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Using a Semantic Wiki for Technology Forecast and Technology Monitoring

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Using a Semantic Wiki for Technology Forecast and Technology Monitoring

Purpose: This paper aims to present extensions of Semantic MediaWiki for the purpose of technology forecast and technology monitoring. The user friendliness and applicability of the components is evaluated by task-based user studies.
Design/methodology/approach: Based on the requirements given by potential end users (technology experts), visualization possibilities were designed and implemented. Potential users used the new features of technology forecast and monitoring within a semantic wiki and were controlled regarding the effectiveness.
Findings: Although semantic wikis are ideal tools for knowledge management in industry settings, especially due to their user-friendly way of storing and retrieving knowledge, they have rarely been used for technology forecast and monitoring purposes so far. We show that the additional requirements for such purposes can be met and provide established technology analysis possibilities within Semantic MediaWiki. In that way, a new application area of Semantic MediaWiki is introduced.
Originality/value: Tools and techniques for Semantic MediaWiki are presented, opening the application area of Semantic MediaWiki for technology and innovation management. Our research provides evidence that the open-source implemented visualization and storage techniques can be applied in real-world settings, where so far mainly costly dedicated software has had to be used.
Keywords: Semantic Wikis, Semantic MediaWiki, Technology Forecast, Technology Monitoring, Technology and Innovation Management

1 Introduction: Problem Statement and Proposed Solution

Technology managers of technology companies of almost any size face the challenge of being continuously well informed about the technologies used in the company and about technologies that are relevant beyond that. Besides the monitoring of known technologies, it is also crucial to forecast technologies in order to remain in business in the long run. Technology forecast and technology monitoring are key areas of technology and innovation management in general.
Technology forecast and technology monitoring require huge and extensive processes within a company. We can distinguish between the following main steps for performing these tasks (cf. (Warschat, et al., 2015)):

1. **Defining a search strategy.**
   The user specifies what and how he/she wants to search for.
2. **Retrieving information.**
   Based on search requests the user retrieves information (often unstructured documents or expert statements) according to his/her information needs.
3. **Extracting relevant information.**
   The user gains relevant information according to his/her information needs (specified as search strategy in Step 1). This is often done with the help of text mining tools.
4. **Storing relevant information and preparing the results.**
   The user stores all relevant knowledge and creates tables and/or figures for assessing the technologies.

Step 2, 3, and 4 can be performed repeatedly for an actual technology monitoring over time. The whole technology and innovation management process is primarily performed by technology experts. Technology experts are the people who are responsible for the technology monitoring and forecast within a company. They are sometimes also called technology field mentor, technology coordinator, or technology forecast committee. In this article, we assume that technology experts are not very familiar with the technical details of the used information system technologies, especially not with semantic queries within a semantic wiki. The setup and maintenance of the information systems is therefore left for appropriate experts.

In this article, we focus on the last step, namely the suitable information aggregation and visualization for the sake of technology monitoring and forecast. This step requires a knowledge management tool that fits needs such as the ability to create and aggregate content in an easy way to visualize the states of the observed objects such as technologies, products, and patents. In addition, the knowledge management tool should have low costs for installation and maintenance.

Semantic MediaWiki is a free, open-source semantic wiki that stores information in a semantically structured way. Hence, the stored data can be queried and displayed also in a semantic-structured fashion. For instance, all technologies that have been assessed by technology experts as highly relevant for a company can be retrieved very easily and dynamically. However, the functionality of Semantic MediaWiki and its available extensions cannot be used for technology monitoring and forecast yet. The main limitation is the lack of visualization possibilities, such as embedding technology radars and technology portfolios in wikis where technologies are described. Employees conducting technology monitoring and forecast therefore have to use other software tools than Semantic MediaWiki which either often require licensing fees to be paid or which do not exploit the benefits of storing data in a semantically-structured way such as consistent data storage and the dynamic creation of visualizations.

In this paper, we present a configuration of Semantic MediaWiki where the necessary extensions for performing the above mentioned Step 4 within the process of technology monitoring and forecast are included. We do not address the other steps and assume that the proposed Semantic MediaWiki gains the stored information via the inputs of the users and/or via interfaces to other information systems.

2 Approaches to Technology Forecast and Monitoring

Storing information about technologies that are used in the company and that are strategically relevant for the company is usually not done by technology experts only for inventory reasons. Instead, the declared aim is to forecast which technologies will be important for the company in the future and in which technologies the company should not invest anymore.

Miscellaneous methods of technology forecast may be applied (see (Gerpott, 2005, p. 108) for an overview and (Lichtenthaler, 2008, p. 73) for a survey on this topic).

The technology radar and the technology portfolio are two widely used methods for technology monitoring and forecast in industry. In the following, we present these two methods in more depth, since they are an integral part of the semantic technology wiki implementation presented later on.

2.1 Technology Radar

The technology radar is used to monitor and assess technologies. Its purpose is to detect technologies that fulfill a certain requirement profile. This profile can be adjusted for current or future products, services, or processes (Schimpf & Lang-Koetz, 2010, p. 15).

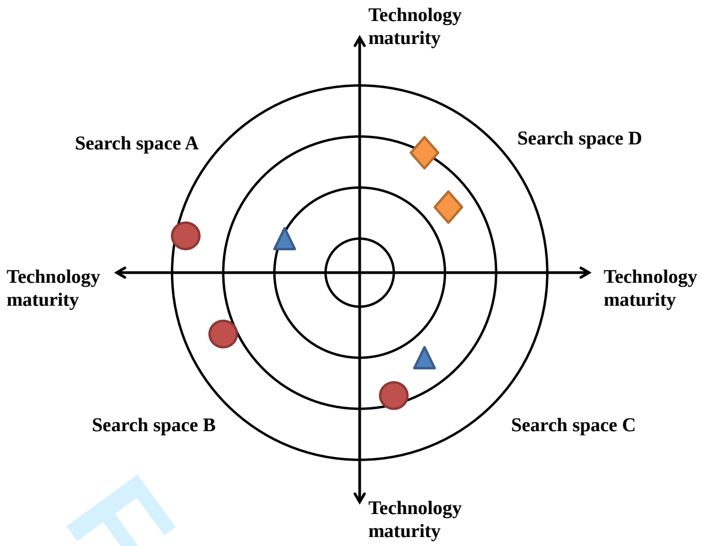

Figure 1: Constitutive elements of a technology radar (Wellensiek, et al. 2011, 119).

