version 2. Some points of critique were:

- The size of the both normative and non-normative documentation will discourage publishers to consult the guidelines;
- The time between the first version of WCAG to receive recommendation status (May 5th, 1999) and the second version (December 11th, 2008) was a time of strong growth and fast development. Many technologies developed in the early 2000's were built on outdated or inapplicable guidelines;
- The language used in the documentation is largely incomprehensible, vague in regard to definitions and newly introduced terms;
- Disregard of standards compliance, such as valid HTML [Kelly, Sloan, Brown, Seale, Petrie, Lauke and Ball, 2007],
- A short-sighted, technically-oriented approach instead of focussing on user needs [Kelly, Sloan, Brown, Seale, Petrie, Lauke and Ball, 2007]

Furthermore, a formal objection signed by at least 52 domain experts and working group members was submitted to the public WCAG 2.0 mailing list in 2006 [Seeman, 2006]. The objection was directed against the claim the WCAG would provide means to incorporate users with cognitive disabilities and learning difficulties.

Kelly et al. [Kelly, Sloan, Brown, Seale, Petrie, Lauke and Ball, 2007] raise the question whether WCAG increases web accessibility at all, as there is no evidence, no feedback, on the impact of any accessibility guidelines. An investigation led by the Disability Rights Commission [DRC, 2004] in 2004 concluded that no relationship between any subjective or objective measure of accessibility and the number of violations of accessibility guidelines could be found. A similar work, a study of the accessibility of international museum websites, found the website with highest compatibility to WCAG the most difficult to use for their user panel of visually impaired and dyslexic users [Petrie, Hamilton and King, 2005].

Finally, the conformance to accessibility guidelines remains a subjective measure. It varies between subjects and can only be superficially tested by automated programs. No program is able to find or solve a sufficient amount of accessibility problems without the review of a field expert [Mankoff, Fait and Tran, 2005; Ivory and Chevalier, 2002].

The largely subjective nature of accessibility assessment leaves much room for interpretation on the publisher's side. On the W3C's WCAG conformance page, it is written: "Content providers are solely responsible for the use of these logos."⁸ A study of 20 e-commerce websites revealed that only 30% were making accurate claims concerning accessibility and conformance to guidelines [Petrie, Badani and Bhalla, 2005]. More important, however, may be the observation in this study that only 8% (40 out of 500) of all examined websites make any official statement about their accessibility.

2.6.2. International Laws and Policies

The following is a list of the most rigorous and influential national legislations which relate to web accessibility. Any web designer and developer should be aware of these and integrate their considerations into their work:

- Disability Discrimination Act 1992, Australia
- Canadian Human Rights Act of 1977, Canada
- Act on Equal Opportunities for Disabled Persons of 27 April 2002, Germany
- The Disability Act 2005, Ireland
- The Equal Rights for People with Disabilities Law, Israel

⁸ Source: <http://www.w3.org/WAI/WCAG1-Conformance>

- Provisions to support the access to information technologies for the disabled, Italy
- Human Rights Amendment Act 2001, New Zealand
- Resolution of the Council of Ministers Concerning the Accessibility of Public Administration Web Sites for Citizens with Special Needs, Portugal
- LAW 34/2002, Services of the Information Society and Electronic Commerce, Spain
- Ordonnance sur l'égalité pour les personnes handicapées, Switzerland
- The Disability Discrimination Act 1995, United Kingdom
- Rehabilitation Act, Section 504, United States of America
- Rehabilitation Act Amendments of 1998, Section 508, United States of America [W3C, 2006]

2.6.3. Section 508, US American Rehabilitation Act

Section 508 of the *Rehabilitation Act* amendments of 1998 is based on the first priority WCAG guidelines. It requires that all information technology developed or purchased by federal governments be accessible for people with disabilities [Foley and Regan, 2002] “to the extent it does not pose an undue burden on an agency. [McLawnhorn, 2001]“ It does not apply to private businesses.

Agencies are not required to upgrade technology installed before June 21st, 2001, but failure to match technologies with the standards installed after this date may result in a federal lawsuit. These technologies include websites as well as telecommunication systems, photocopiers or application software [USA, 1988] (§1194.4).

Six exceptions apply to the compliance rule. If an agency can explain why meeting the standards is an „undue burden“, and if it can provide alternative access, it is exempt from complying with the law. *Section 508* does not apply to national security, intelligence and weapons systems. The third exception applies if no accessible alternative to a commercial product to purchase exists. Furthermore, products in spaces only frequented for maintenance or monitoring are not required to comply with the law. Also, the changes made to a product to comply with the law should not „require a fundamental alteration in the nature of a product or its components [USA, 1988] (§1194.3).“ Lastly, the requirement to guarantee access to information is location-

bound, meaning that access on a certain location which falls under this law does not require the agency to offer access anywhere else. [McLawhorn, 2001]

Although *Section 508* only applies to websites and information technology owned by federal agencies, it is said to be unique in its possible impact on the private economy. Any purchased product by an agency receiving funding under the *Technology Related Assistance for Individuals with Disabilities Act* [USA, 1988] must comply with the law. Furthermore, many consulting firms and organizations offer solutions for agencies to comply with the law [Hellbusch, 2010].

Section 508 shows two things: first, WCAG has strong influence on other accessibility guidelines and is considered a frame of reference for many. Second, accessibility for users with disability remains a side issue. Considering that no privately run website is affected by the law, and that such vague phrases as “*undue burden*” [USA, 1988] (§1194.1, 1194.2) or “*no accessible products are available*” [McLawhorn, 2001] are used to define exceptions to the applicability of the law, it is unsurprising that studies on accessibility of websites frequently find less than 10% of all websites having an official accessibility policy [DRC, 2004; Petrie, Badani and Bhalla, 2005].

3. RDF and Linked Data

The *Accessible RDF* project is about delivering readable structured data to web users. HTML is the obvious choice of data format to deliver the data to the user, as it is the most common transfer protocol and compatible with most widespread platforms. The remaining question is how the information encoded by HTML should be stored so that it can be retrieved easily *and* be expressive? To answer this question extensively would go beyond the scope of this work, but the *Semantic Web* and *Linked Data* initiative have a history of dealing with this question, which shall be explored in this chapter.

3.1. The History of Hypertext

Most of the visual content we consume from the web is delivered in *Hypertext Markup Language* (HTML). HTML was designed and published by Sir Timothy Berners-Lee, a British computer scientist and professor at the Massachusetts Institute of Technology. In March 1989, Berners-Lee proposed a “distributed hypertext system” for the “management of general information about accelerators and experiments” to his employers at the *Conseil Européen pour la Recherche Nucléaire* (*CERN*), the European Organization for Nuclear Research [Berners-Lee, 1998]. This hypertext system became known as HTML and the standard language of the World Wide Web. For the advancement of HTML, HTTP and URIs, Berners-Lee was the first person to receive the Millennium Prize in 2004, presented by the Finnish president Tarja Halonen on June 15, 2004 [CanadianPress, 2004].

Hypertext was seen as potentially groundbreaking by some as early as 1988. Jeff Conklin addresses the question why some call hypertext the coming “basis for global scientific literature” in his article “Hypertext: An Introduction and Survey” [Conklin, 1987].

In his original proposal to CERN, Berners-Lee wrote: “*If a CERN experiment were a static once-only development, all the information could be written in a big book*” [Berners-Lee, 1998]. What follows is the description of hypertext, an idea he had already written software for in the early 1980s. Information was then stored in one place, retrievable by anyone. As the World Wide Web developed, the book metaphor was extended to include hypermedia, but the concept remained the same: text was

written in one document that contained links to other documents. As we can see today, this was and still is a very powerful way of exchanging information.

The rise of so-called web services – programming interfaces (*APIs*) of websites and online applications – shows how important programmatic access to data has become. The online world grew so large, and at the same time so much data is being collected and created, that companies offer free access to their data, so that it can be processed for applications outside the company's reach. The Linked Data community tries to free the data from the *APIs* as they differ from one data provider to another and therefore each requires different code. Instead of publishing the data in an open format, data providers channel the data and access to it through their *APIs*, isolating the data from the rest of the web. By doing so, they maintain control over how the data is accessed. At the same time, the structure of the accessible data and the *API* remains private and free to modify by the owner. This makes open development and use of that data labour- and maintenance-intensive. The Linked Data community often refers to *APIs* as “data silos” [Idehen and Erling, 2008; Hassanzadeh, Lim, Kementsietsidis and Wang, 2009], as the data is being kept in a restricting container.

3.2. The Linking Open Data Initiative (LOD)

The idea of linking to digital objects other than HTML files was already known in 1989, when Berners-Lee wrote: “*If one sacrifices portability, it is possible so make following a link fire up a special application, so that diagnostic programs, for example, could be linked directly into the maintenance guide* [Berners-Lee, 1998].” The Semantic Web and particularly the Linked Data idea take the concept further: “*The vision of the Semantic Web is to extend principles of the Web from documents to data* [Herman, 2009].” In particular, data on the Semantic Web should be machine-readable and -understandable.

We see here the progress that was made in computer networking and online collaboration. While the hypertext system at *CERN* was supposed to be seen and edited by a limited number of people, the Semantic Web now envisions a wholly connected world in which any data should be available anywhere.

While HTML is a language to mark the structure of web documents and to interlink between documents, the Semantic Web is not about delivering documents but information on real-world entities and properties. To enable and encourage the publication of structured data, the W3C started the *Linking Open Data* community project. Its aim is to build a “data commons”, to link between data items between data sets and to make this data available. It also aims to lower the barrier to use and create linked data [Heath, 2010]. The “LOD cloud” – the interlinked data sets included in the project – now spans more than 13 billion (13.000.000.000) triples and 142 million (142.000.000) links. It is built around *DBpedia*, a collection of structured data extracted from Wikipedia. Figure 3.1 visualizes the data sets and their connections.

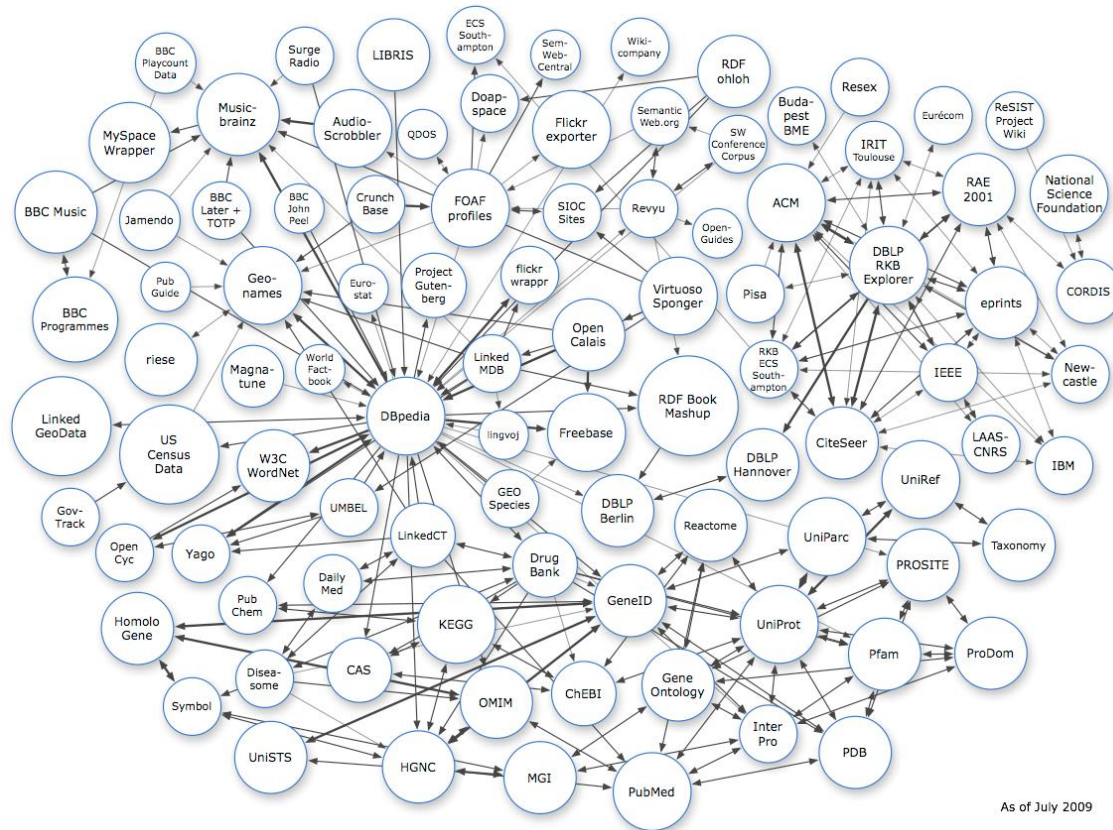


Figure 3.1: Data sets interlinked in the Linking Open Data project, as of July 2009. Arrows represent links between data sets.

Figure 3.2⁹ shows the ontologies used in the LOD cloud. The arrows in the diagram represent `owl:sameAs` relationships between elements. The thicker the arrow, the

⁹ Used under Creative Commons Attribution-Share Alike 3.0 Unported Licence. Source: http://umbel.org/lod_constellation.html

more relationships there are between the ontologies. “owl:sameAs” is a construct from the owl ontology which became the standard to link sources describing the same entities on the Semantic Web.

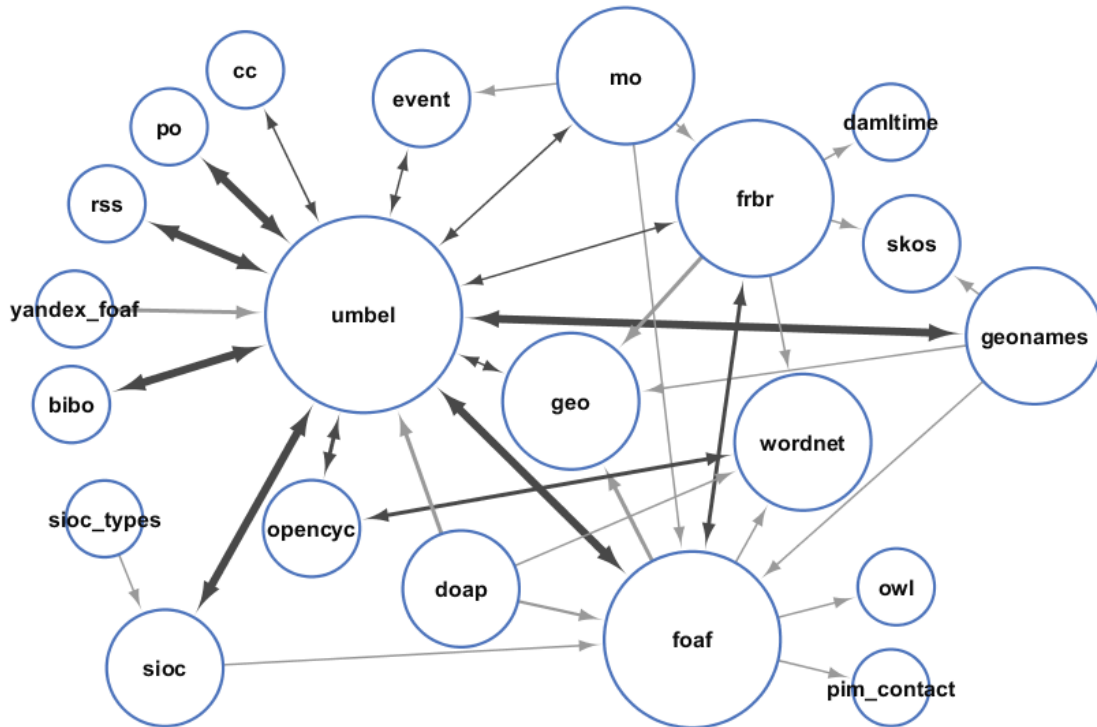


Figure 3.2: Prominent ontologies in the LOD cloud

3.3. Available Data

To give the reader an understanding of what data is available on the Semantic Web and how it is structured, we will now introduce some of the most prominent ontologies.

UMBEL aims at relating web content to a standard set of subject concepts¹⁰. This vocabulary can be seen as a road map, backbone or lightweight ontology. In fact, *UMBEL* contains only three different entities (SubjectConcept, AbstractConcept and Semset). This allows any entity to be related to *UMBEL*, which is particularly useful for ontologies which no related or similar ontology exists yet.

