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Collecting and Enriching Medical Information Through Human Computation

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Diplomarbeit

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München, den 28.08.2009 Andreas Attenberger

Abstract

Despite the nowadays widespread availability of various medical information in computer-readable formats, it still remains challenging to structure and employ this information in order to improve medical services. For online health websites it is crucial to dispose of clear and concise medical information that can be served on a variety of levels to different users. With the advent of the ”informed patient”, who is deeply involved in making decisions about his health and treatment options, the available information has to be presented in such a way that both patients as well as health care professionals or other potential users are served data according to their expertise. This thesis discusses a novel way of collecting information such as laymen terms for medical symptoms, while ensuring both correctness and appropriateness of the data. It is based on human computation in the form of Games With A Purpose (GWAP) and can easily be integrated into a social health website. Finally, an approach for implementing GWAPS in a generic and extensible way is outlined.

Zusammenfassung

Trotz der heutzutage weitgehend zur Verfügung stehenden medizinischen Informationen in computerlesbaren Formaten bleibt es eine Herausforderung, diese Informationen zu strukturieren und für die Verbesserung von medizinischen Dienstleistungen einzusetzen. Für Gesundheitseiten im Internet ist es von erheblicher Bedeutung, über klare und deutliche medizinische Informationen zu verfügen, die den unterschiedlichen Nutzern auf verschiedenen Ebenen angeboten werden können. Während sich das Konzept des ”aufgeklärten Patienten”, der aktiv an den Entscheidungen über seine Gesundheit und Behandlungsoptionen teil hat, immer größerer Beliebtheit erfreut, müssen die medizinischen Daten so geliefert werden, dass sie sowohl den Patienten wie auch den Beschäftigen im Gesundheitssektor und anderen interessierten Personen entsprechend ihres Erfahrungs- oder Ausbildungsgrades bereit stehen. Diese Diplomarbeit betrachtet eine neuartige Methode, Informationen wie beispielsweise Laienbegriffe für medizinische Symptome zu sammeln und dabei gleichzeitig die Korrektheit und Angemessenheit dieser Daten sicherzustellen. Sie basiert auf dem Prinzip der ”Human Computation” in der Form von Games With A Purpose (GWAP) und ist einfach in eine Online-Gesundheitswebseite integrierbar. Abschließend wird eine Möglichkeit aufgezeigt, wie eine allgemeine und erweiterbare GWAP Implementierung erstellt werden kann.

Acknowledgments

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Of course, this thesis would not have been possible without the generous support and the opportunities given to me by the EpiHelp AG. It was an honor for me to be able to work in such a close-knit and highly motivated team. Thank you Raimar Boehlke for always being available despite having such a very busy schedule, Markus Mitter for making sure that all of the legal and financial issues were always in order, Norbert Pongratz for helping me in finding the right direction for my thesis, Werner Schwarz for giving me a ride to the office on so many occasions and Christoph Drieschner for having the right idea at the right time to jump-start my thesis. I will always fondly remember the cheerful atmosphere in the office that made getting the work done a breeze. I think the EpiHelp idea is groundbreaking and desperately needed in this time and at the current state of our health care systems and I hope to continue being part of this revolution along with all of you.

Finally, I am extremely grateful to all of my family and friends for keeping up with me during the up and downs of writing this thesis. I am sorry for the little availability on my part during the last months and hope to make up for it now. Thank you so much for all of your advice, your patience and your support!

Contents

Chapter 1

Building an Online Health Community - The EpiHelp AG

1.1 The Rising Cost of Health Care

The EpiHelp AG, which was founded in 2007 and operates out of Murnau, Germany sets out to create one of the leading online health community websites on the Internet. The founders' own experiences in the health systems of both the USA and Germany lead to the idea of collecting medical data directly from patients and consolidating it in order to gain statistically relevant information about conditions and treatment options. This is especially relevant against the backdrop of the rising costs and inadequate care of current health systems in both Germany and the USA as can be seen in figures 1.1 and 1.2. While costs of health care continue to rise in Germany and constitute an increasing financial threat [50], health care spending in the US has already reached 18% of the GDP - higher than in any other country [29] - while not offering universal coverage for all citizens.