The radar is divided in different sections (also called search spaces), as can be seen in Figure 1. The sections are typically the different fields of technologies (technology classes), which are stored as attributes of the technologies. One could also regard trends or functions of products as sections. Generally *technology maturity* is the dimension (metric) used in the technology radar, as depicted in Figure 1. The maturity can be stored in the corresponding technology profile as, for instance, a numeric value between 1 (Status: basic research) and 5 (Status: presence in the market). The closer a technology is located to the center of the technology radar, the readier the technology is for an application and the shorter is the time interval for a real-world application. If a technology is oriented toward products, then it is very ready for application. On the other side, technologies that are mentioned in vision statements are far from being ready for their applications; however, they are listed to keep an eye on them.
The technologies depicted in the figure have different shapes and colors depending on the company-specific relevance assessment of these technologies. Often, the technologies are classified into *low relevancy*, *medium relevancy*, *high relevancy*, and *no declaration*. The information about the relevancy can be taken from the technology profile, analogously to the degree of maturity. The depicted degree of relevance in this kind of visualization contributes primarily to an overview of the technological orientation of the company.

Technology radars are appropriate for a continuous assessment of technologies, either of technologies used in the company or technologies not used yet. Owing to the simplistic design of technology radars, technology experts can directly deliver input for creating or modifying such radars without any problem.

2.2 Technology Portfolio according to Pfeiffer et al.

If one wants to qualitatively evaluate technology alternatives, technology portfolios are preferred, owing particularly to their simple design (Haag, et al., 2011, p. 319). One of the best-known portfolio types is the technology portfolio according to Pfeiffer et al. (Pfeiffer, et al., 1982). Here, the matrix depicts relevant technologies that are necessary for a final product and the corresponding production processes. The matrix has the dimensions *technology attractiveness* and *resource strength*.
Technology attractiveness is an external quantity and mostly not controllable. Technical and economic advantages that may be fruitful in the course of further developments of the technology area are considered here (Specht & Beckmann, 2002, p. 95). It embraces technological chances and risks.

Resource strength describes a company's internal and thereby uninfluencable parameters. Its core is the technical and economical control of the technology field by the company in relation to the most important competitors (Brockhoff, 1999, p. 222). Thus, resource strength focuses on the strengths and weaknesses of the company.

The values for the main components, technology attractiveness and resource strength, are determined from diverse single parameters (Spath & Renz, 2011, p. 223). Pfeiffer et al. prescribed specific subparameters from which the main components can be calculated (see (Pfeiffer, et al., 1987, p. 88) for more details).

Figure 2 contains an example of a technology portfolio. The circles represent technologies, and their positions in the diagram show the technology attractiveness and the resource strength.

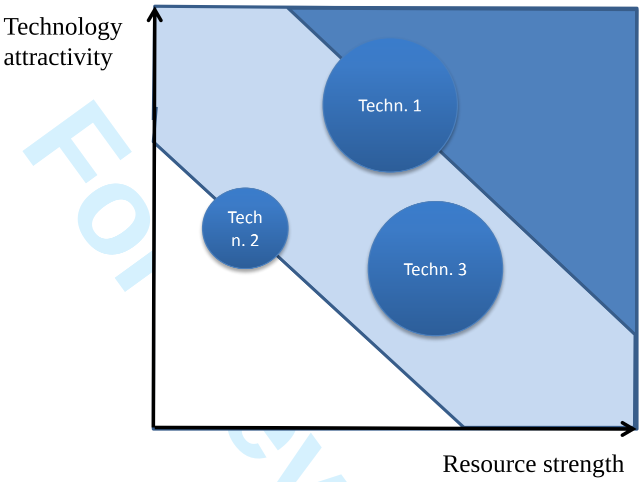

Figure 2: Technology portfolio after Pfeiffer et al.

Technology portfolios are quite popular because the integration of a company's internal and external factors is kept simple here. Technology portfolios serve as a basis for discussing the strategic direction of a company regarding the technologies that might be used (Bullinger & Warschat, 1994, p. 167), particularly in the context of competition.

Technology portfolios are difficult in the sense that every technology must be regarded on its own and no overall plan is developed. Owing to the final restriction to two dimensions (resource strength and technology attractiveness), the representation is quite reductionist, and an interpretation of the presented classification of technologies is to be handled with care.

3 Software Tools for Technology and Innovation Management Used So Far

For assessing or monitoring technologies, it is primarily necessary to collect data over a long period of time. Therefore, (traditional) database systems are often used.

The organization and process of Technology and Innovation Management requires the use a time- and locale-flexible system in which experts can also enter data in a user-friendly manner (Wellensiek, et al., 2011, p. 140). Isenmann (Isenmann, 2008, p. 240ff.) studied eight representative software tools, from prototypes to end use. The following key messages emerged from the report:

- For IT support of technology forecast and technology monitoring, a client-server architecture is typically used because it allows for collaboration, so information may be collected and updated by technology experts. A suitable environment for collaboration can be enabled via additional features such as an edit barrier in case of simultaneous utilization.