BIBO is a bibliographic ontology. It contains types of documents (Article, Bill, Book, etc.), their properties (citedBy, subject, title, etc.) and relations between them (isPartOf, contributorList, etc.). One powerful use case of

cf. ¹⁰ <http://umbel.org/intro.html>

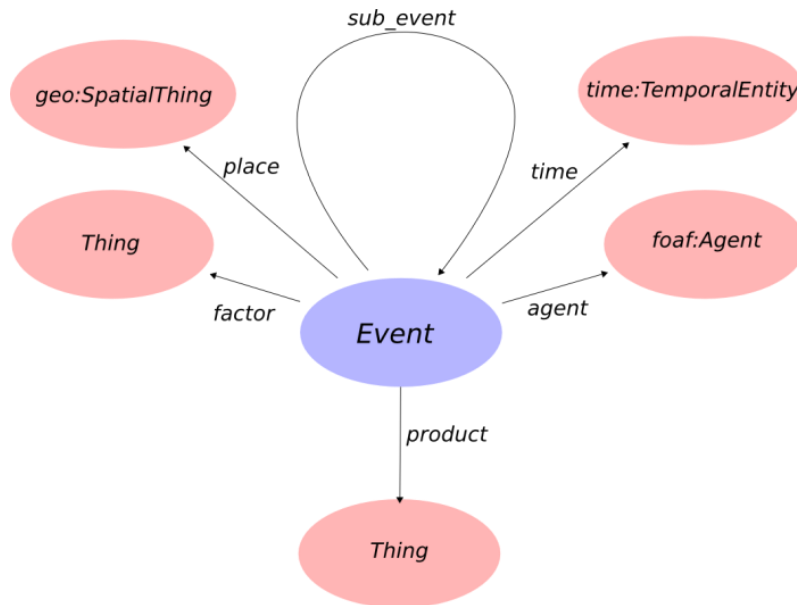


Figure 3.3: Event model of the BIBO ontology.

BIBO would be to be used as an online reference administration tool. For works like this, it would be possible to retrieve any available information on a publication once a work has been identified on the LOD cloud. Instead of creating a local copy of this information on any author’s hard drive, the information could be fetched from the Semantic Web when needed, and would be up-to-date at any time. Figure 3.3 shows an example of an entity in the *BIBO* ontology including its relationships to other entities both in and outside of *BIBO*. `geo:SpatialThing` is described as “Anything with spatial extent, i.e. size, shape, or position.” [W3C, 2009] and define the Event’s geospatial properties, such as latitude and longitude.

FOAF [Brickley and Miller, 2010] is an ontology to describe people and their relations. It defines classes such as `Person`, `Group` or `OnlineAccount`. Commonly used properties include `depiction`, `firstName`, `familyName`, `homepage`, `interest` and `knows`. The latter connects two persons who know each other. *FOAF* has had a large impact on online communities and has been adopted by blogging websites and browsers [Golbeck and Rothstein, 2008].

3.4. History and Recent Development

As we showed earlier in Section 3.1, the web originated from the idea of replacing books (manually compiled, offline documentation) with online hypertext documents.

Until the late 1990's, the principles that made the World Wide Web strong had never been applied to data on a large scale. In 1999, the first version of RDF was published.

At that time, few open Linked Data projects existed, but RDF made its way into science and industry [Hausenblas, 2009]. The reason why, even today, much of the interesting data gathered is not being published is that private companies do not want to assist their competitors. Also, compared to Web documents, there is little possibility of monetizing published data. As Rob McCool put it [McCool, 2005]:

“Because of [...] a desire not to assist their competitors, corporations typically don't share databases unless they have to. Even hobbyists [...] want to ensure that they have a way to recover labour and hosting costs. On the Web, advertising provides this revenue.”

In 2006, Tim Berners-Lee published a design note on Linked Data which became a frame of reference for all Linked Data publishers and Semantic Web developers. The note centres around four “design principles” [Berners-Lee, 2006a]:

1. *Use URIs as names for things*
2. *Use HTTP URIs so that people can look up those names.*
3. *When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL)*
4. *Include links to other URIs, so that they can discover more things.*

Here it becomes obvious what the difference between the *Semantic Web* and *Linked Data* is. While the Semantic Web envisions inference from data, the Linked Data concept deals with the technical side of publishing data only. The differentiation is said to encourage adoption among non-experts [Hausenblas, 2009].

In 2007, the *Linking Open Data Project* was started. In 2008, *SPARQL*, *GRDDL* and *RDFa* became W3C standards. To give the reader an understanding of how the Linked Data landscape looks like today, in terms of available data and applications, we will now take a short tour through the LOD cloud and where it is used.

DBpedia is one of the largest datasets in the cloud; not in terms of number of triples, but in terms of links to other data sources and incoming links from other sources. Figure 3.1 visualizes this. As of September 2009, *DBpedia* is documented to contain more than 2.5 million (2.500.000) links to 25 other datasets. There are also more than 1 million documented incoming links from 32 other datasets [W3C, 2010a]. The largest datasets in terms of number of triples are the “*Data-gov wiki*” which translates open government datasets into RDF [Ding, DiFranzo, McGuinness, Hendler and Magidson, 2009], “*LinkedGeoData*” which publishes geospatial data from *OpenStreetMap*¹¹ [Auer, Lehmann and Hellmann, 2009], and the “*2000 US Census*”. They contain 5, 3 and 1 billion (1.000.000.000) triples, respectively [W3C, 2010b]. For examples of Linked Data being used in commercial applications, see Section 4.1. For a description of other data and the vocabulary being used, see Section 3.2.

Trying to determine the size of the Semantic Web is like trying to determine the size of the World Wide Web. It would require an index of all existing documents that are accessible online. Since this does not exist, we have to start with a large sample and derive numbers from it. Hausenblas et al. [Hausenblas, Halb, Raimond and Heath, 2008] argue in favour of this approach. However, size is not properly defined for abstract concepts such as the Semantic Web, therefore different measures exist. The authors believe that the sheer number of triples does not sufficiently represent the size of the Semantic Web. The number of links from and to data sets plays an important role in shaping the Web. Looking at Table 3.1, we see that the relative number of triples and links varies considerably. Also, not only the number of outgoing links matter but the number of different relations and datasets and the “specificity” of the properties. No absolute values on the size can be made at this point, as the quality of links is very important to the usefulness of the Semantic Web. While automatic interlinking commonly generates large amounts of links, their quality is often lower than manually set links.

Name of dataset	Triples (at least, in thousands)	Outgoing Links (at least, in thousands)
ACM	12.644	213

¹¹ <http://www.openstreetmap.org/>

AudioScrobbler	600.000	100
BBC	20.287	313
Bio2RDF	2.419.905	51.195
DBPedia	409.000	2749
Geonames	93.900	500
Linked MDB	6.148	205
Musicbrainz	60.000	401
Open Archive Initiative	216.428	430
Revyu	20	402
Telegraphis Data	14	1

Table 3.1: Sample of datasets in the LOD cloud, with number of triples and number of links to other datasets

3.5. Linked Data Applications

To show the reader what is possible with the available data and what has been done in recent years with Linked Data, we now present a small selection of Linked Data-driven applications.

*Revyu*¹² is a review and rating website using Semantic Web technologies and standards. It allows users to review and rate anything from books to food take-away services. While this service is not new, the resulting data is: *Revyu* exposes the data as RDF, interlinked with external data sources. As opposed to other review websites, such as Amazon¹³ or Epinions¹⁴, the user is not bound to a site-specific data and object structure. Instead, users can freely choose keyword tags with which to describe the reviewed item. Only afterwards semantic information is being added to the review and the review integrated into the Semantic Web. For example, ISBN numbers of books are parsed from linked web pages and movie titles are compared to entities on *DBpedia*. *Revyu*'s data can be accessed through a SPARQL endpoint¹⁵. [Heath and Motta, 2007]

BBC's *Music* website¹⁶ is built around the *MusicBrainz*¹⁷ database which contains information to more than 400.000 artists. *MusicBrainz* is a user-maintained community that collects and publishes music metadata. By identifying artists by their *MusicBrainz*

¹² <http://revyu.com>

¹³ <http://www.amazon.com/>

¹⁴ <http://www.epinions.com/>

¹⁵ <http://revyu.com/sparql/welcome>

¹⁶ <http://www.bbc.co.uk/music>

¹⁷ <http://www.musicbrainz.org/>

ID, *BBC Music* can access information on related tracks, releases, labels and even identify the artist on *Wikipedia*¹⁸, which in turn identifies the user on *DBpedia*. The website shows news, biographical information, blog posts, reviews and media for artists. All data collected by *BBC Music* about an artist can be fetched as RDF.

DBpedia Mobile is a location-aware Linked Data browser for mobile phones. It was developed at the Freie Universität Berlin, where also the *DBpedia* project originated from. *DBpedia Mobile*'s core feature is a map view centered around the user's geographical position if the device is GPS-enabled. The map shows all entities from *DBpedia* that falls into the range of the map. Upon request, the client software shows more information about an entity from *DBpedia* and *Revyu*.

*dbrec*¹⁹ is a music recommendation website, basing recommendations on relationships between related entities. To calculate recommendations, *dbrec* searches for RDF triples connecting an artist with other artists and the same values. For example, both Janis Joplin and Bob Dylan have published records under the Columbia Records label. Both artist's instrument is the guitar and both appear on the "Watchmen: Music from the Motion Picture" record. The more data is available for a certain artist, and the more data is shared between two authors, the stronger is the connection between the two. Recommendations are available as *RDFa* annotations on *dbrec*'s web pages. It is developed and maintained by Alexandre Passant from the *Digital Enterprise Research Institute*. [Passant and Decker, 2010]

3.6. RDF, XML and HTML

HTML was and is a mixture of elements denoting document structure and physical appearance. While the separation of structure and presentation was not clear in the past, the latest HTML specifications allow presentational markup only in the "Transitional" variation. RDF does not aim at including presentational information in its vocabulary specification. Rather, RDF is a model to represent statements about objects in XML format.

When talking about RDF, one needs to distinguish between the data model RDF and the serialization format *RDF/XML*. These terms are often used interchangeably, but

¹⁸ <http://www.wikipedia.org/>

¹⁹ <http://dbrec.net/>

looking at design notes [Berners-Lee, 2006a] and “best practice” proposals [Hausenblas, 2009], it is possible to publish and consume RDF data without using the *RDF/XML* data format. A RDF data model can likewise be serialized in *Notation 3 (N3)* format [Berners-Lee, 2006b].

RDF started out as an attempt to include metadata in web resources. The *Dublin Core Metadata* [DCMI, 1998], specifically mentioned in the first *RDF Model and Syntax Specification* [Lassila and Swick, 1999], only includes elements describing metadata of web resources, such as *Title*, *Author*, or *Publisher*. As a whole, *RDF* is a set of specifications put forward by the World Wide Web Consortium (*W3C*). The specifications describe a metadata data model, which is used to describe or model information in online resources. Historically, it was intended to represent metadata about web resources, such as title and author of a web page.

RDF data takes the form of triples. They are implemented in the form of *subject* – the information resource of interest –, *predicate* – a named property – and *object* – the property’s value. The *subject* always constitutes a resource denoted by a *Universal Resource Identifier (URI)*. Although it is considered “good practice” for a URI to resolve to a web resource, it is not a requirement according to the RDF specification [Hayes and McBride, 2004]. Rather, URIs are used to identify a *subject*, regardless of what information can be found on that subject under the URI.

RDF statement *subjects* and *objects* can be blank nodes. That means that in a triple, the subject or object is given a non-URI, local identifier. For example, if we know the birthday of a friend of a friend, but not his name, we can locally identify this person as “that friend of my friend, whose birthday is on that date” (cf. code below).

```

1 <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
2   xmlns:foaf="http://xmlns.com/foaf/0.1/">
3   <foaf:Person rdf:about="http://example.org/Person#Peter">
4     <foaf:knows>
5       <foaf:Person foaf:birthDate="05-25"/>
6     </foaf:knows>
7   </foaf:Person>
8 </rdf:RDF>

```

Listing 3.1: RDF/XML document including a blank node

Predicates are usually denoted as URIs. Opposed to *subjects* and *objects*, they refer to a relationship rather than an entity; the relationship between the triple's *subject* and *object* (i.e. the property which connects the *subject* and a value) in particular. Since *predicates* are identified as URIs, they can nevertheless occur as *subject* or *object* in a triple. However, most vocabulary and RDF publishers disclaim publishing extensive information about *predicates*. Many times a parent *predicate* and label can be found but, in principle, relationships should be self-explanatory and unambiguous in themselves and their relationships with other *objects*.

RDF as a data model specification should not be confused with the serialization format also called RDF. Although the serialization format was introduced as a part of the W3C specifications, it is neither necessary nor suggested that RDF triples be written in this format. In addition to the XML-based RDF serialization format, the W3C introduced Notation 3 (*N3*) as a non-XML format for RDF models [Berners-Lee, 2006b].

The W3C RDF Primer specifically states that "*RDF is intended for situations in which this information needs to be processed by applications, rather than being only displayed to people*" [Manola, Miller and McBride, 2004]. While HTML is designed to deliver structured documents to the user, RDF carries raw data and is therefore often hard to read. For example, some ontologies identify objects through a multi-digit number or annotate predicates with labels just as cryptic as the predicate's URI.

Many of the problems accessibility tools have with converting web pages to different media arise from invalid structure. The HTML specification [Raggett, Le Hors and Jacobs, 1999] defines legal properties, parent and child elements for each tag. Thanks to the commonly natural definition of RDF vocabulary (*subjects* representing real-world *objects* and *predicates* representing real-world properties), there is no need to build artificial conceptual models of the data as it is being done for HTML [Zajicek and Powell, 1997]. Additionally, real-world information can be modelled into well-defined data types, through which synergy effects may emerge: objects of RDF triples can not only be URIs (RDF subjects) but links to other programs and services. For example, postal addresses could be linked to an address book, dates to a personal calendar and GPS coordinates to the local navigation software. On the basis of the predicates it could be programmatically determined how each data type is to be handled.

As mentioned previously, HTML is being misused for visual appearance. Due to its lack of visual interpretation, it is unlikely that this will become a common practice for RDF.

```

1 <rdf:Description rdf:about=
2 "http://dbpedia.org/resource/University_of_Tampere">
3   <geo:lat xmlns:geo=http://www.w3.org/2003/01/geo/wgs84_pos#
4     rdf:datatype="http://www.w3.org/2001/XMLSchema#double">
5     61.494166666666666
6   </geo:lat>
7 </rdf:Description>
8
9 <rdf:Description rdf:about=
10 "http://dbpedia.org/resource/University_of_Tampere">
11   <dbpprop:nativeName
12     xmlns:dbpprop="http://dbpedia.org/property/" xml:lang="en">
13     Tampereen yliopisto
14   </dbpprop:nativeName>
15 </rdf:Description>

```

Listing 3.2: Extract from http://dbpedia.org/data/University_of_Tampere

3.7. Resource Description Framework in Attributes (RDFa)

So far, we have explained how HTML and HTTP laid the foundations for the web of documents, and how data can be published and retrieved in the “web of data” using RDF. However, maintaining two separate files for every purpose without any connection would be a major design flaw in the concept of the Semantic Web. To bridge the gap between the webs, and to make documents for human consumption more “machine-understandable”, RDFa allows embedding of RDF style attributes in other markup languages.

RDFa is specification of attributes in markup languages to express structured data. Listing 3.3 shows an example of a HTML file which is augmented with RDFa. The markup is valid XHTML and renders properly in any modern web browser. At the same time, the RDFa attributes give machine-readable meaning to each part of the page, allowing other applications to extract the information and process it, or render them differently. The outmost `<div>` tag defines an entity of type `foaf:Person` identified by the preceding URI. The following `<div>` tag defines the person’s business card. All following elements containing `vcard` properties then contain a part of this business card, including street address, phone number and country.

```

1 <h2>Business Card</h2>
2 <div about="http://sw-app.org/mic.xhtml#i" typeof="foaf:Person">
3   <div rel="ov:businessCard">
4     <div about="http://sw-app.org/mic.xhtml#businesscard"
5       typeof="vcard:VCard">
6       <div rel="vcard:org">
7         <div about="http://sw-app.org/mic.xhtml#org"
8           typeof="vcard:Organization">
9           <span property="vcard:street-address"
10             datatype="xsd:string">
11             Digital Enterprise Research Institute (DERI),<br />
12             National University of Ireland, Galway<br />
13           </span>
14           <span rel="owl:sameAs"
15             resource="http://dbpedia.org/resource/
16             Digital_Enterprise_Research_Institute" />
17         </div>
18       </div>
19     <div rel="vcard:workAdr">
20       <div about="http://sw-app.org/mic.xhtml#postaladdress"
21         typeof="vcard:Address">
22         <span property="vcard:street-address">IDA Business Park,
23         Lower Dangan</span>,<br />
24         <span property="vcard:locality">Galway</span>,<br />
25         <span property="vcard:country-name">Ireland</span>
26       </div>
27     </div>
28     Tel.: <span property="vcard:workTel">+353 91 495730</span>
29   </div>
30 </div>
31 </div>
32

```

Listing 3.3: Extract from a HTML document augmented with RDFa²⁰

RDFa enables web developers to maintain web pages and Linked Data in a single file. This minimizes workload to publish data in more than one format and enriches the web by making data traceable through semantics.

3.8. SPARQL Protocol and RDF Query Language (SPARQL)

RDF allows data to be stored distributed and decentralized. Any application can connect to multiple RDF data sources to merge data into a single RDF model [McCarthy, 2005]. Serialized RDF can be simply exchanged over HTTP. Since data stores can be large (the W3C SWEO project “*Linking Open Data*” contains more than 13.000.000.000 triples [W3C, 2010b]) and bandwidth expensive, a refined language query language to retrieve triples with specific attributes is necessary. Many query languages for RDF triple stores

²⁰ Example taken from <http://rdfa.info/wiki/Tutorials> under the Creative Commons Public Domain License

have been proposed and implemented [Haase, Broekstra, Eberhart and Volz, 2004], but *SPARQL* is the most commonly used and is emerging as a quasi-standard.