- There are many modules to create interfaces to other tools, i.e., to get information from other tools (inquiry/information extraction) or to send information to other tools (export/processing). There are often interfaces to Microsoft Office.
- In case of the considered IT tools, the different visualization options are often put in the foreground.
- Also, the possibility to cover the whole palette with one tool, from poster building for concept layout to scanning of products, is emphasized.
- For describing technologies, technology profiles are built.
- All considered systems use a central database as data storage system and provide export functionality for humans (e.g., PDF) and for machines (e.g., CSV).
- More and more tools are web based.
- The biggest challenges of Technology and Innovation Management are the variety and the unstructuredness of the available data. The task of information extraction, independent of information aggregation, is described as extremely time and work intensive. It is possible to capture the diversity of the material through the possibilities for structured storage that semantic wikis provide (Lang, 1998).

In the next chapter, we give a general introduction into Semantic MediaWiki. Section 5 then addresses the qualification and the use of Semantic MediaWiki in the scope of Technology and Innovation Management.

4 Semantic MediaWiki – A Tool for Collaborative Knowledge Management

Semantic MediaWiki is a semantic wiki based on the open-source software MediaWiki. MediaWiki is not only deployed for Wikipedia but used in countless public, private, and corporate environments. The MediaWiki software was designed not only to enable collaboration between different users but to actively support this collaboration with several functionalities, such as the *edit history*. Content in MediaWiki wikis is written following the wiki markup. This syntax is a simplified version of HTML and enables the user to set tags in order to format text. Due to this simplified syntax, even relatively unexperienced users can efficiently work in wiki environments.

Semantic MediaWiki is an extension of MediaWiki, among many other available extensions; hence, all functionalities of MediaWiki can be used within Semantic MediaWiki. Furthermore, Semantic MediaWiki contains additional functionalities that enable better compliance to the following information system criteria (Krötzsch, et al., 2007):

1. **Consistency**. Information is often stored in different places in the wiki, since all users have their own way of structuring things and their own model to archive information. Even though storing information in different places might be helpful, it might also lead to inconsistencies regarding the incorporated information. Information might get updated in just one place, or the amount of information might be different. MediaWiki provides no assistance functionality to keep information consistent across different places.
2. **Access to knowledge**. Finding information in the wiki may be very expensive and time consuming.
3. **Reuse of information**. Information in nonsemantic wikis is stored as plain strings and is not separable from other information on the wiki page. The retrieval of information in wikis can happen only by a browser or similar applications.

These items are congruent with the observation mentioned in Section 3 that for technology monitoring and forecast, data is typically provided in different ways and in an unstructured way which makes the technology and innovation management an extremely time and work intensive task. In the following, we consider how knowledge can be stored consistently and in a structured way within MediaWiki, so that the wiki is well suited for the task of technology monitoring and forecast:

MediaWiki provides the possibility to link from one wiki page to others so that users browsing a wiki page can browse to related pages. A simple example of wiki linkage is the following sentence in wiki syntax:

```
Germany has as its capital [[Berlin]].
```

Via this linkage a relation between the current wiki page (here “Germany”) and the linked wiki page (here “Berlin”) is established. However, the kind of the relation, i.e., the meaning of the relation is just expressed linguistically through the (part of the) sentence in which is the relation stands. There is no possibility for the machine to recognize the kind of the relation. Formally, we have the following untyped relation at hand:

At this point Semantic MediaWiki comes into play by introducing attributes (also called properties). Attributes allow the user to deposit the intended meaning of any relation between objects (here wiki pages) with the help of special wiki syntax constructs. In that way, not only the user but also the machine is able to process and interpret the information. For instance, the statement

```
Germany has as its capital [[hasCapital::Berlin]].
```

states that Berlin is the capital of Germany:

The annotation `[[hasCapital::Berlin]]` formally introduces a relation that carries an explicit designation. Together with the fact that every wiki page in a wiki has a unique identifier (namely, the title), it is enough to operate with the objects and relations on a semantic level. A logical-formal representation of the stored knowledge in a wiki (objects and their relations) is not necessary.

By introducing attributes, Semantic MediaWiki has the following benefits in comparison to a pure MediaWiki:

1. **Browsing:** All facts (attributes with their values) can be presented per wiki page in a unified way.
2. **Queries:** Relations expressed by attributes can be specifically requested. In the simplest case, results can be listed in tabular form. Retrieved data can also be further processed, for instance, for dynamical visualizations. So-called inline queries allow the embedding of attribute values directly in wiki pages without knowing the retrieved value. That way, the population of a city, for example, may be kept consistent on different pages because the actual value is stored just once, which resolves the problem of the consistency, as mentioned above.
3. **Recovery:** Relations expressed via annotations are machine understandable. This means that attribute values may be not only queried in a semantically structured way but also processed

and exported in a semantically structured way, even outside of the wiki, for example, as a Resource Description Framework (RDF) export.

Besides directly annotating running text (cf. `Germany has as capital [[hasCapital::Berlin]].`), templates also may be built. With the help of templates, several attributes can be set at once and also represented together on wiki pages. This makes sense when several instances of the same class, and therefore with (partly) the same attributes (but maybe different attribute values), should be stored. In the case of a wiki for Technology and Innovation Management, templates are typically created for technologies, products, and companies described in the wiki. A template is stored as regular wiki page (but containing special wiki markup) within the namespace "Template". An example is `Template:Technology`. Section 5.2.1 shows a prototypical technology template.

5 Semantic MediaWiki for Technology Forecast and Monitoring

5.1 Applicability of Semantic MediaWiki for Technology Forecast and Monitoring

Technology management and innovation management can be perceived as knowledge management: Knowledge is gathered and aggregated with quantitative and/or qualitative methods. Wikis are a widely used tool for collecting knowledge and may be used in the context of technology and innovation management. Wikis offer the following advantages:

1. Use rights can be assigned individually.
2. Collaboration is promoted.
3. The collected knowledge can be stored in a structured way.
4. The knowledge can be retrieved and edited easily.

As described above, non-semantic wikis such as MediaWiki struggle with challenges such as the consistency. In the context of technology management and innovation management, semantic wikis such as the Semantic MediaWiki have the following advantages compared to non-semantic wikis and many alternative tools for monitoring and forecasting technologies as described in Section 3:

- Instances of technologies, products, companies, etc. cannot only be tagged with categories representing the classes the instances belong to. Instead, a **template** may be created per class (or subclasses of a class) so that, for instance, every technology description has the same structure and the single values (raw texts, numeric data, links, etc.) can be stored as single **attributes** of a technology. For every instance of a class, certain attributes are allowed or set as default (e.g., technical aspects of a technology). This leads to consistent and well-structured data which is often not available for Technology and Innovation Management purposes (see Section 3). **Technology profiles** (see Section 5.2.1 for an implementation in Semantic MediaWiki) are virtually predestinated to be stored as templates and can be edited via **forms** in a user-friendly manner. Pictures can be added to templates without extensive effort. Texts and additional notes can be placed easily.

- The fairly **simple handling** of wikis still remains. There is no noteworthy training period necessary. Thus, technology experts and other employees do not need to worry about undergoing an intensive training first. Templates can be edited easily if classes such as technologies should have further attributes to choose from. Forms are aligned to the templates and allow for a user-friendly interaction.

- The **data types of attribute values** are determined initially by the user. This enables type-specific processing. Numeric data, for instance, can be combined arithmetically via given formulas (cf. the creation of the technology radar or technology portfolio), and date specifications enable the sorting or filtering of products.

- The attributes with their attribute values can be retrieved with **semantic queries** and further processed via, e.g., RDF export or CSV export. For example, it is possible to submit a single request to retrieve the common characteristics of all products that have been produced with technologies associated with a certain technology area.

- It is possible to dynamically generate **visualizations** based on the stored data. These visualizations can be embedded in wiki pages (see Section 5.2.2 and Section 5.2.3). They serve as a basis for discussions and for strategic decision making. As we have seen in Section 3, persons who are responsible for technology monitoring and forecast build their opinions and decisions primarily based on such visualizations.

- Through the collection of many descriptions of technologies, products, etc., the **landscape** and **portfolio** of a company can be made visible. Employees in higher levels can get a survey about used objects such as products and technologies.

- Due to the structured storage of information, the data stored in the wiki (e.g., about technologies, companies, persons, etc.) can be **reused for searching** for relevant content, thereby starting again at Step 1 in the general technology monitoring and forecast workflow. In this way, knowledge stored in the wiki and the associated visualizations grow systematically over time.

To the best of our knowledge, none of the freely available semantic wikis – such as Semantic MediaWiki, IkeWiki (Schaffert, 2006), Kaukolu (Kiesel, 2006), SWEET Wiki (Buffa, et al., 2008), and OntoWiki (Auer, et al., 2006) – have been explicitly used for Step 4 of the technology monitoring and forecast process (see the workflow outlined in Section 1) so far, especially not for the creation of technology portfolios and technology radars based on wiki content. We can state the following main reasons for that:

1. **Lack of appropriate visualization possibilities**: One reason for that might be that these wikis do not provide per default the functionalities which are needed in such contexts, such as the possibility to build dynamically visualizations for technology monitoring and forecast. Our semantic technology wiki – presented in detail in Section 5.2 –, in contrast, satisfies all those requirements. Table 1 contrasts in this context the observations made by Isenmann (Isenmann, 2008, p. 240ff.) regarding tools for technology and innovation management with the characteristics of our semantic technology wiki.
2. **Company-intern workflows**: At the moment, many companies use dedicated software for technology monitoring and forecast. If the company is small, often no specific software besides Microsoft Office is used. If dedicated software is used, it covers not only Step 4, the information storage and visualization, but also other steps of the process (Isenmann, 2008, p. 240ff.) and was especially designed for the technology and innovation management process in the company, which often differ technically and organizational from company to company. Also non-semantic wikis are therefore not very widely used.
3. **Security concerns**: Many companies either do not want to rely on open-source software at all due to security reasons or they want to have access control in their wikis and therefore do not deploy wikis such as MediaWiki or Semantic MediaWiki. Especially for Semantic MediaWiki, however, an up-to-date extension for fine-grained role-based access control

(down to the attributes of pages) was released lately.[1] Despite these issues, there are employees responsible for technology monitoring and forecast who deliberate about using Semantic MediaWiki for their tasks, as the evaluation in Section 5.2.4 will show.

Table 1. Observations made by Isenmann (Isenmann, 2008, p. 240ff.) vs. characteristics of the proposed semantic technology wiki.

Observation	Support by SMW
Often client-server architecture (for collaboration possibilities)	SMW is a client-server application and as wiki ideal for collaboration.
Often interfaces to other information systems and Microsoft Office	Own extensions can be built for using interfaces to other information systems; data can be exported to CSV, RDF, etc.
Visualization possibilities are important	The Technology Portfolio and the Technology Radar are the key components of the SMW.
Wide range of functionality	Focus on storing knowledge in a semantically-structured way.
Technology profiles are used	Technology profiles can be easily created by means of templates.
Data export functionality is provided (PDF, CSV)	Data can be exported as RDF, CSV and other formats (sometimes further extensions necessary).
Often Web-based	Web-based.
Variety and unstructuredness of available data as burden. High effort on Information extraction.	Information is stored semantically-structured and can be queried semantically.

5.2 Implemented Semantic MediaWiki Components for Technology Forecast and Monitoring

The main contributions of this paper are the Semantic MediaWiki extensions for visualizing technology radars and the technology portfolios. Both kinds of visualization were chosen because they are among the most common forms in the area of technology and innovation management.

The following **nonfunctional requirements** were given by professional end users (employees responsible for technology monitoring and forecast) regarding both mentioned Semantic MediaWiki extensions:

- Inserting visualizations on wiki pages and providing the data for these visualizations should be as easy as possible. Only in this way can employees with little wiki expertise also work with Semantic MediaWiki as a tool in the process of technology early detection and technology monitoring.
- For the technology portfolio, there should be the ability to declare the weighting and aggregation function for calculating the values of the two main dimensions of each diagram.
- The data values of the technologies should be both stored in and retrieved from the wiki in a semantically structured way.
- Both the technology portfolio and the technology radar should be clear and understandable so that an assessment of the technologies on the basis of the former and an investigation of the technologies and a technology forecast on the basis of the latter are possible.