SPARQL Protocol and RDF Query Language is a W3C recommendation since January 15th, 2008 [Prud'hommeaux and Seaborne, 2008]. It is a graph-based query language for RDF. This chapter introduces *SPARQL*'s syntax and functionality.

3.8.1. Definition of SPARQL

A *SPARQL Abstract Query* is a tuple (E, D, R) where

- E is a *SPARQL algebra* expression,
- D is an RDF *dataset* and
- R is a *query form*. [Prud'hommeaux and Seaborne, 2008].

There are four *query forms* in *SPARQL*: “*SELECT*” returns all variables matching a query pattern; “*CONSTRUCT*” allows construction of graphs by unifying matching triples of a graph template and substituting declared variables; “*ASK*” returns a Boolean value determining whether a query pattern has a solution in the dataset; “*DESCRIBE*” creates a single result RDF graph with any information available for given resources.

A *dataset* is a set of graphs, consisting of at least one graph (the *default graph*) and any number of *named graphs*, identified by an *IRI* (*Internationalized Resource Identifier*, a Unicode-enabled subset of *URIs*).

A *SPARQL algebra* expression is the declaration of all variable values and the operators defining and combining them. For example, the W3C recommendation [Prud'hommeaux and Seaborne, 2008] defines the *FILTER* operator as

$$\text{Filter}(\text{expr}, \Omega) = \{ \mu \mid \mu \text{ in } \Omega \text{ and } \text{expr}(\mu) \text{ is an expression that has an effective boolean value of true } \},$$

where *expr* is a triple expression and Ω the set of possible solutions. Other operators include *Join*, *Diff*, *Union*, *OrderBy* and *Distinct*, among others. However, the functional definition of *SPARQL*'s algebra operators is beyond the scope of this work and will therefore be omitted.

3.8.2. Example Query

Listing 3.4 shows an example of a simple *SPARQL* query against the source file `johnDoe.rdf`.

`PREFIX` defines abbreviations of URIs, so that resources can be identified by this abbreviation inside the query. This makes the query easier to read. In the example, every occurrence of “`foaf:`” in can be replaced with the URI given in the first line. This is, in fact, what happens when a *SPARQL* parser converts the query into an *Abstract Query* (see Section 3.8.1).

```

1 PREFIX foaf: <http://xmlns.com/foaf/0.1/>
2 SELECT ?url
3 FROM      <johnDoe.rdf>
4 WHERE    {
5     ?contributor foaf:name "John Doe" .
6     ?contributor foaf:weblog ?url .
7 }

```

Listing 3.4: SPARQL query example

The `SELECT` clause specifies the return values of the query, in this case a single variable named `url`. Variable names in *SPARQL* are prefixed with “?”. The `FROM` clause specifies the dataset to use. In the example, this is a single file named `johnDoe.rdf`. `FROM` clauses can also point to URIs.

The lines written within the curly brackets (the “*WHERE* clause”) are triple patterns. Together, they form a graph pattern that is matched against the dataset. In this case, the graph pattern contains two conditions: the subject’s name, or `foaf:name`, must be “John Doe”, and it must be listed as “contributor” of a weblog. The query returns all URLs of which John Doe is a contributor. The variable name “`?contributor`” is freely chosen, it is merely an interpretation of the `foaf:weblog` property. The *FOAF* Vocabulary Specification [Brickley and Miller, 2010] does not specify what the exact relationship of subject and object under this property is. It is described as “*relat[ing] a [sic] Agent to a weblog of that agent.* [Brickley and Miller, 2010]”

Any part of the graph pattern can be a variable. It is possible to query for triples in which the subject, the object or the property is variable, or any two of them. Each triple in the dataset that matches the graph pattern becomes a query solution. The set of

solutions of a query is called a *solution sequence*. There may be one solution, multiple or no solutions. [Prud'hommeaux and Seaborne, 2008]

3.8.3. Optional Query Elements

After retrieving the solution sequence of a graph pattern over a dataset, it is possible to refine the results further. *SPARQL* offers six *solution sequence modifiers* and a filter option. The *SELECT* modifier is described in Section 3.8.2; *LIMIT* and *OFFSET* apply upper and lower bounds to the solution sequence; the remaining shall be described shortly here.

The *ORDER BY* modifier establishes an order among the solutions in the solution sequence. The order is based on a sequence of order comparators. Not all RDF terms have a defined order²¹, but all terms are compared to each other by the “<” (“smaller than”) operator which is defined for numeric values, simple literals, strings and Boolean values. The direction of the sort can be defined with the *ASC()* and *DESC()* modifiers.

The *DISTINCT* and *REDUCED* modifiers define whether duplicate results are combined into one or preserved individually. *DISTINCT* eliminates duplicates while *REDUCED* only allows duplicates to be removed. The number of results for a *REDUCED* query therefore lies somewhere between the *DISTINCT* query and the query without modifier.

It is possible to combine any number of these modifiers (except *DISTINCT* and *REDUCED*) in a query. For example, the query

```
SELECT DISTINCT ?x WHERE { ... } ORDER BY ?x LIMIT 5
OFFSET 10
```

returns the 11th to 15th result, ordered by values of variable *x*, without duplicates.

The *FILTER* keyword extends *SPARQLs* pattern matching capabilities by functions to restrict the value of variables beyond the graph patterns. All data types feature a set of test functions by which their value can be constrained. The functions return a Boolean value by which the inclusion or exclusion of the triple from the solution

1. ²¹ For example, the order between two literals with language tags is undefined. For a complete list, see the SPARQL Query Language for RDF specification [Prud'hommeaux and Seaborne, 2008].

sequence is evaluated. Filters can be applied to a subset of the triple patterns and can be combined using logical operators (|| and &&) [McCarthy, 2005].

4. “Accessible RDF” – An accessible RDF search engine

So far, we have established what sort of problems users with impairments encounter when browsing the Web. We have argued that a uniform markup of information such as *RDF* and *RDFa* and an accessible interface to browse the information would greatly improve web accessibility and usability for these users. For all information to be published marked up yet requires a rethinking of how web designers and entrepreneurs view the services they offer. The interface to access this information, however, can be established today. This is the idea behind *Accessible RDF*.

4.1. Motivation

In an article about the *Semantic Web Accessibility Platform (SWAP)*, Lisa Seeman writes:

“[...] the integration of the Semantic Web and Web Accessibility can precipitate substantial progress in Web accessibility and accessible interfaces. [Seeman, 2004]”

In particular, Seeman is referring to is the annotation of text and HTML elements with RDF tags. *SWAP* creates alternative renderings of websites through annotations in RDF format. The concept has since been adapted by W3C’s *RDFa* recommendation [Adida and Birbeck, 2008], among others.

With *ARDF* we are looking at the integration of the real and the virtual world from a different perspective: instead of enriching digital information with semantic data, we seek to synchronize digital and real-world information. That is to say, instead of working from what already exists on the World Wide Web towards what can be expressed with semantic meta-data, we model the real world with the help of RDF, and make it accessible through HTML.

The goal is to create a work of reference for anything that can be represented as structured data. This concept works particularly well for data-intensive models such as gene databases [Belleau, Nolin, Tourigny, Rigault and Morissette, 2008], but vocabulary and “wrappers” to model less structure-dependent data exist. For example, *Friend of a Friend (FOAF)* models social networks; *Semantic Drupal*, *Last.fm RDFizer*

and *OpenStreetMap Wrapper* are frameworks to publish web content, information about music and musicians and geographic data as RDF.

The request to web designers and developers to publish their data in another, separate format so as to accommodate one user group would remain unheard. However, publishing data in *RDF*, *N3* or *Microformats* is not only about making your data accessible. It is about making data available. The industry has long recognized the power of the *Semantic Web*. *CNET*²², an international media company, announced to publish their data as *Linked Data*²³; *Google* includes so-called “rich snippets” in their results and invites publishers to include *RDFa* or *microformats* on their pages; *Newsweek*, one of the largest weekly news magazines in the US, tags their articles with *RDFa*; The US American CIO (Chief Information Officer), Vivek Kundra, launched the website that publishes RDF, *Data.gov*, to increase public access to high value, machine readable datasets generated by the Executive Branch of the Federal Government. All this information is backed by academic and online communities: as of May 2010, the *Linking Open Data* project contained over 13 billion (13,112,409,691) triples [W3C, 2010b] interlinked by around 142 million RDF links [W3C, 2010a] from 121 sources. *Sindice* [Tummarello, Delbru and Oren, 2008], its API *ARDF* uses to gather *Linked Data*, has about 96 million semantic web documents indexed.

4.2. System Architecture

ARDF is hosted on an *Apache Tomcat 5.5.26* server, using *Java Development Kit 1.6.0_07*. The server is hosted by the German company *inetsolutions.de*. *ARDF* was written using the integrated development environment *Eclipse Java EE Galileo*.

4.2.1. Interface

All pages are written in *Java Server Pages*. According to the *W3C Markup Validation Service*²⁴, they generate valid HTML under the *HTML 4.01 Strict* specification [Raggett, Le Hors and Jacobs, 1999] in *UTF-8 (UNICODE)* encoding. For a discussion of accessible HTML, see Section 4.3.

²² <http://www.cnet.com>

²³ cf. http://www.readwriteweb.com/archives/cnet_partners_with_thomson_reuters_on_linked_data.php

²⁴ <http://validator.w3.org/>

4.2.2. Queries

When the user enters a keyword (as opposed to a URI (see below)), ARDF uses the *Sindice*²⁵ *Sigma* API²⁶ to retrieve documents and triples containing at least one of the keywords.

Sigma is built and maintained by the *Digital Enterprise Research Institute (DERI)*²⁷. It is a tool to search for data on *Sindice*, an index of RDF, RDFa and microformat data on the web. As of June 2010, *Sindice*'s index contains more than 107 million documents and more than 6.5 billion triples.

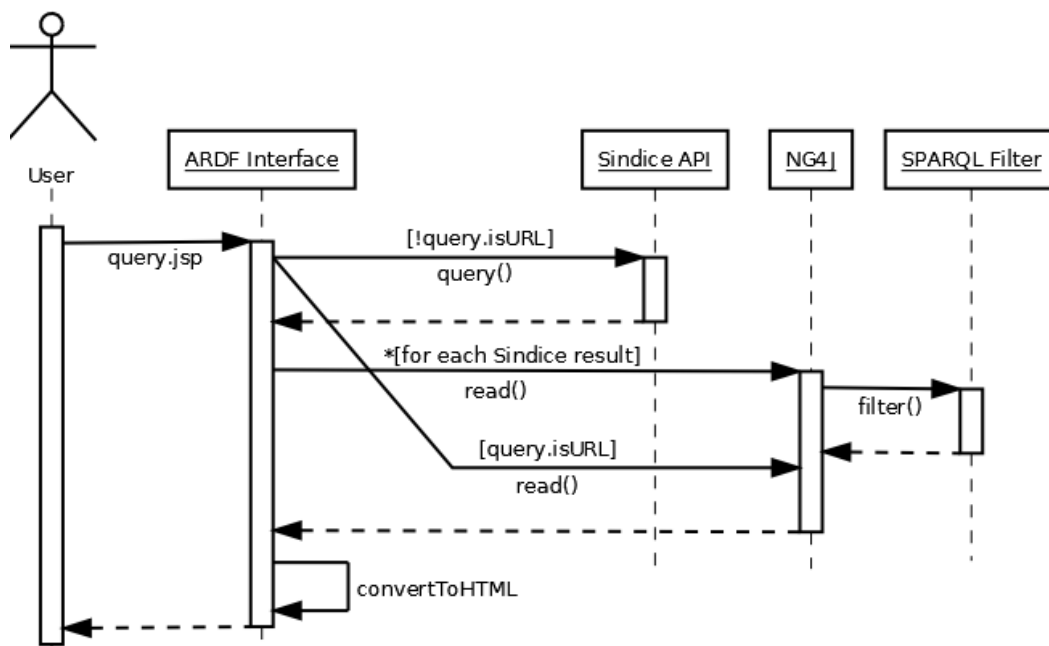


Figure 4.1: Sequence diagram of an ARDF query

For each query, *Sigma* returns an RDF document with the URIs of 20 documents and the relevant triples they contain. The number of returned triples is independent of the number of RDF triples found within each of these documents. This is the reason why the number of result triples on each *ARDF* page varies. Since the number of triples can be very large, only those triples that contain at least one of the keywords are returned as results. When the user enters a URI and the retrieved document contains RDF data, the data is read directly from the source and returned as HTML in unfiltered

²⁵ <http://www.sindice.com/>

²⁶ <http://www.sindice.com/developers/api>

²⁷ <http://deri.ie/>

form in addition to the results from the *Sigma* API call. Listing 4.1 summarizes the behaviour in pseudocode.

```

1  String query = readSearchFormInput();
2  List sigmaResults = sigmaAPI(query);      // Query Sigma API
3  add sigmaResults to dataModel;           // Add results to data model
4
5  if <query is URI>
6      List httpResults = HttpRequest(query); // Query URI
7      add httpResults to dataModel;         // Add results to data model
8
9  // Select only triples relevant to query
10 sparql(dataModel, query);                // Filter results
11
12 if <dataModel.size = 0>
13     fallback();                           // Offer alternative links
14 else
15     convert dataModel to Html;             // Print results in HTML
16     print();

```

Listing 4.1: ARDF behaviour for a single query in pseudocode

4.2.3. Data Storage/Caching

After querying *Sindice*, we retrieve the results via *HTTP* and write all triples into a data model. This model is provided by the *Named Graphs API for Jena (NG4J)* [Bizer, Cyganiak and Watkins, 2005]. NG4J is an extension of the *Jena Semantic Web Framework* and is free to use and distribute under a BSD licence.

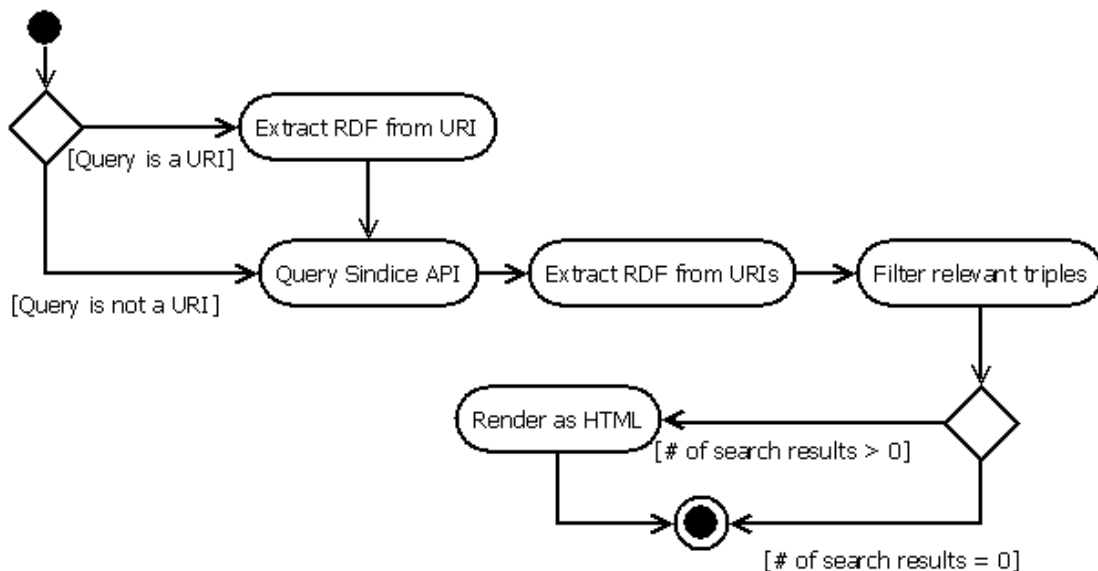


Figure 4.2: ARDF activity diagram

4.2.4. Jena

Jena is a Java framework for building Semantic Web applications. It was developed under the *HP Labs Semantic Web Programme*²⁸ and is available open source. It includes an API to read and write *RDF/XML*, *N3* and *N-Triples* and a *SPARQL* query engine, among others.

We use *Jena* and *NG4J*, which is built to extend *Jena*, for data storage, graph manipulation and graph querying. To give the reader an understanding of how *Jena* works, we will now go through a code sample from *ARDF* in which an RDF model is populated with data from online sources and subsequently queried.

Listing 4.2: Example of *Jena* used in *ARDF* shows a simplified version of how *ARDF* uses *Jena* to store and query RDF data. Line 2 shows how a default RDF model is created in memory. `ModelFactory` implements several methods to create simple standard models, including ontology and *RDFS* models.

Models in *Jena* are sets of statements. Statements consist of a subject, an object (both `Resource` objects) and a predicate (an instance of type `Property`). In *ARDF*, we differentiate between two kinds of queries: URI queries and keyword queries²⁹. Line 5 determines whether the query entered is a URI by matching patterns regularly occurring in URIs against the input. If the query is a URI, we proceed to check if RDF data is found under the given URI by calling the model's `read` method.

```

1 //Reset model
2 com.hp.hpl.jena.rdf.model.Model model =
3     ModelFactory.createDefaultModel();
4
5 boolean isURI = queryBean.getQuery().isURI();
6 if(isURI) {
7     try {
8         model.read(queryBean.getQuery());
9     } catch(NullPointerException npe) {
10    } catch(com.hp.hpl.jena.shared.JenaException je) {
11        <jsp:include page="error.jsp" />
12    }
13 }
14 // [...]
15 Query sparql = QueryFactory.create(sparqlQuery, Syntax.syntaxARQ);
16 QueryExecution qe = QueryExecutionFactory.create(sparql,
17     queryBean.getModel());
18 ResultSet rs = qe.execSelect();

```

²⁸ <http://www.hpl.hp.com/semweb/>

²⁹ Note that the distinction between URL and URI is an important factor of Linked Data design. In this case, however, we cannot know whether the user input is an identifier for a resource (URI) or the location of a document (URL). Since URLs are a subset of URIs, we will adhere to the commonly used term URI here.

Listing 4.2: Example of Jena used in ARDF

A URI entered as a query in *ARDF* may or may not “resolve”. This means that, while the common design practices suggest that a URI should return information, it is not necessary. We can still find information on an entity identified by a URI if the URI itself does not resolve, because the URI may be referred to in other resources

Before we continue to write the data into the *JSP* page, the data is post-processed. Most of the post-processing handles readability of the search results. As mentioned earlier, Linked Data is designed primarily for machine readability. Therefore, some RDF triples are difficult to read for humans. Many RDF resources contain human readable labels (`rdf:label`) (cf. *Appendix A*), but collecting labels for all resources which may be displayed on a results page proved to be too time consuming. Instead, *ARDF* relies on two mechanisms. First, some of the most common ontologies in the LOD cloud are stored in the default *Jena* model. This ensures that most properties are readable. Second, if no label can be found in either the source of the triple in question or the ontologies, we apply a set of rules by which most Linked Data resources are named, such as “Camel casing” or replacing spaces by underscores. . If the URI resolves, all triples are added to the (in this case) empty model. If the URI does not resolve or does not return Linked Data, the user is informed (Line 11) and *ARDF* proceeds to search for the URI with *Sigma*.

After all data is collected and added to the `model`, it needs to be filtered. In our case, this means filtering any triples from *Sigma*’s response that are not related to the keyword (source URIs, search statistics). Jena provides methods to parse SPARQL queries from Strings (`QueryFactory.create()`) with different syntaxes, which return a `Query` object that encapsulates the parsed query. Similarly, triples with a language tag other than the one declared in the search options are filtered. `QueryExecution.execSelect()` executes the statement and returns all relevant triples as a `ResultSet`. Now we can iterate over all triples and extract the data we need to display.

Before we continue to write the data into the *JSP* page, the data is post-processed. Most of the post-processing handles readability of the search results. As mentioned earlier, Linked Data is designed primarily for machine readability. Therefore, some

RDF triples are difficult to read for humans. Many RDF resources contain human readable labels (`rdf:label`) (cf. *Appendix A*), but collecting labels for all resources which may be displayed on a results page proved to be too time consuming. Instead, *ARDF* relies on two mechanisms. First, some of the most common ontologies in the LOD cloud are stored in the default *Jena* model. This ensures that most properties are readable. Second, if no label can be found in either the source of the triple in question or the ontologies, we apply a set of rules by which most Linked Data resources are named, such as “Camel casing” or replacing spaces by underscores.

4.3. Accessibility

A survey on search engine interface accessibility [Buzzi, Andronico and Leporini, 2004] revealed that 92% of sighted users, but only 7% of blind users found search engines easy to use. Almost half of the participants (46.15%) indicated having trouble reading the search results, a third found the available functions and/or the interface unclear (38.46% and 30.77%). Most importantly, however, is that only 38% of the blind users found useful information, compared to 90% of the sighted users. In a follow-up publication, the authors collected eight design principles for accessible search engine interfaces [Leporini, Andronico and Buzzi, 2004], which we have incorporated:

- **Labelling and positioning of search form**

The text field and search options are placed at the top of the page, after the navigation (which can be skipped). The interface elements are kept at a minimum, and each is labelled at length.

- **Accessibility of result list**

The table of results is accessible through the first link on the page (“Jump to search results”) and is described by a `summary` attribute.

- **Arrangement of results**

There can be several search results in one table row if a triple shares subject and predicate but has several objects. This happens often for example when text is available in different languages. In such a case, the results share a table row, and the different objects are arranged in an unordered list.

- **Recognition of sponsored links**

No sponsored links are displayed on *ARDF*, and no plans exist to do so in the future.

- **Navigation and help links**

Links to skip the navigation, accessibility information and general help are added at the top of each results page, links to jump between results pages are added at the bottom of each page.

- **Quick navigation**

ARDF does not make use of the `tabindex` attribute (for a discussion of `tabindex`, see Section 4.3.1). However, `accesskeys` enable to jump to common functionality through simple keystrokes, and the search results can be navigated by selecting second- and third-order headings.

- **Sound alerts and aural style sheets**

We have abdicated the use of sound for maximum compatibility.

It should be noted that the authors had ordinary World Wide Web search engines in mind when writing the guidelines. Some of them therefore apply more, some less to the design of *ARDF*.

Besides implementing guidelines of how to design for different users, accessibility also requires designing for different user agents. It is where accessibility and usability overlap. While the vast majority of users with visual impairment use a Windows PC and the JAWS software to access the web, ignoring other soft- and hardware would be the same mistake as ignoring users with impairments altogether. Accessibility to us therefore also means to serve out-of-date browsers, devices with small screens, niche and custom agents.

To assure compatibility with accessibility agents, all pages within *ARDF* are checked to be compliant with W3C's HTML 4.01 (strict) specification. The only exception to this rule is the inability to assure that results are written with UNICODE [Unicode Consortium, 2007] encoding.

4.3.1. Guidelines Implemented

Large parts of WCAG apply to media and techniques that were not used in the implementation of *ARDF*. For example, *Guidelines 1.1*³⁰ and *1.2*³¹ do not apply because we deal with textual information only. *Guideline 2.2*³² does not apply because there is no time limit for any of the pages. In the following, we will review some of the WCAG 2.0 guidelines that were of particular importance for our concern, and describe what was done to adapt the website to each guideline.

Guideline 1.3 Adaptable: Create content that can be presented in different ways (for example simpler layout) without losing information or structure.

The layout of *ARDF* is minimal. Apart from HTML, only CSS is used, to increase usability (for example, by framing and colour coding focused interface elements). In the search results section of the page, there is little to simplify without losing information. The results are organized in a 3-column table, one column for subjects, predicates and objects (see Section 3 for a description of these terms). In a sense, we do not ‘create’ the content presented. We, as the designers, are limited to a layout that represents the underlying data content and structure. However, it is possible to present the content in different ways, as we show in the table-free version of the results page (see Section 4.2).

Success criterion *1.3.1* requires that “Information, structure, and relationships conveyed through presentation can be programmatically determined or are available in text.” The structure of the data and the relationships between them can be determined through the layout of the table. The main language of the page (English) and therefore the reading direction – left to right, top to bottom – can be determined programmatically. Furthermore, a textual description of the content of each column is given through the `table summary` property.

³⁰ ”Guideline 1.1 Text Alternatives: Provide text alternatives for any non-text content so that it can be changed into other forms people need, such as large print, braille, speech, symbols or simpler language.” [Caldwell, Cooper, Guarino-Reid and Vanderheiden, 2008a]

³¹ “Guideline 1.2 Time-based Media: Provide alternatives for time-based media.” [Caldwell, Cooper, Guarino-Reid and Vanderheiden, 2008a]

³² “Guideline 2.2 Enough Time: Provide users enough time to read and use content.” [Caldwell, Cooper, Guarino-Reid and Vanderheiden, 2008a]

No other guidance should be necessary to browse and understand the structure of the page.

Guideline 1.4 Distinguishable: Make it easier for users to see and hear content including separating foreground from background.

Table 4.1 shows all colours used in *ARDF*'s interface. It must be noted that none of the foreground colours are defined anywhere in the source code. Rather, the client chooses which colours to use for text, links and visited links. The colours in the table are sample colours from the *ARDF* query page viewed in *Opera 10.51* running on *Windows 7*. Leaving the choice of colours to the user client means that we cannot be sure how the content is presented. This way, however, we do not interfere with custom colour changes from the users, who might know better which colours suit their needs.

Assuming the user views *ARDF* with its standard colours, the minimal contrast ratio between background and foreground is 8.3:1, in accordance with and exceeding guidelines 1.4.3 and 1.4.6.

Name	Hex Value	RGB Value
<i>Background Colours</i>		
White	#FFFFFF	255, 255, 255
Gallery	#F0F0F0	240, 240, 240
<i>Foreground Colours</i>		
Dark Blue	#0000CC	0, 0, 204
Black	#000000	0, 0, 0
Fresh Eggplant	#800080	128, 0, 128

Table 4.1: Colours used in *ARDF*'s interface, including inferred standard colours

Guideline 2.1 Keyboard Accessible: Make all functionality available from a keyboard.

One of the most discussed properties of HTML elements to increase accessibility is the *tabindex*. Its effect is that when a user “tabs” through the page elements, more elements can be accessed and the order can be defined by the programmer. We decided not to use *tabindex* for several reasons:

- It is not supported by all browsers
- It causes behaviour different from the browser's default behaviour
- Its interpretation is different between browsers
- It may cause illogical jumps through pages that confuse the user³³

Consequently, some users may not be able to browse ARDF by “tabbing” only. However, every browser and screen reader configuration allows to access all form elements and links on a page through few keystrokes. Therefore, we believe that advantages of maintaining default behaviour exceeds those of a custom tab order.

Access keys are popular navigational aids among screen reader users. In a survey among over 1000 screen reader users, 59% claimed to use access keys at least sometimes [WebAIM, 2009a]. *ARDF* defines the following access keys as suggested by the British e-Government Web Handbook [CabinetOffice, 2002]:

- S – Skip navigation
- 1 – Landing page
- 6 – Help
- 0 – Access key overview
- T – Tabular search results page³⁴

Other success criteria for the keyboard accessibility guideline are absence of keyboard traps (if a component can be focussed using the keyboard, the focus must be removable using the keyboard only) and timing-independent input (cf. success criteria 2.1.1, 2.1.2 [Caldwell, Cooper, Guarino-Reid and Vanderheiden, 2008a]).

Guideline 2.4 Navigable: Provide ways to help users navigate, find content, and determine where they are.

In the case of Guideline 2.4, finding content refers to two important features: the user should be able to bypass blocks of content that repeat on multiple pages. In our case, the navigation links on top of each page can be considered a repeated block of content. Therefore, the first link in the list is a “skip navigation” link that guides the user to the search form on the start page and the results table on a results page.

³³ cf. <http://www.webaim.org/techniques/keyboard/tabindex.php>

³⁴ Not part of the e-Government Web Handbook

Dealing with focus order is a controversial issue. While the HTML specification offers manual control over the order in which interface elements receive focus through “tabbing”, in practice it is often preferable not to influence the standard behaviour of the browser and leave the `tabindex` tag altogether. There are some arguments for the use of `tabindex`: complex interfaces with non-trivial alignment of interface elements should support the user by defining the order in which elements are focussed. Elements which are only important for users who do not use a mouse (e.g. “skip content” links) can be placed at the bottom of the page and still receive focus first. Finally, some browsers’ default tabbing behaviour does not include focussing on links (Opera 10.53) or other inconvenient behaviour. Although it can be assumed that users relying on keyboard access do not use these browsers, it can be an additional help to include `tabindex` in the design.

One of the most ignored accessible design rules is to clarify a link’s purpose. The purpose of a link should be determinable through the link text only, or through the text and its programmatically determinable context. For example, a hyperlink to send an email to the author of a text should be written as “Send an email to the author” rather than just “email”, “author” or “send”. Alternatively, the `title` attribute of a link, often used to display tooltips, is often used to augment a link’s description, as we chose to use in *ARDF*.

Guideline 3.1 Readable: Make text content readable and understandable.

Fulfilling the success criteria for this guideline is twofold: for the human language of the website’s interface to be programmatically determinable, setting the `lang` property of the `<html>` tag is sufficient. Objects of RDF triples, however, can be in any language, and to programmatically determine the language of a body of text can be difficult and expensive in time and processing power. Fortunately, the RDF syntax allows augmentation of data with metadata, such as data types and language tags. Alternatively, each predicate can be extended using the `xml:lang` attribute, which takes the same values as the language tag. Listing 3.2: Extract from http://dbpedia.org/data/University_of_Tampere shows usage of the language and data

type attributes in RDF, Listing 4.3: Exemplary use of the lang attribute, as used in ARDF (stylised HTML)

shows the equivalent ARDF transformation to HTML. Note that the English text does not require a separate tag as the document's default language is defined as English.

```

1 <!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN"
2   "http://www.w3.org/TR/html4/strict.dtd">
3 <html lang="en">
4   <head>
5     <title>http://dbpedia.org/data/University_of_Tampere</title>
6   </head>
7   <body>
8     <ul>
9       <li><span lang="sv">Tammerfors universitet</span></li>
10      <li><span lang="fi"> Tampereen yliopisto</span></li>
11      <li><span lang="es">Universidad de Tampere</span></li>
12      <li><span lang="nl">Universiteit Tampere</span></li>
13      <li>University of Tampere</li>
14      <li><span lang="de">Universität Tampere</span></li>
15      <li><span lang="fr">Université de Tampere</span></li>
16    </ul>
17  </body>
18 </html>

```

Listing 4.3: Exemplary use of the lang attribute, as used in ARDF (stylised HTML)

Guideline 3.3 Input Assistance: Help users avoid and correct mistakes.

As it is the case with any user input, it is sometimes hard to determine what is done on purpose, and what a mistake is. There are four aspects in *ARDF* that help the user avoid mistakes or correct them:

- All input fields are labelled with at least one of the following: `<label>` tag (`<input>`, `<select>`), `<legend>` (`<fieldset>`) tag, `<alt>` (``) or `title` (`<a>`) attribute,
- If no RDF data is found under a given URI, a link to open the URI outside of *ARDF* is given,
- If no RDF data in the specified language is found, a link to search for data in any language is given,
- Illegal characters (in URIs) are removed when a URI is entered, and the effect is explained to the user on the results page

Guideline 4.1 Compatible: Maximize compatibility with current and future user agents, including assistive technologies.

The first and foremost design decision incorporated in our design to maximize compatibility was to use HTML and CSS as the only technologies used in the page design. Technically, user agents can ignore the CSS and the pages are still accessible. Figure 4.3 shows a screenshot of the ARDF landing page in Opera 10.53, and Figure 4.4 shows the same page as seen in text-based web browser Lynx³⁵.

While newer technologies allow faster and more powerful browsing, they also tend to be less accessible than HTML. HTML remains the lowest common denominator among web browsing agents. Another reason not to overload the interface with high-level features is to retain the structure inherent in RDF data: as mentioned in Chapter 3, RDF represents mostly real-world objects and their properties, which have a natural structure. While a conversion to HTML is required to deliver the data to the user, any additional interface element will distract the user from the data structure. Since every user creates a conceptual model of what is presented [Zajicek and Powell, 1997], structures that do not follow this ideal should be avoided as long as they do not greatly enhance usability.

To maximize compatibility with user agents, all pages of *ARDF* are validated against the *HTML 4.01 Strict* specification. The main difference between the *Strict* and *Transitional* (and *Frameset*) sub-specifications is that the latter allow presentational markup, including among others: underline (<u>), strike-through (<s>), center (<center>) tags, as well as background, bgcolor, align and compact attributes in various elements and <iframe> and <noframes> elements in the *Frameset* specification. To overcome this limitation, *Cascading Style Sheets (CSS)* are used.

³⁵ <http://lynx.isc.org/>



Figure 4.3: Landing page of ARDF as seen in Opera 10.53



Figure 4.4: Landing page of ARDF as seen in Lynx 2.8.5

4.3.2. Page Layout

The layout of all pages can be split into three segments. All pages contain a list of navigation links at the top of the page. Since the landing (or index) and results page are the most accessed pages, the first element is a link to skip the navigation and jump to the content below it. According to a survey, 66% of all screen reader users use “skip links” [WebAIM, 2009b]. The navigation on these pages also contain links to a help page (“Help”), a description of the project (“About”) and a description of the underlying accessibility mechanisms on the page (“Accessibility options”).

The second segment of the page layout is the content. For the results page, this includes the search form and the table of results. Pages that contain text only have the content split into paragraphs (<p>) and ordered headings (<h1> to <h6>), according to WCAG techniques *H42*, *H69* and *G141* [Caldwell, Cooper, Guarino-Reid and Vanderheiden, 2008b]. All rows in the results table contain at least one *predicate* and *object*. The results are ordered by subject. For each subject, the first row contains the name of the subject in the leftmost column. Every predicate is in a new row. If more

than one value (*object*) for a property exists, the values are presented in a single cell, as an unordered list.