In addition to these items were the following **functional requirements**:

[1] See https://www.mediawiki.org/wiki/Extension:Access_Control_List.

- The implementation of the extensions should be realized as *Result Printer* within the *Semantic Result Formats* (SRF) extension.
- The Semantic MediaWiki attributes should be used for the visualizations. Every technology should be described on its own wiki page.
- The specification of the parameter for the diagram legend and of height and width should be optional.

Given the situation of Step 4 within the technology monitoring and forecast process (see Introduction), we can state the following basic workflow steps w.r.t. the usage of the implemented semantic technology wiki:

1. **A new object is added as page to the wiki.**
   New objects can be technologies and all related things such as companies, persons, organizations, locations, patents, etc. For each object, an own wiki page is created and the corresponding template is used.
   This insertion is done by a technology expert or initially by a Semantic MediaWiki expert.

2. **Attribute values of objects are added or modified.**
   This assumes that the wiki page already exists; otherwise this step is done simultaneously with Step 1.
   This step is typically done by the technology expert – maybe in interaction with an information system providing the information.

3. **A *Technology Portfolio* visualization is created or modified.**
   A technology portfolio in general often incorporates a few selected technologies represented in the wiki.
   This step is typically done by a Semantic MediaWiki expert, but can also be done by the technology expert, since he/she only needs to copy the semantic query (as string within a wiki page), change the parameters such as "technology field" and store the query as wiki content on another page.

4. **A *Technology Radar* visualization is created.**
   A technology radar often incorporates all technologies stored in the wiki or a large fraction of them.
   Since technology radars do not need to be created so often, they can be initially set by the wiki expert.

In the remainder of this section, we show the components implemented for the mentioned process steps and finally show an evaluation on the core components, namely the Technology Radar and the Technology Portfolio.

5.2.1 Technology Profiles as Templates with Forms

A wiki for technology monitoring contains meta-information about relevant technologies. Therefore, it is appropriate to define a template that contains possible attributes of the technologies, such as *description*, *advantages*, *disadvantages*, and *degree of maturity*. The template itself contains template-specific wiki-markup and is stored as an ordinary wiki page within the namespace "Template". A template for technologies, hence, can be stored on the page `Template:Technology`. Once a template for technologies has been created, it can be used for any technology that should be stored in the wiki. A filled-in and shortened technology template – here for the technology "Alkaline fuel cell" – could look like the following:

```
{{Technology
|project_room=e-mobility
|technology_class=fuel cell
|description=Alkaline Fuel Cell (AFC) is a low-temperature fuel cell.
Normally a watery potassium hydroxide solution is used as electrolyte. The
cell’s name is based on the fact that the solutions are alkaline.
|operand=energy
|operation=transformation
|purposes=give energy
|market_ranges=industry
|scope=aerospace industry
|characteristics=This kind of cell operates at 60-120°C.
}}
```

Thanks to the MediaWiki extension *Semantic Forms*, the attribute values can be filled in in a user-friendly fashion with the help of form fields (cf. Figure 3) and do not need to be written as semantic annotations or template calls in wiki syntax. Experts without wiki knowledge can thus participate in the process of technology monitoring and technology assessment.

Figure 4 shows how knowledge stored with a technology template is represented internally in the shape of a graph.

Templates can be installed in Semantic MediaWiki without any further extensions. For the use of forms, the open-source extension *Semantic Forms* is necessary, but no further implementations.

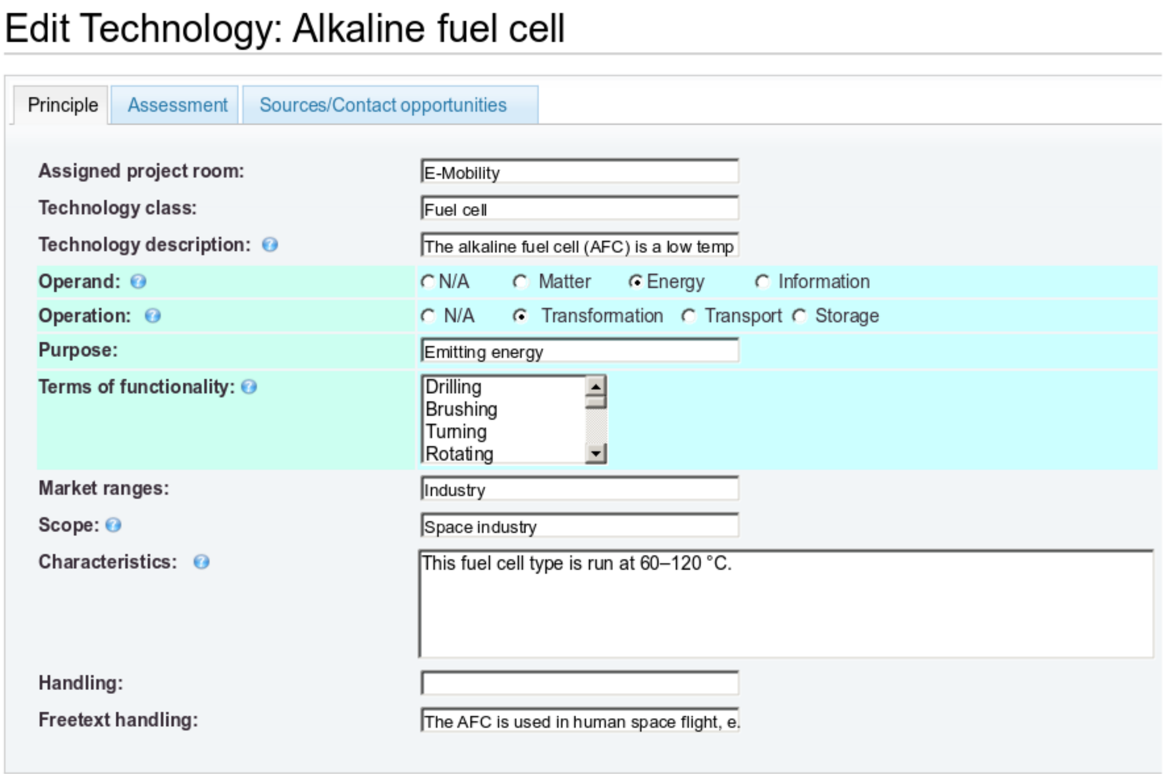

Figure 3: Example of a form in Semantic MediaWiki for enteringinformation about a technology (here, “Alkaline fuel cell”).