Lastly, all pages contain a footer with information relevant to the page, such as a link to jump to the top of the page, or suggestions how to improve search results.

5. Evaluation

To evaluate the usability of *ARDF*, the approach suggested by field literature [Mankoff, Fait and Tran, 2005; Ivory and Chevalier, 2002] to use more than one evaluation technique is followed. First, a representative sample page from *ARDF* is chosen as input for several automated accessibility evaluation tools. Second, an online survey among users of *ARDF* was conducted.

5.1. Automated Accessibility Evaluation

Automated testing of web accessibility reportedly is a difficult endeavour and in the worst cases might lead to illusive results. One of the reasons is that automated tools can only recognize problems that can be determined programmatically. Some accessibility issues, however, are not. Nevertheless, under consideration of these limitations, studies suggest these tools can help identify some accessibility issues before users and experiment participants do [Mankoff, Fait and Tran, 2005; Ivory and Chevalier, 2002].

After *W3C's Web Accessibility Initiative's* guidelines on “Preliminary Review of Web Sites for Accessibility”³⁶, we have conducted a series of automated tests with the following results. The results are taken from each tool’s report, using *ARDF*’s results page for the search query “University of Tampere”. At the time of writing, this query returned 65 triples, with 33 predicates in two languages.

Checking against Section 508 and WCAG 2.0 guidelines, *A-Checker*³⁷ [Gay and Li, 2010] did not find any known problems. It found 84 “likely” problems, all of which suggested that the “Link text may not be meaningful”. There are 84 links on the page.

The *Functional Accessibility Evaluator (FAE)* [Gunderson, Rangin and Hoyt, 2006] checks against the *DRES/CITES Web Accessibility Best Practices*, which are designed to comply with *Section 508, WCAG 1* and the Illinois Information Technology Accessibility Act [IITAA, 2010]. *FAE* groups its tests into five categories. The first category, „Navigation and Orientation“, contains 26 best practices, of which the test page failed one. *FAE* correctly identified a confusion of table cells and table headers in the results table: every table row should start with a header (<th>), as specified in Guideline 5 of WCAG 1 [Chisholm, Vanderheiden and Jacobs, 1999b]. Also, *FAE*

³⁶ <http://www.w3.org/WAI/eval/preliminary.html>

³⁷ <http://achecker.ca/checker>

recognized the duplicate assignment of an access key (see Section 4.3.1). Both issues have been fixed. *ARDF* passed all tests in the other four categories („Text Equivalents, Scripting, Styling and HTML Standards“).

EvalAccess 2.0 is a *WCAG 1* evaluator developed at the Laboratory of Human-Computer Interaction for Special Needs in Spain [Abascal, Arrue, Fajardo, Garay and Tomás, 2004]. *EvalAccess* groups its findings into three priorities, equal to the priorities defined in *WCAG 1*. Three errors were found, two with priority two, one with priority three (one being highest priority, three lowest). First, `cellpadding` in the results table was defined using an absolute pixel value. Although this is in accordance with *WCAG 2.0*, it was changed to a relative value. The second error found referred to a missing `label` for one of the form elements. However, the affected form element was of type “hidden” and should therefore be excluded from requiring a label. Also, *EvalAccess* suggested providing abbreviations for header labels. This idea stems from the *HTML Techniques for Web Content Accessibility Guidelines 1.0*³⁸ [Chisholm, Vanderheiden and Jacobs, 2000]. In the latest version of *WCAG 2.0* [Caldwell, Cooper, Guarino-Reid and Vanderheiden, 2008a], this concept is not mentioned. However, in an outdated version of *WCAG 2.0*, this guideline can be found under the topic „Data Tables“ [Cooper and Chisholm, 2003]. Whether the results table in *ARDF* is a data table is doubtful, as the information within is not tabular in nature. The author further claims that the table is not a layout table, either. The table merely supports the structure of the information provided and serves as a supportive frame to browse the information. Furthermore, the content of the header cells changes for every search query, finding an abbreviation is therefore complex and might only confuse the user.

*Wave*³⁹ is a free web accessibility evaluation tool maintained by *WebAIM*, an organization within the *Center for Persons with Disabilities (CPD)* at Utah State University. *Wave* searches for 20 common errors in inaccessible designs, such as missing alternative texts or empty table headers, and hints at 44 other programmatically determinable issues. It detected no accessibility errors.

³⁸ “5.1.1 Providing summary information: Provide terse substitutes for header labels with the “abbr” attribute on TH. These will be particularly useful for future speaking technologies that can read row and column labels for each cell. Abbreviations cut down on repetition and reading time.”

³⁹ <http://wave.webaim.org/>

Hera is a free accessibility checker developed by the Sidar Foundation⁴⁰. *Hera* checks compliance of web pages with all three conformance levels of the Web Content Accessibility Guidelines 1. It assists developers by highlighting errors within the page and allowing to view the deficient source code. For our sample *ARDF* page, *Hera* found one error, namely two link elements (<a>) without a printable character in between them. This error derives from Checkpoint 10.5: „[...] include non-link, printable characters (surrounded by spaces) between adjacent links. [Chisholm, Vanderheiden and Jacobs, 1999b]” However, in the case of the sample page, one of the <a> elements represented an anchor, not a link. The anchor is not visible or functional and therefore does not confuse a user. *Hera* failed to differentiate between anchors and links.

The *Accessibility Tools Framework (ACTF)* is an extensible accessibility framework developed by IBM for the *Eclipse* platform [Yesilada, Harper and Chen, 2008; Obrenović, 2009]. *ACTF* includes a collection of tools for developers to support accessibility, divided into 3 core areas: validation (*HTML*, *ODF*, *Java*, among others), presentation (simulate low vision, visualize blind usability) and alternative interfaces (e.g. UI transformer, text-to-speech). For a blind usability test, *ACTF* rates guideline compliance, “listenability” and navigability of the page. The guidelines included are: WCAG 1, WCAG 2.0, Section 508, the *Japanese Industrial Standard (JIS)*⁴¹ and the *IBM Web Accessibility Checklist*⁴². *ACTF* is therefore the most comprehensive of all evaluation tools used. While the index page received an “excellent” rating (100% compliance, 100% listenability, 98% navigability), the sample page was rated “unsatisfactory” with ratings of 98% compliance, 95% listenability and 83% navigability. The missing percentages to 100% are based on two findings: First, the list of preferred languages to filter search results was suggested to be split in `optgroups`. The list was then split in groups of alphabetical order. Second, all internal links (to an *ARDF* page) were suggested to be possibly unusable without script. Unfortunately, no

⁴⁰ <http://www.sidar.org/>

⁴¹ JIS X 8341-1. Identical to ISO standard *ISO 9241-20: Ergonomics of human-system interaction -- Part 20: Accessibility guidelines for information/communication technology (ICT) equipment and services*. For more information, see: <http://www.webstore.jsa.or.jp/webstore/Com/FlowControl.jsp?lang=en&bunsyoId=JIS+X+8341-1%3A2010&dantaiCd=JIS&status=1&pageNo=37>. A preview for an English but outdated version can be retrieved from: http://www.webstore.jsa.or.jp/webstore/PrevPdfServlet?dc=JIS&fn=pre_jis_x_08341_003_000_2004_ed10_ch.pdf.

⁴² Available at: <http://www-03.ibm.com/able/guidelines/web/accessweb.html>

documentation exists which explains in which cases the links might not be usable. After manual testing, the author came to the conclusion that all relative links cause this behaviour in *ACTF*. It was therefore decided to leave the links relative, as no knowledge of relative links causing accessibility barriers can be found in the literature. *ACTF*'s "Low Vision Simulation" did not find any issues.

Lastly, the *W3C CSS Validator*⁴³ did not find any errors in the CSS parts of the page.

Evaluation Tool	Issues found	Issues resolved ⁴⁴
A-Checker	0	0
Functional Accessibility Evaluator	2	2
EvalAccess 2.0	3	1
Wave	0	0
Hera	1	0
W3C CSS Validator	0	0
Accessibility Tools Framework	2	1

Table 5.1: Tools used to evaluate ARDF accessibility, the number of changes suggested by each tool and the number of changes actually made.

5.2. Online Survey

An online survey among the users of *ARDF* was conducted. The survey was available via a hyperlink on the landing page and was sent with a descriptive text to a mailing list of NKL, the Finnish Federation of the Visually Impaired. The survey was available in both English and Finnish. The survey consisted of 20 questions regarding personal experience using the website and similar services.

15 subjects participated in the survey, 3 female, 12 male. They were between 22 and 49 years old (average: 31). Six participants suffered from a visual impairment (one of six categories according to the *World Health Organization*'s "International classification of Diseases" [Brämer, 1988] (cf. [Resnikoff, Pascolini, Etya'ale, Kocur, Pararajasegaram, Pokharel and Mariotti, 2004]) based on visual field and visual acuity). All participants used computers for both private and job-related purposes and had been using computers for more than six years.

⁴³ <http://jigsaw.w3.org/css-validator/>

⁴⁴ Only issues which are clearly stated and in compliance with WCAG 2.0 are resolved.

5.2.1. Quantitative Analysis

On a 5-point Likert scale (1 – strongly disagree, 5 – strongly agree), the participants rated the usability, usefulness and personal benefit of *ARDF* towards online research.

Among the visually impaired users, 50% strongly agreed that Linked Data search would be a useful additional or alternative information source for online research (Median: 4). 83% of users with visual impairment agreed that a service such as *ARDF* would be beneficial for their online research (Median: 4).

Among the users without visual impairment, 33% agreed that Linked Data search would be a useful additional or alternative information source (Median: 3). 22% considered Linked Data search potentially beneficial for their online research (Median: 3).

53% of all users found the *ARDF* website usable or very usable (Median: 4), among them 50% of visually impaired (Median: 4) and 33% of the not visually impaired users (Median: 4). Only one visually impaired user (6,6%) found the website to be unusable.

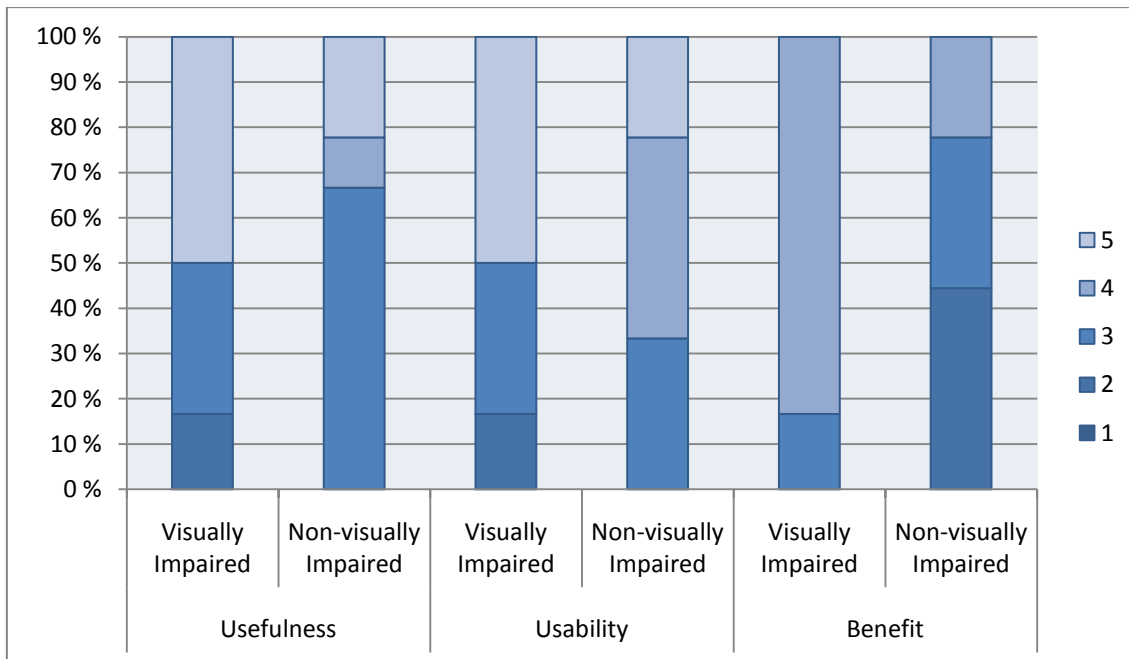


Figure 5.1: Responses of survey participants on usability, usefulness and benefit of *ARDF* as percentages of responses on a 5-point Likert scale (1 – strongly disagree, 5 – strongly agree).

We proceed to test for statistically significant differences in responses in each of the categories between visually impaired and non-visually impaired users. To do so, we combine answers 4 and 5 (*agree* and *strongly agree*) and 1 and 2 (*disagree* and *strongly disagree*).

disagree) and apply a χ^2 (chi-square) test. Testing for null hypothesis H_0 (there is no statistically significant difference between visually impaired and non-visually impaired users in *agreeing or disagreeing* to the statements above), we enter the above data into the chi-square formula

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Where O is the expected number of responses for each category and E is the actual number of responses in that category. For both the usefulness and the usability statement, we get a chi square value of below 1. We therefore conclude that there is no difference in perception of usefulness and usability of ARDF between visually impaired and non-visually impaired users.

For the statement of benefit of *ARDF* towards online research, we get a chi square value of 5.23. Therefore, with a level of confidence of 0.05 ($\chi^2_{.05}$ (1 degree of freedom) = 3.84 [Howell, 2009]), we can reject H_0 .

5.2.2. Qualitative Analysis

The survey participants were further asked to state their positive and negative experiences using *ARDF*, to give their opinion on how the service performs compared to other online resources and how it could be improved.

Several participants pointed out that some of the search results are irrelevant. In fact, this can be observed in other Linked Data search engines as well (e.g. Sigma⁴⁵). Usually, the reason is that the search engine cannot know when and if the user is looking for a specific entity, a phrase or just triples with at least one keyword in them. One participant reported that the search did not return any results.

In general, the users were satisfied with the website's interface. They found the website to be "very clear", easy to navigate" and "easy to read". A user with visual impairment pointed out that the text and layout were "simple" and "very clear". None of the participants reported problems using the interface. One participant asked for the possibility to choose English as the preferred language of search results. English was, in fact, not on the list of languages as it is the default language of the Semantic Web.

⁴⁵ <http://sig.ma>

Several users found the search to be too slow. *ARDF* was designed to fetch results from Sigma and is therefore dependent on the speed of response of Sigma. A timeout in *ARDF* ensures that the user receives a response before the request times out, but in some cases this may still take up to 30 seconds. When Sigma is unresponsive and the user searches for keywords (as opposed to a URI), this leads to zero search results.

6. Discussion

Accessible RDF is a website for both sighted and visually impaired users to access information that is available as Linked Data. Since there is no comparable service on the World Wide Web, it is difficult to evaluate the impact the idea behind *ARDF* has on web accessibility in general.

We have shown that, within the population of survey participants, there was no significant difference in the assessment of usability between visually impaired and not visually impaired users. This can be considered a success, as usability for visually impaired users is generally harder to achieve. However, due to the aforementioned reasons, it is not possible to tell how *ARDF* performs against other, similar services in terms of usability.

The results of the survey further reveal that the “triple” concept is readable and understandable. This is an important aspect of using Linked Data as information source. The quality of the search results could be improved significantly by accessing more data sources and applying artificial intelligence algorithms to determine a most likely targeted subject and to filter unreadable or irrelevant triples.

It was shown that a design which puts the data format above high-end features and interface can have positive effects on the usability of the data. None of the participants mentioned difficulties understanding the results, their layout or connections between them. This is despite HTML being a less than optimal medium for structured data to be transmitted. A stand-alone application could make better use of keyboard shortcuts, screen space and accessibility tools such as screen readers. However, this would have excluded a number of users who run different platforms or exceptional hardware.

Despite the mixed results, it is to believe that Linked Data will play a role in web accessibility in the near future. *ARDF* has shown potential benefit, and with a more thorough search and more elaborate data processing similar services might become a powerful information source in the future. Irrelevant and unreadable search results could be filtered through semantic and orthographic filters. The quality and quantity of Linked Data will most likely increase in the next years. Search and navigation options through the “Web of Data” are still at an early stage and might improve significantly performance-wise.

In the future, *ARDF* might include more sources in its search, or crawl the web by itself. While *Sigma* is one of the largest Semantic Web indexes, its design is not optimal for the purpose of *ARDF*. In the future, search results could be ordered by relevance or date, or by a measure of readability. Results without labels could be filtered, thereby further improving readability.

The speed of searching and delivering search results is a major factor in search engine design. Due to the limited time, these factors could not be accounted for. This is reflected in the user survey's results.

ARDF does not replace services on the World Wide Web, it is merely another node to access a specific kind of data. Since the Web is so much more than just data, *ARDF* should not be seen as a replacement for any other website. What it aims at is improving access to the "read-only" part of the Web.

One important property of *ARDF* which has not been mentioned in this work is its openness. The author believes that independence of corporations and proprietary data formats is one of the main advantages of the World Wide Web. That is not to say that a service such as *ARDF* runs free of cost. However, instead of artificially restricting access to information as can be observed all around the world, information access should be extended constantly. *ARDF* is just one example of doing so.

We have shown that Linked Data can have a beneficial effect for web users who have to rely on accessibility technology. We hope to have created a spark among Semantic Web and Web Accessibility developers and encourage everyone to work towards a more accessible web.

7. Summary

The Semantic Web is the idea of a World Wide Web so tightly knit that semantic information about all real world entities are programmatically available. The primary goal of the Semantic Web is to make semantic reasoning programmatically accessible in order to create more “intelligent” and logically sound search results. However, a user group which might also benefit from the semantic data being published is the one using accessibility technology. The term accessibility technology refers to all software, hardware and guidelines which enable users that are for any reason unable to access online information to gain access to these. Due to the major advancements in speech synthesis and the widespread use of audio interfaces, screen readers have become the primary accessibility tool for visually impaired WWW users. Other technologies such as refreshable Braille cells and screen magnifiers exist which aim at visually impaired computer users. Despite the efforts, however, the constantly growing Web and surfacing new technologies make it difficult for developers and legislature to keep up with the demands of essential online content. We have developed a website called *Accessible RDF*, which aims at optimizing and extending access to Linked Data beyond the accessibility borders of currently existing services. Linked Data is a concept mainly used in relation with the Semantic Web in which information is published on the Web and connected to related information. The architecture of Linked Data stresses searchability and navigability of information. It is published as “triples”, a connection between an object and another object or a description of the object’s properties. The structure of interconnected data becomes a part of the data itself or, to put it in Semantic Web terms, we move from a web of documents towards a web of data.

Accessible RDF searches for Linked Data relevant to the user’s search query. It uses Sindice Sigma’s API to search for triples in Sindice’s index and reads triples from a source given by URI. It presents the search results in a slim HTML and CSS only interface. The website implements W3C’s Web Content Accessibility Guidelines 2.0 and is compatible with most other guidelines. This architecture allows *Accessible RDF* to be maximally accessible. The search results are presented in a table and lists, supporting the structure of the data.

A user survey revealed that visually impaired and not visually impaired users are equally satisfied with the usability of the website. Users with visual impairments

generally showed a stronger interest in the concept and rated it significantly higher in offering benefits as an alternative or additional information source. The survey also revealed that specific improvements to the system could further improve usability and benefit for the user: First, search results may in the future be improved. This can be achieved by querying more or different Semantic Web indexes and by applying filters to unreadable and irrelevant search results. Second, response time of the service may be lowered so as to optimize usability and to harness the power of navigability of the data.

The increasing speed and frequency of publications regarding Semantic Web technology and the rising number of published data indicate a strong push of conventional websites and services towards including Linked Data in their systems. Unfortunately, no project exists as of yet that tries to capitalize on the power of semantic information for users with impairments. We hope to have sparked an idea of how Linked Data can be used to improve conventional interfaces and to combine data structures and medium structures into one. The presented approach is only one of many possible, all of which hopefully lead to a better mutual understanding and better access to information for anyone.

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Appendix A

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Accessible RDF

Search options

Keywords or address: Preferred Language:

Search results for "http://dbpedia.org/resource/RDF"

[RDF](#) [abstract](#)

- RDF is a three-letter acronym that may refer to: In technology: Resource Description Framework, an official World Wide Web Consortium (W3C) Semantic Web specification for metadata models Radial distribution function, the probability of finding an atom at a certain distance away from another atom Radio direction finder Random dopant fluctuation Reuters Data Feed Refuse-derived fuel In military: Rwandan Defence Forces Reserve Defence Forces, Ireland Rapid deployment force(s): Finnish Rapid Deployment Force, Finland United States Rapid Deployment Forces Royal Dublin Fusiliers In organizations: Richard Dawkins Foundation for Reason and Science, a non-profit organization RDF Media, a television production company RDF Group plc, an IT services provider (Recruitment, Managed Services, Products, Learning Services). (No connection with RDF Media) Reichsbund Deutsche Familie (Reich's League for the German Family), the pronatalist organization in Nazi Germany. In entertainment: Robotech Defense Force, or Robotech Armed Forces, a military faction in the fictional Robotech universe Radical Dance Faction, a band from the United Kingdom Other: Reality distortion field, a facetious term for the ability of charismatic people to convince others to believe almost anything Radial distribution function
- RDF kan betekenen: Resource Description Framework, een W3C standaard voor een metadata model Radio Direction Finder, een apparaat om de richting van herkomst van een radiosignaal mee te bepalen Refuse Derived Fuel, brandstof uit afval Radical Dance Faction, Engelse ska-punk-dub band Red Dot Finder, een hulpmiddel op een telescoop om hemelobjecten mee te vinden
- RDF son unas siglas puede referirse a: RDF: sigla del inglés "Resource Description Framework", Marco de Descripción de Recursos, un del W3C. RDF: sigla del inglés "Radio Direction Finder", Búsqueda por RadioDirección, un sistema de detección electrónica de largo alcance más tarde denominado radar. RDF: Sigla del inglés "Radial Distribution Function", Función de Distribución Radial, una función que describe en media como están distribuidos radialmente los átomos alrededor de otros en un sistema. RDF: Rechazo de Foso.
- ang. Radio direction finder – pol. Radionamiernik Radiodiffusion Française – francuska instytucja publiczna odpowiedzialna za publiczne radio i telewizję w latach 1945-1949 Resource Description Framework – jedna ze specyfikacji modelu metadanych Refused Derived Fuel – wysoko kaloryczne frakcje odpadów wysortowane z opadów przemysłowych bądź miejskich Richard Dawkins Foundation for Reason and Science – brytyjska fundacja non-profit założona przez biologa Richarda Dawkinsa

[hasPhotoCollection](#)

- [RDF](#)

[comment](#)

- RDF kan betekenen: Resource Description Framework, een W3C standaard voor een metadata model Radio Direction Finder, een apparaat om de richting van herkomst van een radiosignaal mee te bepalen Refuse Derived Fuel, brandstof uit afval Radical Dance Faction, Engelse ska-punk-dub band Red Dot Finder, een hulpmiddel op een telescoop om hemelobjecten mee te vinden
- RDF son unas siglas puede referirse a: RDF: sigla del inglés "Resource Description Framework", Marco de Descripción de Recursos, un del W3C. RDF: sigla del inglés "Radio Direction Finder", Búsqueda por RadioDirección, un sistema de detección electrónica de largo alcance más tarde denominado radar. RDF: Sigla del inglés "Radial Distribution Function", Función de Distribución Radial, una función que describe en media como están distribuidos radialmente los átomos alrededor de otros en un sistema.
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[label](#)

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- [RDF](#)
- [RDF](#)
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- [RDF](#)
- [RDF](#)
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[page](#)

- <http://en.wikipedia.org/wiki/RDF>

18 results

- No more sources
- [Jump to top of page](#)

Appendix A: Image of the *ARDF* results page for "http://dbpedia.org/resource/RDF"

Appendix B

```

1  <!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN"
2  "http://www.w3.org/TR/html4/strict.dtd">
3
4  <HTML lang="en">
5  <HEAD>
6  <META http-equiv="Content-type" content="text/html; charset=UTF-8">
7  <TITLE>Accessible RDF search results for "University of Tampere"</TITLE>
8  <STYLE type="text/css">
9  a:focus {
10     color: red;
11 }
12 body {
13     font-size: 150%;
14 }
15 * {
16     font-family: Verdana, sans-serif;
17 }
18 </STYLE>
19 </HEAD>
20 <BODY>
21
22 <UL style="padding: 0;">
23     <LI style="display: inline; border: 2px solid black; margin: 3pt; padding:
24 4pt; line-height: 200%"><A
25     name="top"></A><A href="#results" accesskey="S" title="Skip the beginning
26 of the page and go to the first search result">Jump
27     to search results</A></LI>
28     <LI
29     style="display: inline; border: 2px solid black; margin: 3pt; padding: 4pt;
30 line-height: 200%"><A
31     href="index.jsp?query=null&amp;page=0" accesskey="1"
32     title="Return to the Accessible RDF Homepage">Home</A></LI>
33     <LI
34     style="display: inline; border: 2px solid black; margin: 3pt; padding: 4pt;
35 line-height: 200%"><A
36     href="query.jsp?&amp;query=University of
37 Tampere&amp;page=1&amp;noTables=true"
38     title="Open this page without tables, if you have difficulties reading the
39 search results"
40     accesskey="T">Table-free version</A></LI>
41
42     <LI
43     style="display: inline; border: 2px solid black; margin: 3pt; padding: 4pt;
44 line-height: 200%"><A
45     href="help.jsp" accesskey="6"
46     title="Read instructions how to use this page">Help</A></LI>
47     <LI
48     style="display: inline; border: 2px solid black; margin: 3pt; padding: 4pt;
49 line-height: 200%"><A
50     href="help.jsp#who" title="Read about the Accessible RDF
51 idea">About</A></LI>
52     <LI
53     style="display: inline; border: 2px solid black; margin: 3pt; padding: 4pt;
54 line-height: 200%"><A
55     href="help.jsp#access" accesskey="0"
56     title="How to browse this page with assistive technologies">Accessibility
57     options</A></LI>
58     <LI
59     style="display: inline; border: 2px solid black; margin: 3pt; padding: 4pt;
60 line-height: 200%"><A
61     href="survey.jsp" title="Fill out our web survey">Survey</A></LI>
62 </UL>
63
64
65 <H1><A name="search">Accessible RDF</A></H1>
66 <FORM action="query.jsp" method="get" accept-charset="UTF-8">
67 <FIELDSET><LEGEND>Search options</LEGEND> <LABEL for="query">Keywords
68 or address: </LABEL> <INPUT name="query" id="query" type="text"
69     style="font-size: larger" size="40" maxlength="100"
70     value="University of Tampere"> <LABEL for="language">Preferred
71 Language:</LABEL> <SELECT style="font-size: larger" name="language"

```

```

72     id="language" size="1">
73     <OPTION selected>Any</OPTION>
74     <OPTION>Catalan</OPTION>
75     <OPTION>Chinese</OPTION>
76     <OPTION>Czech</OPTION>
77     <OPTION>Dutch</OPTION>
78     <OPTION>English</OPTION>
79     <OPTION>Finnish</OPTION>
80     <OPTION>French</OPTION>
81     <OPTION>German</OPTION>
82     <OPTION>Hungarian</OPTION>
83     <OPTION>Italian</OPTION>
84     <OPTION>Japanese</OPTION>
85     <OPTION>Norwegian</OPTION>
86     <OPTION>Polish</OPTION>
87     <OPTION>Portuguese</OPTION>
88     <OPTION>Romanian</OPTION>
89     <OPTION>Spanish</OPTION>
90     <OPTION>Swedish</OPTION>
91     <OPTION>Turkish</OPTION>
92 </SELECT> <INPUT type="submit" style="font-size: larger" value="Search">
93 <INPUT type="hidden" name="page" value="1"></FIELDSET>
94 </FORM>
95
96 <P><A name="results"></A></P>
97 <TABLE cellpadding="5%" cellspacing="0"
98     summary="This table contains all search results. Column 1 and 3 contain
99     objects, or data, and column 2 describes their relationship. Column 3 may contain
100    several objects, they are therefore arranged in a list.">
101     <CAPTION>Search results for "University of Tampere"</CAPTION>
102     <COLGROUP>
103         <COL style="max-width: 30%">
104         <COL style="max-width: 30%">
105         <COL style="max-width: 50%">
106     </COLGROUP>
107     <TR style="background-color: #F0F0F0;">
108         <TH align="left" style="max-width: 30%" valign="top" id="s1">
109             <H2><A name="this"></A>University of Tampere</H2>
110         </TH>
111         <TD align="left" valign="top" headers="s1" id="p1">
112             <H3><A
113                 href="query.jsp?&query=http://sig.ma/property/alt_label"
114                 title="alt label"><u>alt label</u></A></H3>
115         </TD>
116         <TD align="left" valign="top" headers="s1 p1" style="max-width: 60%;">
117         <UL>
118
119             <LI>TaY</LI>
120             <LI>Tampere University</LI>
121             <LI>Tampereen yliopisto</LI>
122         </UL>
123     </TD>
124 </TR>
125     <TR style="background-color: #FFFFFF;">
126         <TD headers="s1"></TD>
127         <TD align="left" valign="top" headers="s1" id="p2">
128             <H3><A href="query.jsp?&query=http://sig.ma/property/campus"
129                 title="campus">campus</A></H3>
130         </TD>
131         <TD align="left" valign="top" headers="s1 p2" style="max-width: 60%;">
132         <UL>
133
134             <LI>Urban</LI>
135         </UL>
136     </TD>
137 </TR>
138     <TR style="background-color: #F0F0F0;">
139         <TD headers="s1"></TD>
140         <TD align="left" valign="top" headers="s1" id="p3">
141             <H3><A href="query.jsp?&query=http://sig.ma/property/caption"
142                 title="caption">caption</A></H3>
143         </TD>
144         <TD align="left" valign="top" headers="s1 p3" style="max-width: 60%;">
145         <UL>

```

```

146
147     <LI>The Finnish logo of the university.</LI>
148   </UL>
149 </TD>
150 </TR>
151 <TR style="background-color: #FFFFFF;">
152   <TD headers="s1"></TD>
153   <TD align="left" valign="top" headers="s1" id="p4">
154     <H3><A
155       href="query.jsp?&query=http://sig.ma/property/chancellor"
156       title="chancellor">chancellor</A></H3>
157   </TD>
158   <TD align="left" valign="top" headers="s1 p4" style="max-width: 60%;">
159     <UL>
160
161       <LI>Krista Varantola</LI>
162     </UL>
163   </TD>
164 </TR>
165 <TR style="background-color: #F0F0F0;">
166   <TD headers="s1"></TD>
167   <TD align="left" valign="top" headers="s1" id="p5">
168     <H3><A href="query.jsp?&query=http://sig.ma/property/city"
169       title="city">city</A></H3>
170   </TD>
171   <TD align="left" valign="top" headers="s1 p5" style="max-width: 60%;">
172     <UL>
173
174       <LI><A
175         href="query.jsp?&query=http://dbpedia.org/resource/Tampere"
176         title="Tampere">Tampere</A></LI>
177     </UL>
178   </TD>
179 </TR>
180 <TR style="background-color: #FFFFFF;">
181   <TD headers="s1"></TD>
182   <TD align="left" valign="top" headers="s1" id="p6">
183     <H3><A href="query.jsp?&query=http://sig.ma/property/comment"
184       title="comment">comment</A></H3>
185   </TD>
186   <TD align="left" valign="top" headers="s1 p6" style="max-width: 60%;">
187     <UL>
188
189       <LI>Tampere University of Technology (TUT) is Finland's largest
190       university in engineering sciences. The university is located in
191       Hervanta, a suburb of Tampere. The university's statutory duty is to
192       pursue research and give highest education in its field. The
193       research, conducted by some 1,800 staff and faculty members, mostly
194       focuses on applied science and often has close ties to many different
195       companies.</LI>
196       <LI>Tampere University of Technology (TUT) is Finland's largest
197       university in engineering sciences. The university is located in
198       Hervanta, a suburb of Tampere. The university's statutory duty is to
199       pursue research and give highest education in its field. The
200       research, conducted by some 1,800 staff and faculty members, mostly
201       focuses on applied science and often has close ties to many different
202       companies. Located next to the university campus is a Technology
203       Centre Hermia, including a large Nokia research facility. The yearly
204       budget of the university is some 120 million euros. Like all Finnish
205       universities, TUT is state-funded.</LI>
206     </UL>
207   </TD>
208 </TR>
209 <TR style="background-color: #F0F0F0;">
210   <TD headers="s1"></TD>
211   <TD align="left" valign="top" headers="s1" id="p7">
212     <H3><A href="query.jsp?&query=http://sig.ma/property/country"
213       title="country">country</A></H3>
214   </TD>
215   <TD align="left" valign="top" headers="s1 p7" style="max-width: 60%;">
216     <UL>
217
218       <LI><A
219         href="query.jsp?&query=http://dbpedia.org/resource/Finland"