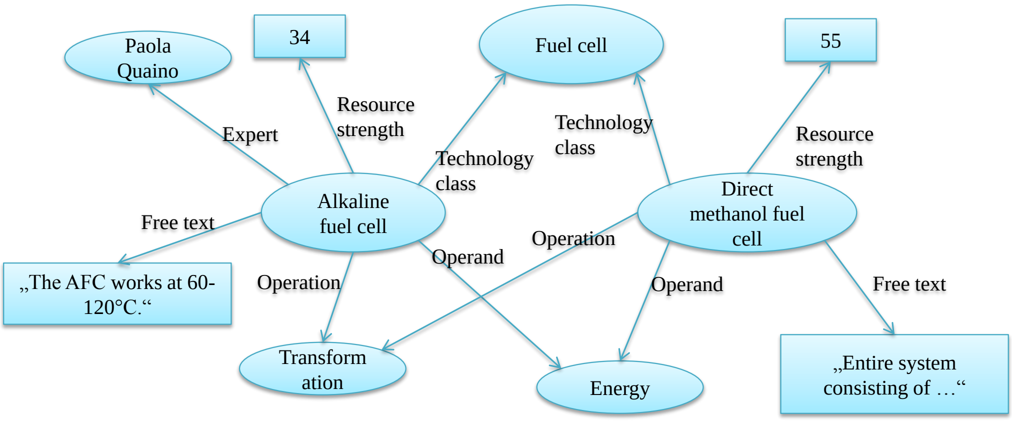

Figure 4: Formal representation of knowledge in Semantic MediaWiki.

5.2.2 Technology Radar in Semantic MediaWiki

As detailed in Section 2.1, the technology radar is used by a company to assess the relevance of technologies. The developed extension[1] can be applied if technologies are stored as wiki pages and the data necessary for the visualization is available as technology attributes. The developed extension queries the attributes of the wiki pages which were assigned to the category *radar*. This category is set on all technology wiki pages if the corresponding check box is set in the technology edit form. In this way only selected technologies are visualized in the technology radar – for instance, all technologies of certain technology areas.

Figure 5 shows a screenshot with the developed Semantic MediaWiki extension *Technology Radar*.

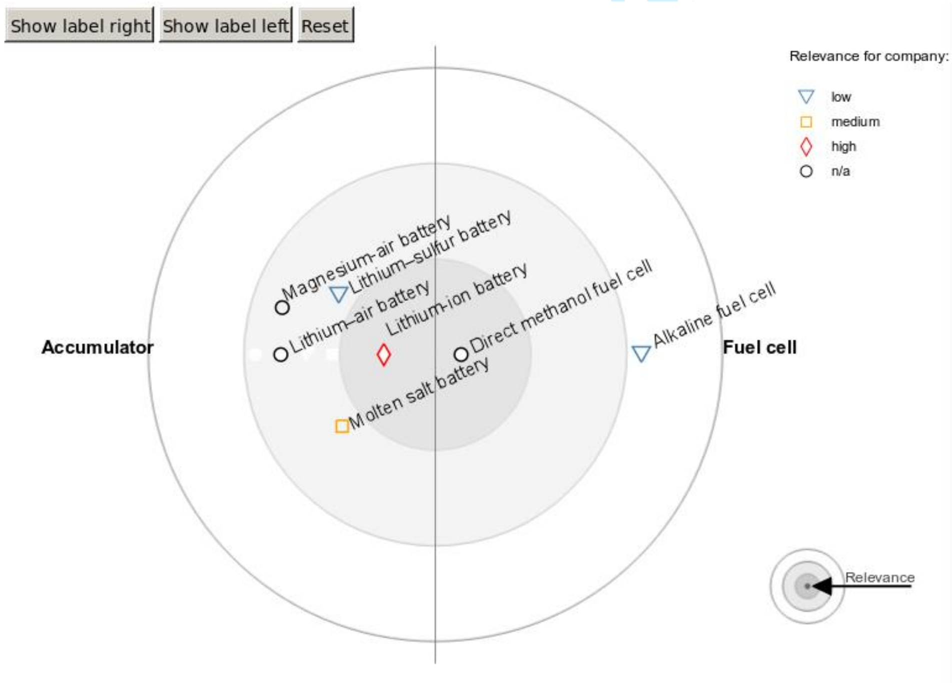

Figure 5. *Technology Radar* visualization in Semantic MediaWiki.

[1] The Web link to the Semantic MediaWiki extension *Technology Radar* will be provided for the final version of this article.

The technology radar is partitioned into several technology areas. The assignments of technologies to technology areas are retrieved from the corresponding technology profiles.
According to the theory of technology radars, the distance between the technology and the radar center illustrates the relevancy of the technology. The numeric relevance value is displayed via tooltip in the visualization.
Additional buttons on the top left allow the user to modify the display of the technology description in the diagram. It is easy to implement the representation of additional technology attributes directly in the technology radar, as well as links to the technologies' corresponding wiki pages.
Based on the different shapes of the items, the user can differentiate the different relevance assessments of the technologies for the company. A typical assessment is *low*, *middle*, and *high* potential or the indication that no assignment has been made.
To get a better overview of all technologies of a certain technology area, a list can be generated via a so-called inline query, which is a query inside a wiki page. *Technology Radar* allows a visual representation of this overview on top.