```

```

220         title="Finland">Finland</A></LI>
221     </UL>
222 </TD>
223 </TR>
224 <TR style="background-color: #FFFFFF;">
225     <TD headers="s1"></TD>
226     <TD align="left" valign="top" headers="s1" id="p8">
227         <H3><A
228             href="query.jsp?&query=http://sig.ma/property/doctoral"
229             title="doctoral">doctoral</A></H3>
230     </TD>
231     <TD align="left" valign="top" headers="s1 p8" style="max-width: 60%;">
232     <UL>
233
234         <LI>1745</LI>
235     </UL>
236 </TD>
237 </TR>
238 <TR style="background-color: #F0F0F0;">
239     <TD headers="s1"></TD>
240     <TD align="left" valign="top" headers="s1" id="p9">
241     <H3><A href="query.jsp?&query=http://sig.ma/property/domain"
242         title="domain">domain</A></H3>
243     </TD>
244     <TD align="left" valign="top" headers="s1 p9" style="max-width: 60%;">
245     <UL>
246
247         <LI>en.wikipedia.org</LI>
248     </UL>
249 </TD>
250 </TR>
251 <TR style="background-color: #FFFFFF;">
252     <TD headers="s1"></TD>
253     <TD align="left" valign="top" headers="s1" id="p10">
254     <H3><A
255         href="query.jsp?&query=http://sig.ma/property/established"
256         title="established">established</A></H3>
257     </TD>
258     <TD align="left" valign="top" headers="s1 p10" style="max-width: 60%;">
259     <UL>
260
261         <LI>1925</LI>
262         <LI>1972</LI>
263     </UL>
264 </TD>
265 </TR>
266 <TR style="background-color: #F0F0F0;">
267     <TD headers="s1"></TD>
268     <TD align="left" valign="top" headers="s1" id="p11">
269     <H3><A href="query.jsp?&query=http://sig.ma/property/faculty"
270         title="faculty">faculty</A></H3>
271     </TD>
272     <TD align="left" valign="top" headers="s1 p11" style="max-width: 60%;">
273     <UL>
274
275         <LI>1082</LI>
276         <LI>376</LI>
277     </UL>
278 </TD>
279 </TR>
280 <TR style="background-color: #FFFFFF;">
281     <TD headers="s1"></TD>
282     <TD align="left" valign="top" headers="s1" id="p12">
283     <H3><A
284         href="query.jsp?&query=http://sig.ma/property/faculty_size"
285         title="faculty size">faculty size</A></H3>
286     </TD>
287     <TD align="left" valign="top" headers="s1 p12" style="max-width: 60%;">
288     <UL>
289
290         <LI>1082</LI>
291         <LI>376</LI>
292     </UL>
293 </TD>

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294 </TR>
295 <TR style="background-color: #F0F0F0;">
296 <TD headers="s1"></TD>
297 <TD align="left" valign="top" headers="s1" id="p13">
298 <H3><A
299 href="query.jsp?&query=http://sig.ma/property/family_name"
300 title="family name">family name</A></H3>
301 </TD>
302 <TD align="left" valign="top" headers="s1 p13" style="max-width: 60%;">
303 <UL>
304
305 <LI>Tampere</LI>
306 <LI>Technology</LI>
307 </UL>
308 </TD>
309 </TR>
310 <TR style="background-color: #FFFFFF;">
311 <TD headers="s1"></TD>
312 <TD align="left" valign="top" headers="s1" id="p14">
313 <H3><A
314 href="query.jsp?&query=http://sig.ma/property/former_name"
315 title="former name">former name</A></H3>
316 </TD>
317 <TD align="left" valign="top" headers="s1 p14" style="max-width: 60%;">
318 <UL>
319
320 <LI>Tampereen teknillinen korkeakoulu, also translated as
321 Tampere University of Technology</LI>
322 </UL>
323 </TD>
324 </TR>
325 <TR style="background-color: #F0F0F0;">
326 <TD headers="s1"></TD>
327 <TD align="left" valign="top" headers="s1" id="p15">
328 <H3><A
329 href="query.jsp?&query=http://sig.ma/property/former_names"
330 title="former names">former names</A></H3>
331 </TD>
332 <TD align="left" valign="top" headers="s1 p15" style="max-width: 60%;">
333 <UL>
334
335 <LI>Tampereen teknillinen korkeakoulu, also translated as
336 Tampere University of Technology</LI>
337 </UL>
338 </TD>
339 </TR>
340 <TR style="background-color: #FFFFFF;">
341 <TD headers="s1"></TD>
342 <TD align="left" valign="top" headers="s1" id="p16">
343 <H3><A
344 href="query.jsp?&query=http://sig.ma/property/geometry"
345 title="geometry">geometry</A></H3>
346 </TD>
347 <TD align="left" valign="top" headers="s1 p16" style="max-width: 60%;">
348 <UL>
349
350 <LI>POINT(23.7781 61.4942)</LI>
351 <LI>POINT(23.86 61.4494)</LI>
352 </UL>
353 </TD>
354 </TR>
355 <TR style="background-color: #F0F0F0;">
356 <TD headers="s1"></TD>
357 <TD align="left" valign="top" headers="s1" id="p17">
358 <H3><A
359 href="query.jsp?&query=http://sig.ma/property/given_name"
360 title="given name">given name</A></H3>
361 </TD>
362 <TD align="left" valign="top" headers="s1 p17" style="max-width: 60%;">
363 <UL>
364
365 <LI>Tampere</LI>
366 <LI>University</LI>
367 </UL>

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368     </TD>
369 </TR>
370 <TR style="background-color: #FFFFFF;">
371   <TD headers="s1"></TD>
372   <TD align="left" valign="top" headers="s1" id="p18">
373     <H3><A
374       href="query.jsp?&query=http://sig.ma/property/homepage"
375       title="homepage">homepage</A></H3>
376   </TD>
377   <TD align="left" valign="top" headers="s1 p18" style="max-width: 60%;">
378     <UL>
379
380       <LI><A href="http://www.tut.fi/public/index.cfm?siteid=32"
381         title="External link:
382 http://www.tut.fi/public/index.cfm?siteid=32">http://www.tut.fi/public/index.cfm?
383 siteid=32</A></LI>
384       <LI><A href="http://www.uta.fi/"
385         title="External link: http://www.uta.fi/">http://www.uta.fi/</A></LI>
386     </UL>
387   </TD>
388 </TR>
389 <TR style="background-color: #F0F0F0;">
390   <TD headers="s1"></TD>
391   <TD align="left" valign="top" headers="s1" id="p19">
392     <H3><A
393       href="query.jsp?&query=http://sig.ma/property/identifier"
394       title="identifier">identifier</A></H3>
395   </TD>
396   <TD align="left" valign="top" headers="s1 p19" style="max-width: 60%;">
397     <UL>
398
399       <LI><A
400 href="query.jsp?&query=http://rdf.freebase.com/ns/guid.9202a8c04000641f800000
401 00002d68dd"
402 title="guid.9202a8c04000641f80000000002d68dd">guid.9202a8c04000641f80000000002d68
403 dd</A></LI>
404       <LI><A
405 href="query.jsp?&query=http://semanticweb.org/index.php?title=Special:ExportR
406 DF/Tampere_University_of_Technology&xmlmime=rdf"
407 title="Tampere University of Technology&xmlmime=rdf">Tampere
408 University of Technology&xmlmime=rdf</A></LI>
409       <LI><A
410 href="query.jsp?&query=http://www.linkedin.com/companies/tampere-
411 university-of-technology"
412 title="tampere-university-of-technology">tampere-university-of-
413 technology</A></LI>
414       <LI><A
415 href="query.jsp?&query=http://www.linkedin.com/companies/university-of-
416 tampere"
417 title="university-of-tampere">university-of-tampere</A></LI>
418       <LI><A
419 href="query.jsp?&query=http://www.mpii.de/yago/resource/University_of_Tampere
420 "
421 title="University of Tampere">University of Tampere</A></LI>
422     </UL>
423   </TD>
424 </TR>
425 <TR style="background-color: #FFFFFF;">
426   <TD headers="s1"></TD>
427   <TD align="left" valign="top" headers="s1" id="p20">
428     <H3><A
429       href="query.jsp?&query=http://sig.ma/property/image_name"
430       title="image name">image name</A></H3>
431   </TD>
432   <TD align="left" valign="top" headers="s1 p20" style="max-width: 60%;">
433     <UL>
434
435       <LI>Tty logo suomi.gif</LI>
436     </UL>
437   </TD>
438 </TR>

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442     </TD>
443 </TR>
444 <TR style="background-color: #F0F0F0;">
445   <TD headers="s1"></TD>
446   <TD align="left" valign="top" headers="s1" id="p21">
447     <H3><A
448       href="query.jsp?&query=http://sig.ma/property/is_affiliation_of"
449       title="is affiliation of">is affiliation of</A></H3>
450   </TD>
451   <TD align="left" valign="top" headers="s1 p21" style="max-width: 60%;">
452     <UL>
453
454       <LI><A
455         href="query.jsp?&query=http://semanticweb.org/id/Jaakko_Salonen"
456         title="Jaakko Salonen">Jaakko Salonen</A></LI>
457     </UL>
458   </TD>
459 </TR>
460 <TR style="background-color: #FFFFFF;">
461   <TD headers="s1"></TD>
462   <TD align="left" valign="top" headers="s1" id="p22">
463     <H3><A
464       href="query.jsp?&query=http://sig.ma/property/is_alma_mater_of"
465       title="is alma mater of">is alma mater of</A></H3>
466   </TD>
467   <TD align="left" valign="top" headers="s1 p22" style="max-width: 60%;">
468     <UL>
469
470       <LI><A
471         href="query.jsp?&query=http://dbpedia.org/resource/Jyrki_Katainen"
472         title="Jyrki Katainen">Jyrki Katainen</A></LI>
473       <LI><A
474         href="query.jsp?&query=http://dbpedia.org/resource/Kim_Weckstr%C3%B6m"
475         title="Kim Weckström">Kim Weckström</A></LI>
476     </UL>
477   </TD>
478 </TR>
479 <TR style="background-color: #F0F0F0;">
480   <TD headers="s1"></TD>
481   <TD align="left" valign="top" headers="s1" id="p23">
482     <H3><A
483       href="query.jsp?&query=http://sig.ma/property/is_alternate_of"
484       title="is alternate of">is alternate of</A></H3>
485   </TD>
486   <TD align="left" valign="top" headers="s1 p23" style="max-width: 60%;">
487     <UL>
488
489       <LI><A
490         href="query.jsp?&query=http://semanticweb.org/wiki/Tampere_University_of_Tech
491         nology"
492         title="Tampere University of Technology">Tampere University of
493         Technology</A></LI>
494     </UL>
495   </TD>
496 </TR>
497 <TR style="background-color: #FFFFFF;">
498   <TD headers="s1"></TD>
499   <TD align="left" valign="top" headers="s1" id="p24">
500     <H3><A
501       href="query.jsp?&query=http://sig.ma/property/is_defines_of"
502       title="is defines of">is defines of</A></H3>
503   </TD>
504   <TD align="left" valign="top" headers="s1 p24" style="max-width: 60%;">
505     <UL>
506
507       <LI><A
508         href="query.jsp?&query=http://semanticweb.org/wiki/Special:ExportRDF/Tampere_
509         University_of_Technology"
510         title="Tampere University of Technology">Tampere University of
511         Technology</A></LI>

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516     </UL>
517     </TD>
518 </TR>
519 <TR style="background-color: #F0F0F0;">
520     <TD headers="s1"></TD>
521     <TD align="left" valign="top" headers="s1" id="p25">
522     <H3><A
523         href="query.jsp?&query=http://sig.ma/property/is_education_of"
524         title="is_education_of">is_education_of</A></H3>
525     </TD>
526     <TD align="left" valign="top" headers="s1 p25" style="max-width: 60%;">
527     <UL>
528
529         <LI><A
530
531 href="query.jsp?&query=http://dbpedia.org/resource/Fabien_Ch%C3%A9reau"
532         title="Fabien Chéreau">Fabien Chéreau</A></LI>
533     </UL>
534     </TD>
535 </TR>
536 <TR style="background-color: #FFFFFF;">
537     <TD headers="s1"></TD>
538     <TD align="left" valign="top" headers="s1" id="p26">
539     <H3><A
540         href="query.jsp?&query=http://sig.ma/property/is_primary_topic_of"
541         title="is_primary_topic_of">is_primary_topic_of</A></H3>
542     </TD>
543     <TD align="left" valign="top" headers="s1 p26" style="max-width: 60%;">
544     <UL>
545
546         <LI><A
547
548 href="query.jsp?&query=http://en.wikipedia.org/wiki/Tampere_University_of_Tec
549 hnology"
550         title="Tampere University of Technology">Tampere University of
551         Technology</A></LI>
552     </LI><A
553
554 href="query.jsp?&query=http://en.wikipedia.org/wiki/University_of_Tampere"
555         title="University of Tampere">University of Tampere</A></LI>
556     </LI><A
557
558 href="query.jsp?&query=http://www.tut.fi/public/index.cfm?siteid=32"
559         title="index.cfm?siteid=32">index.cfm?siteid=32</A></LI>
560     <LI><A href="query.jsp?&query=http://www.uta.fi/"
561         title="http://www.uta.fi/">http://www.uta.fi/</A></LI>
562     </UL>
563     </TD>
564 </TR>
565 <TR style="background-color: #F0F0F0;">
566     <TD headers="s1"></TD>
567     <TD align="left" valign="top" headers="s1" id="p27">
568     <H3><A href="query.jsp?&query=http://sig.ma/property/label"
569         title="label">label</A></H3>
570     </TD>
571     <TD align="left" valign="top" headers="s1 p27" style="max-width: 60%;">
572     <UL>
573
574         <LI>TaY</LI>
575         <LI>Tampere University of Technology</LI>
576         <LI>Tampere University of Technology - Company Profile |
577         LinkedIn</LI>
578         <LI>Tampereen teknillinen yliopisto</LI>
579         <LI>Tampereen yliopisto</LI>
580         <LI>Universitatis Tamperensis</LI>
581     </UL>
582     </TD>
583 </TR>
584 <TR style="background-color: #FFFFFF;">
585     <TD headers="s1"></TD>
586     <TD align="left" valign="top" headers="s1" id="p28">
587     <H3><A href="query.jsp?&query=http://sig.ma/property/lat"
588         title="lat">lat</A></H3>
589     </TD>

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590 <TD align="left" valign="top" headers="s1 p28" style="max-width: 60%;">
591 <UL>
592
593 <LI>61.44940948486328</LI>
594 <LI>61.449411111111111</LI>
595 <LI>61.494166666666666</LI>
596 </UL>
597 </TD>
598 </TR>
599 <TR style="background-color: #F0F0F0;">
600 <TD headers="s1"></TD>
601 <TD align="left" valign="top" headers="s1" id="p29">
602 <H3><A
603 href="query.jsp?&query=http://sig.ma/property/latin name"
604 title="latin name">latin name</A></H3>
605 </TD>
606 <TD align="left" valign="top" headers="s1 p29" style="max-width: 60%;">
607 <UL>
608
609 <LI>Universitatis Tamperensis</LI>
610 </UL>
611 </TD>
612 </TR>
613 <TR style="background-color: #FFFFFF;">
614 <TD headers="s1"></TD>
615 <TD align="left" valign="top" headers="s1" id="p30">
616 <H3><A
617 href="query.jsp?&query=http://sig.ma/property/located_in"
618 title="located in">located in</A></H3>
619 </TD>
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621 <UL>
622
623 <LI><A
624 href="query.jsp?&query=http://semanticweb.org/id/Hervanta"
625 title="Hervanta">Hervanta</A></LI>
626 <LI><A
627 href="query.jsp?&query=http://semanticweb.org/id/Tampere"
628 title="Tampere">Tampere</A></LI>
629 </UL>
630 </TD>
631 </TR>
632 <TR style="background-color: #F0F0F0;">
633 <TD headers="s1"></TD>
634 <TD align="left" valign="top" headers="s1" id="p31">
635 <H3><A
636 href="query.jsp?&query=http://sig.ma/property/location_city"
637 title="location city">location city</A></H3>
638 </TD>
639 <TD align="left" valign="top" headers="s1 p31" style="max-width: 60%;">
640 <UL>
641
642 <LI><A
643 href="query.jsp?&query=http://semanticweb.org/id/Tampere"
644 title="Tampere">Tampere</A></LI>
645 </UL>
646 </TD>
647 </TR>
648 <TR style="background-color: #FFFFFF;">
649 <TD headers="s1"></TD>
650 <TD align="left" valign="top" headers="s1" id="p32">
651 <H3><A
652 href="query.jsp?&query=http://sig.ma/property/location_country"
653 title="location country">location country</A></H3>
654 </TD>
655 <TD align="left" valign="top" headers="s1 p32" style="max-width: 60%;">
656 <UL>
657
658 <LI><A
659 href="query.jsp?&query=http://semanticweb.org/id/Finland"
660 title="Finland">Finland</A></LI>
661 </UL>
662 </TD>
663 </TR>

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664 <TR style="background-color: #F0F0F0;">
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666 <TD align="left" valign="top" headers="s1" id="p33">
667 <H3><A href="query.jsp?&query=http://sig.ma/property/long"
668 title="long">long</A></H3>
669 </TD>
670 <TD align="left" valign="top" headers="s1 p33" style="max-width: 60%;">
671 <UL>
672
673 <LI>23.77805555555555</LI>
674 <LI>23.859975</LI>
675 <LI>23.85997581481934</LI>
676 </UL>
677 </TD>
678 </TR>
679 <TR style="background-color: #FFFFFF;">
680 <TD headers="s1"></TD>