Any wiki page in the wiki can show a *Technology Radar*. The following example inline query shows how the data is retrieved:

```
{{#ask:[[Category:radar]]
|?technique
|?relevancy
|?shape
|format=radar
|height=550
|width=550
}}
```

If this fragment is stored on a wiki page, then with every request of the page, the request is interpreted, the data is queried, and the visualization is dynamically generated. The technology pages in the example wiki have the attributes t*echnique*, *relevancy*, and *shape*. Assigning attribute values to these attributes is either done by annotations of the shape "`technique: [[technique::rolling]]`" or via filling out the appropriate fields in the technology form. It is also possible to fill out the technology template without using a form; this, however, requires the user to understand the wiki syntax and stands in opposition to the requirement of the technology experts that a user-friendly handling with the tool is needed (see Section 3).

5.2.3 Technology Portfolio after Pfeiffer et al. in Semantic MediaWiki

Like the *Technology Radar*, the developed extension *Technology Portfolio*[1] can be used in Semantic MediaWiki if technologies are available as wiki pages and if these pages contain the attributes necessary for the portfolio creation. These are *resource strength*, *technology attractiveness*, and *project scope*. The parameters can also be named differently, so the order of the parameters in each query is crucial.

The portfolio visualization contains circles arranged along the dimensions *resource strength* and *technology attractiveness* (see Section 2.2). Figure 6 shows an example of a technology portfolio generated by the developed extension.

[1] The Web link to the Semantic MediaWiki extension *Technology Radar* will be provided for the final version of this article.

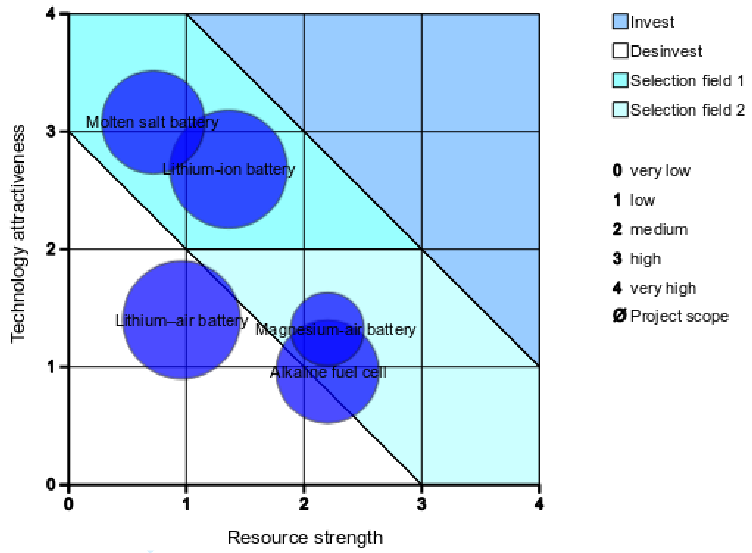

Figure 6. *Technology Portfolio* visualization in Semantic MediaWiki.

The embedding of the visualization into a wiki page is done with the following query:

```
{{#ask:[[Category:portfolio]]
|?resource_strength
|?technology_attractiveness
|?project_scope
|format=portfolio
|caliber=project_scope
|width=550
|height=550
}}
```

Note that the semantic query contains only the actual needed parameters and, thus, can be easily reused also by the technology experts who have only rudimentary wiki knowledge, but who want to create a Technology Portfolio visualization at a new location in the wiki (thereby considering maybe other technologies). The assignment `format=portfolio` ensures that the result of the request is presented not as a list, map, or similar, but with the specifically developed result printer *portfolio*, which generates a portfolio visualization. The assignment of `caliber` indicates what the diameter of the technology circles should represent. In the example, larger circles represent wider project scopes.

5.2.4 Evaluation of the Semantic MediaWiki Extensions

Evaluation Setting

The Semantic MediaWiki extensions *Technology Radar* and *Technology Portfolio* were especially designed for technology forecast and technology monitoring purposes. Their potential applications and their benefits were analyzed by performing a task-based user study with 16 participants. The participants were on average 33 years old; 25% of them had no experience with Semantic MediaWiki, 56.25% had a considerable experience with Semantic MediaWiki, and 18.75% had a moderate experience. Twenty-five percent of the participants knew of the technology radar as a display format, 31.25% had heard of it, 43.75% did not know what it was.

The survey (as presented to the study participants) and its results can be seen online at http://semantic-technology-wiki.org/.

Evaluation Results and Conclusion

Both the technology radar and the technology portfolio proved to be understandable for all users despite the fact that these visualization concepts were unknown to many users before the study. As the responses of the first questions[1] show, they are relatively intuitive forms of visualization. On a scale from 1 to 5 (1 = bad, 5 = very good), both visualization forms were rated with 4 points or higher. Creating the visualizations was judged as more difficult than interpreting them (see Figure 7), since creating visualizations requires to understand semantic queries in Semantic MediaWiki. Nearly every participant was able to copy semantic queries and paste them in a wiki page to present the visualization. Since not all participants had extensive Semantic MediaWiki knowledge, one-fourth of the participants were not able to generate a visualization from scratch but needed a template. This is in accordance with the observation of Isenmann (Isenmann, 2008, p. 240ff.) that the steps to be performed by technology monitoring responsible persons need to be kept simple and should not involve process steps which require huge training efforts.

Modifying a given example was graded as easy (4.6 points), and generating one’s own example was graded as doable (3.6 points in average).