681 <TD align="left" valign="top" headers="s1" id="p34">
682 <H3><A
683 href="query.jsp?&query=http://sig.ma/property/native name"
684 title="native name">native name</A></H3>
685 </TD>
686 <TD align="left" valign="top" headers="s1 p34" style="max-width: 60%;">
687 <UL>
688
689 <LI>Tampereen teknillinen yliopisto</LI>
690 <LI>Tampereen yliopisto</LI>
691 </UL>
692 </TD>
693 </TR>
694 <TR style="background-color: #F0F0F0;">
695 <TD headers="s1"></TD>
696 <TD align="left" valign="top" headers="s1" id="p35">
697 <H3><A
698 href="query.jsp?&query=http://sig.ma/property/number_of_doctoral_students"
699 title="number of doctoral students">number of doctoral students</A></H3>
700 </TD>
701 <TD align="left" valign="top" headers="s1 p35" style="max-width: 60%;">
702 <UL>
703
704 <LI>1745</LI>
705 </UL>
706 </TD>
707 </TR>
708 <TR style="background-color: #FFFFFF;">
709 <TD headers="s1"></TD>
710 <TD align="left" valign="top" headers="s1" id="p36">
711 <H3><A
712 href="query.jsp?&query=http://sig.ma/property/number_of_students"
713 title="number of students">number of students</A></H3>
714 </TD>
715 <TD align="left" valign="top" headers="s1 p36" style="max-width: 60%;">
716 <UL>
717
718 <LI>12181</LI>
719 <LI>15628</LI>
720 </UL>
721 </TD>
722 </TR>
723 <TR style="background-color: #F0F0F0;">
724 <TD headers="s1"></TD>
725 <TD align="left" valign="top" headers="s1" id="p37">
726 <H3><A
727 href="query.jsp?&query=http://sig.ma/property/number_of_undergraduate_students"
728 title="number of undergraduate students">number of undergraduate
729 students</A></H3>
730 </TD>
731 <TD align="left" valign="top" headers="s1 p37" style="max-width: 60%;">
732 <UL>
733
734 <LI>10436</LI>
735 </UL>
736
737 <LI>10436</LI>

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738         <LI>2007</LI>
739         <LI>8631</LI>
740     </UL>
741 </TD>
742 </TR>
743 <TR style="background-color: #FFFFFF;">
744     <TD headers="s1"></TD>
745     <TD align="left" valign="top" headers="s1" id="p38">
746     <H3><A
747         href="query.jsp?&query=http://sig.ma/property/photo_collection"
748         title="photo collection">photo collection</A></H3>
749     </TD>
750     <TD align="left" valign="top" headers="s1 p38" style="max-width: 60%;">
751     <UL>
752
753         <LI><A
754             href="query.jsp?&query=http://www4.wiwiss.fu-
755 berlin.de/flickrwrappr/photos/Tampere_University_of_Technology"
756             title="Tampere University of Technology">Tampere University of
757             Technology</A></LI>
758         <LI><A
759             href="query.jsp?&query=http://www4.wiwiss.fu-
760 berlin.de/flickrwrappr/photos/University_of_Tampere"
761             title="University of Tampere">University of Tampere</A></LI>
762     </UL>
763 </TD>
764 </TR>
765 <TR style="background-color: #F0F0F0;">
766     <TD headers="s1"></TD>
767     <TD align="left" valign="top" headers="s1" id="p39">
768     <H3><A href="query.jsp?&query=http://sig.ma/property/picture"
769         title="picture">picture</A></H3>
770     </TD>
771     <TD align="left" valign="top" headers="s1 p39" style="max-width: 60%;">
772     <UL>
773
774         <LI><A
775             href="http://upload.wikimedia.org/wikipedia/commons/2/2d/Tty_logo_suomi.gif"
776             title="External link:
777             http://upload.wikimedia.org/wikipedia/commons/2/2d/Tty_logo_suomi.gif">http://upl
778 oad.wikimedia.org/wikipedia/commons/2/2d/Tty logo suomi.gif</A></LI>
779     </UL>
780 </TD>
781 </TR>
782 <TR style="background-color: #FFFFFF;">
783     <TD headers="s1"></TD>
784     <TD align="left" valign="top" headers="s1" id="p40">
785     <H3><A href="query.jsp?&query=http://sig.ma/property/point"
786         title="point">point</A></H3>
787     </TD>
788     <TD align="left" valign="top" headers="s1 p40" style="max-width: 60%;">
789     <UL>
790
791         <LI>61.44941111111111 23.859975</LI>
792         <LI>61.494166666666665 23.778055555555554</LI>
793     </UL>
794 </TD>
795 </TR>
796 <TR style="background-color: #F0F0F0;">
797     <TD headers="s1"></TD>
798     <TD align="left" valign="top" headers="s1" id="p41">
799     <H3><A href="query.jsp?&query=http://sig.ma/property/rector"
800         title="rector">rector</A></H3>
801     </TD>
802     <TD align="left" valign="top" headers="s1 p41" style="max-width: 60%;">
803     <UL>
804
805         <LI><A
806             href="query.jsp?&query=http://dbpedia.org/resource/Markku_Kivikoski"
807             title="Markku Kivikoski">Markku Kivikoski</A></LI>
808         <LI>Kaija Holli</LI>
809     </UL>
810 </TD>
811 </TR>

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812     </TD>
813 </TR>
814 <TR style="background-color: #FFFFFF;">
815   <TD headers="s1"></TD>
816   <TD align="left" valign="top" headers="s1" id="p42">
817     <H3><A
818       href="query.jsp?&query=http://sig.ma/property/reference"
819       title="reference">reference</A></H3>
820   </TD>
821   <TD align="left" valign="top" headers="s1 p42" style="max-width: 60%;">
822     <UL>
823
824       <LI><A href="http://www.tut.fi/public/index.cfm?siteid=32"
825         title="External link:
826 http://www.tut.fi/public/index.cfm?siteid=32">http://www.tut.fi/public/index.cfm?
827 siteid=32</A></LI>
828       <LI><A href="http://www.uta.fi/english/"
829         title="External link:
830 http://www.uta.fi/english/">http://www.uta.fi/english/</A></LI>
831       <LI><A href="http://www.uta.fi/studies/sports/index.html"
832         title="External link:
833 http://www.uta.fi/studies/sports/index.html">http://www.uta.fi/studies/sports/ind
834 ex.html</A></LI>
835     </UL>
836   </TD>
837 </TR>
838 <TR style="background-color: #F0F0F0;">
839   <TD headers="s1"></TD>
840   <TD align="left" valign="top" headers="s1" id="p43">
841     <H3><A href="query.jsp?&query=http://sig.ma/property/staff"
842       title="staff">staff</A></H3>
843   </TD>
844   <TD align="left" valign="top" headers="s1 p43" style="max-width: 60%;">
845     <UL>
846
847       <LI>1081</LI>
848       <LI>1564</LI>
849     </UL>
850   </TD>
851 </TR>
852 <TR style="background-color: #FFFFFF;">
853   <TD headers="s1"></TD>
854   <TD align="left" valign="top" headers="s1" id="p44">
855     <H3><A
856       href="query.jsp?&query=http://sig.ma/property/students"
857       title="students">students</A></H3>
858   </TD>
859   <TD align="left" valign="top" headers="s1 p44" style="max-width: 60%;">
860     <UL>
861
862       <LI>12181</LI>
863       <LI>15628</LI>
864     </UL>
865   </TD>
866 </TR>
867 <TR style="background-color: #F0F0F0;">
868   <TD headers="s1"></TD>
869   <TD align="left" valign="top" headers="s1" id="p45">
870     <H3><A href="query.jsp?&query=http://sig.ma/property/subject"
871       title="subject">subject</A></H3>
872   </TD>
873   <TD align="left" valign="top" headers="s1 p45" style="max-width: 60%;">
874     <UL>
875
876       <LI><A
877 href="query.jsp?&query=http://dbpedia.org/resource/Category:Educational_insti
878 tutions_established_in_1925"
879       title="Category:Educational institutions established in
880 1925">Category:Educational
881 institutions established in 1925</A></LI>
882     <LI><A
883 href="query.jsp?&query=http://dbpedia.org/resource/Category:Educational_insti
884
885

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886 tutions_established_in_1972"
887     title="Category:Educational institutions established in
888 1972">Category:Educational
889     institutions established in 1972</A></LI>
890     <LI><A
891
892 href="query.jsp?&query=http://dbpedia.org/resource/Category:Tampere"
893     title="Category:Tampere">Category:Tampere</A></LI>
894     <LI><A
895
896 href="query.jsp?&query=http://dbpedia.org/resource/Category:Technical_univers
897 ities_and_colleges"
898     title="Category:Technical universities and
899 colleges">Category:Technical
900     universities and colleges</A></LI>
901     <LI><A
902
903 href="query.jsp?&query=http://dbpedia.org/resource/Category:Universities_in_F
904 inland"
905     title="Category:Universities in Finland">Category:Universities
906     in Finland</A></LI>
907     </UL>
908     </TD>
909 </TR>
910 <TR style="background-color: #FFFFFF;">
911 <TD headers="s1"></TD>
912 <TD align="left" valign="top" headers="s1" id="p46">
913 <H3><A
914     href="query.jsp?&query=http://sig.ma/property/thumbnail"
915     title="thumbnail">thumbnail</A></H3>
916 </TD>
917 <TD align="left" valign="top" headers="s1 p46" style="max-width: 60%;">
918 <UL>
919
920     <LI><A
921
922 href="http://upload.wikimedia.org/wikipedia/commons/thumb/2/2d/Tty_logo_suomi.gif
923 /200px-Tty_logo_suomi.gif"
924     title="External link:
925 http://upload.wikimedia.org/wikipedia/commons/thumb/2/2d/Tty_logo_suomi.gif/200px
926 -
927 Tty_logo_suomi.gif">http://upload.wikimedia.org/wikipedia/commons/thumb/2/2d/Tty_
928 logo_suomi.gif/200px-Tty_logo_suomi.gif</A></LI>
929 </UL>
930 </TD>
931 </TR>
932 <TR style="background-color: #F0F0F0;">
933 <TD headers="s1"></TD>
934 <TD align="left" valign="top" headers="s1" id="p47">
935 <H3><A href="query.jsp?&query=http://sig.ma/property/type"
936     title="type">type</A></H3>
937 </TD>
938 <TD align="left" valign="top" headers="s1 p47" style="max-width: 60%;">
939 <UL>
940
941     <LI><A
942
943 href="query.jsp?&query=http://dbpedia.org/class/yago/TechnicalUniversitiesAnd
944 Colleges"
945
946 title="TechnicalUniversitiesAndColleges">TechnicalUniversitiesAndColleges</A></LI
947 >
948     <LI><A
949
950 href="query.jsp?&query=http://dbpedia.org/class/yago/UniversitiesInFinland"
951     title="UniversitiesInFinland">UniversitiesInFinland</A></LI>
952     <LI><A
953
954 href="query.jsp?&query=http://dbpedia.org/class/yago/University108286163"
955     title="University108286163">University108286163</A></LI>
956     <LI><A
957
958 href="query.jsp?&query=http://dbpedia.org/ontology/EducationalInstitution"
959     title="EducationalInstitution">EducationalInstitution</A></LI>

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960     <LI><A
961         href="query.jsp?&query=http://dbpedia.org/ontology/Organisation"
962         title="Organisation">Organisation</A></LI>
963     <LI><A
964         href="query.jsp?&query=http://dbpedia.org/ontology/University"
965         title="University">University</A></LI>
966     <LI><A
967
968 href="query.jsp?&query=http://dbpedia.org/resource/Public_university"
969         title="Public_university">Public_university</A></LI>
970     <LI><A
971         href="query.jsp?&query=http://semantic-
972 mediawiki.org/swivt/1.0%23Subject"
973         title="Subject">Subject</A></LI>
974     <LI><A
975         href="query.jsp?&query=http://semanticweb.org/id/Category-
976 3AUniversity"
977         title="Category-3AUniversity">Category-3AUniversity</A></LI>
978     <LI><A
979
980 href="query.jsp?&query=http://www.mpii.de/yago/resource/wikicategory_Universi
981 ties_in_Finland"
982         title="wikicategory Universities in Finland">wikicategory
983         Universities in Finland</A></LI>
984     <LI><A
985
986 href="query.jsp?&query=http://www.mpii.de/yago/resource/wordnet_body_10796508
987 5"
988         title="wordnet body 107965085">wordnet body 107965085</A></LI>
989     <LI><A
990
991 href="query.jsp?&query=http://www.mpii.de/yago/resource/wordnet_university_10
992 8286163"
993         title="wordnet university 108286163">wordnet university
994         108286163</A></LI>
995     <LI><A
996         href="query.jsp?&query=http://www.opengis.net/gml/ Feature"
997         title=" Feature"> Feature</A></LI>
998     <LI><A
999         href="query.jsp?&query=http://www.w3.org/2002/07/owl%23Thing"
1000         title="Thing">Thing</A></LI>
1001     <LI><A
1002
1003 href="query.jsp?&query=http://www.w3.org/2003/01/geo/wgs84_pos%23SpatialThing
1004 "
1005         title="SpatialThing">SpatialThing</A></LI>
1006     <LI><A
1007         href="query.jsp?&query=http://www.w3.org/2006/vcard/ns%23VCard"
1008         title="VCard">VCard</A></LI>
1009     <LI>Public</LI>
1010 </UL>
1011 </TD>
1012 </TR>
1013 <TR style="background-color: #FFFFFF;">
1014     <TD headers="s1"></TD>
1015     <TD align="left" valign="top" headers="s1" id="p48">
1016     <H3><A
1017         href="query.jsp?&query=http://sig.ma/property/undergrad"
1018         title="undergrad">undergrad</A></H3>
1019     </TD>
1020     <TD align="left" valign="top" headers="s1 p48" style="max-width: 60%;">
1021     <UL>
1022
1023         <LI>10436</LI>
1024         <LI>8,631 of whom in attendance</LI>
1025     </UL>
1026     </TD>
1027 </TR>
1028 <TR style="background-color: #F0F0F0;">
1029     <TD headers="s1"></TD>
1030     <TD align="left" valign="top" headers="s1" id="p49">
1031     <H3><A
1032         href="query.jsp?&query=http://sig.ma/property/web_page"
1033         title="web_page">web_page</A></H3>

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```

1034     </TD>
1035     <TD align="left" valign="top" headers="s1 p49" style="max-width: 60%;">
1036     <UL>
1037
1038         <LI><A
1039             href="http://en.wikipedia.org/wiki/Tampere_University_of_Technology"
1040             title="External link:
1041 http://en.wikipedia.org/wiki/Tampere_University_of_Technology">http://en.wikipedi
1042 a.org/wiki/Tampere_University_of_Technology</A></LI>
1043         <LI><A href="http://en.wikipedia.org/wiki/University_of_Tampere"
1044             title="External link:
1045 http://en.wikipedia.org/wiki/University_of_Tampere">http://en.wikipedia.org/wiki/
1046 University_of_Tampere</A></LI>
1047         <LI><A
1048             href="http://istudy.iagora.com/University_of_Tampere/review/"
1049             title="External link:
1050 http://istudy.iagora.com/University_of_Tampere/review/">http://istudy.iagora.com/
1051 University_of_Tampere/review/</A></LI>
1052         <LI><A
1053             href="http://semanticweb.org/wiki/Tampere_University_of_Technology"
1054             title="External link:
1055 http://semanticweb.org/wiki/Tampere_University_of_Technology">http://semanticweb.
1056 org/wiki/Tampere_University_of_Technology</A></LI>
1057         <LI><A href="http://www.tut.fi/public/index.cfm?siteid=32"
1058             title="External link:
1059 http://www.tut.fi/public/index.cfm?siteid=32">http://www.tut.fi/public/index.cfm?
1060 siteid=32</A></LI>
1061         <LI><A href="http://www.uta.fi"
1062             title="External link: http://www.uta.fi">http://www.uta.fi</A></LI>
1063         <LI><A href="http://www.uta.fi/"
1064             title="External link: http://www.uta.fi/">http://www.uta.fi/</A></LI>
1065         <LI>http://www.tut.fi/public/index.cfm?siteid=32</LI>
1066         <LI>http://www.uta.fi</LI>
1067     </UL>
1068 </TD>
1069 </TR>
1070 <TR style="background-color: #FFFFFF;">
1071 <TD headers="s1"></TD>
1072 <TD align="left" valign="top" headers="s1" id="p50">
1073 <H3><A
1074     href="query.jsp?&query=http://sig.ma/property/wordnet_type"
1075     title="wordnet type">wordnet type</A></H3>
1076 </TD>
1077 <TD align="left" valign="top" headers="s1 p50" style="max-width: 60%;">
1078 <UL>
1079
1080     <LI><A
1081 href="query.jsp?&query=http://www.w3.org/2006/03/wn/wn20/instances/synset-
1082 university-noun-2"
1083 title="synset-university-noun-2">synset-university-noun-2</A></LI>
1084     </UL>
1085 </TD>
1086 </TR>
1087 </TABLE>
1088 <P>118 results</P>
1089
1090 <UL>
1091
1092     <LI><A
1093 href="query.jsp?&query=University_of_Tampere&page=2">More
1094 sources</A></LI>
1095
1096     <LI><A href="#top">Jump to top of page</A></LI>
1097 </UL>
1098
1099
1100
1101 </BODY>
1102 </HTML>

```

Appendix B: Source code used in automated accessibility evaluation (see Chapter 5).