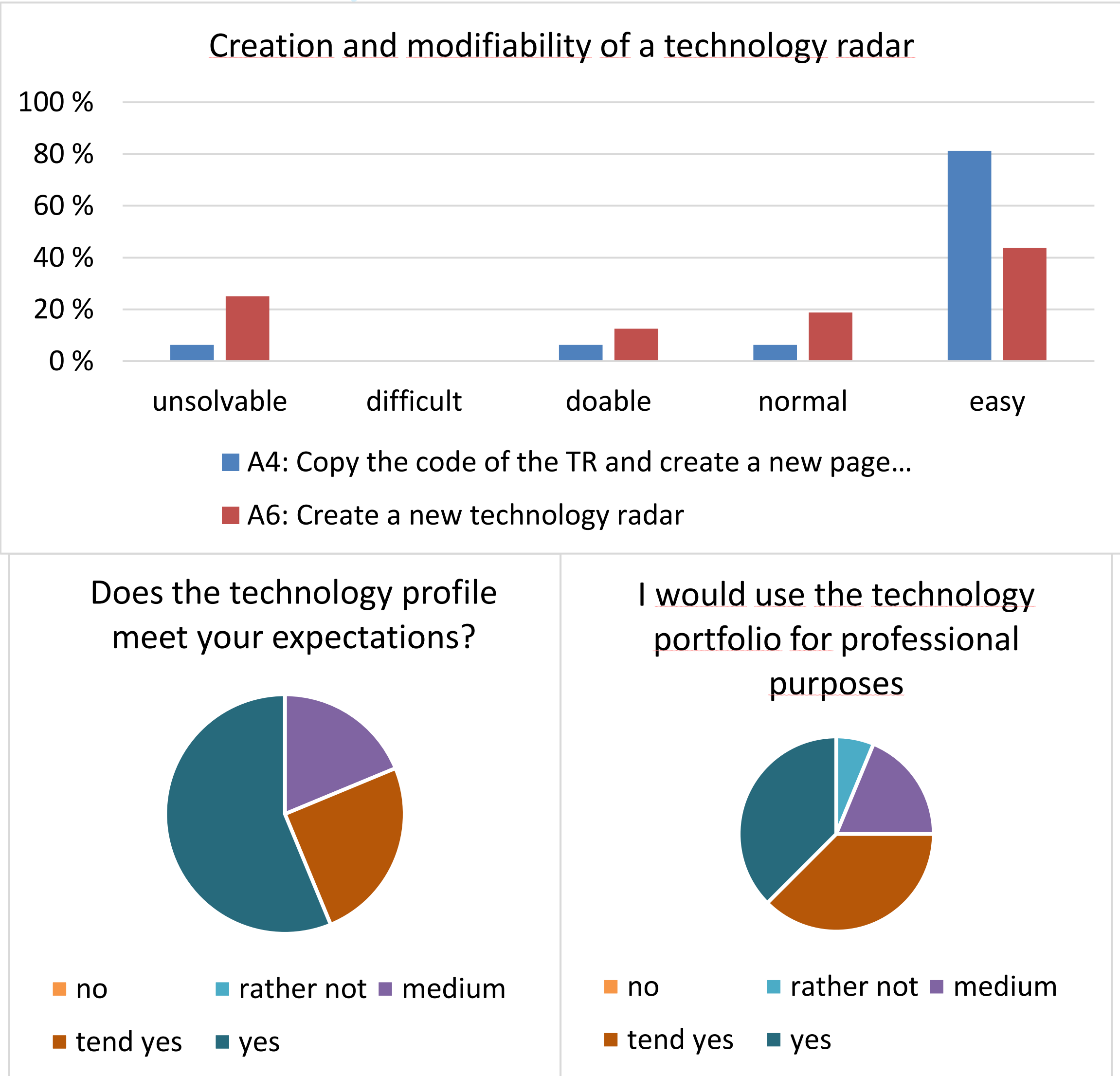

Figure 7. Results of the evaluation.

[1] See the questions of the user study which are available online.

Before attributes such as *technology attractiveness* are used for the first time, a wiki page must be created for that attribute and the right data type must be specified there. This is a characteristic of Semantic MediaWiki per se and turned out to be not very easy. The point is that certain knowledge about data structures is necessary to initialize the attributes. The description of technologies via technology profiles (realized with a template) was graded 4.4 (see Figure 7). Storing technologies via templates in Semantic MediaWiki was regarded as intuitive. Most users (evaluation with 4.1; see Figure 7) indicated interest in further using the extensions.

Altogether one can state that the familiarity with the proposed kinds of visualization was given from the very beginning. The active usage, i.e., assigning the parameter values per technology for generating the visualizations and especially the first use of queries (also for generating the visualizations), turned out to be difficult. The main reason for that may be that the users were not used to think in the semantically-structured way of objects, relations, and classes. But one can imagine that the setting of such diagrams in wiki pages and the initial assignment of attribute values is usually done by experienced Semantic MediaWiki users, not by technology experts. Furthermore, it can be assumed that people who have some background in semantic structures have no difficulties in understanding and using the queries in the wiki. For technology experts it is often sufficient if they can edit technology attribute values with the help of forms and evaluate technologies on the basis of visualizations. Thus, it can be assumed that the developed Semantic MediaWiki components, especially the extensions of Semantic MediaWiki, will see strong demand for use within technology monitoring and technology early detection.

6 Conclusion

Semantic wikis such as Semantic MediaWiki have proven to be helpful tools for knowledge management in industry settings. However, Semantic MediaWiki and other freely available semantic wikis are rarely used for technology forecast and monitoring purposes because there are no freely available software components specifically dedicated to technology and innovation management. For instance, visualization possibilities such as the technology radar and the technology portfolio are missing for Semantic MediaWiki. In this paper, we showed that the additional requirements for such purposes can be met for Semantic MediaWiki by using templates for technology profiles and the specifically designed and implemented visualization extensions. As result, we opened the application area of Semantic MediaWiki for technology and innovation management. Since technology and innovation management is based heavily on costly dedicated software, we provide a software solution for technology monitoring and forecast that is especially attractive for small and medium-sized companies.

7 References

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