1.2 Evidence-Based Medicine

Evidence-based Medicine (EBM) is seen as one potential aid in achieving the goal of reducing cost. It is defined as "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" [4]. This means that the existing clinical knowledge by practitioners should be combined with the evidence collected from reliable research. In addition, the patient should be part of decision processes regarding his treatment. According to analysts from the US Congressional Budget Office [32] there are two main reasons as to why EBM can help reduce health care costs:

- Up to half of all medical treatment in the US may not be backed up by significant evidence. Essentially, this could mean that certain cost intensive therapies do not prove to be more beneficial to the patient than less expensive treatment.
- Due to fee-for-service reimbursement the current system encourages medical personnel to offer more and maybe expensive services to the patient. At the same time, insurance coverage can lead patients to demand unnecessary care which is caused by a lack of knowledge about the actual costs of procedures.

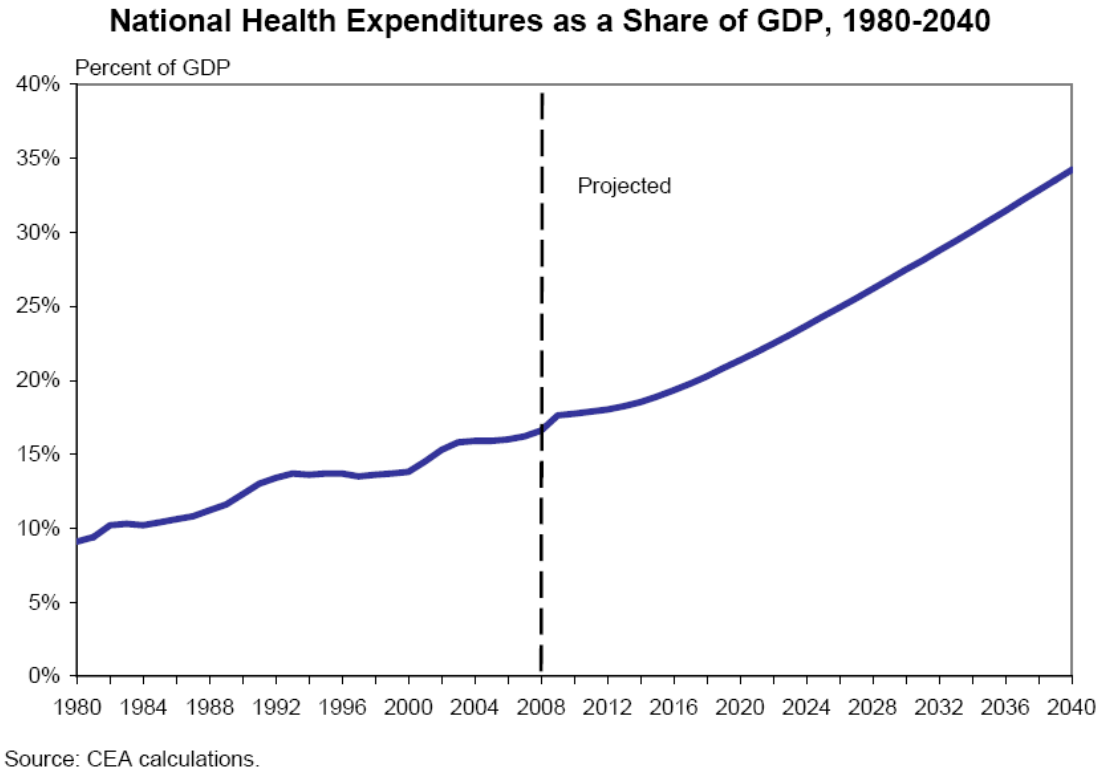

Figure 1.1: Rise of health care spending in the USA [29].

This situation as presented for the US American health care sector is similar to some aspects of the German health care system, which, too, does not rely on evidence-based medicine for the most part. Up to 80% of German doctors are said to not be familiar with international studies published in English [19]. The fee-for-service reimbursement problem similiarly exists in Germany where patients with public health insurance have no possibility of checking treatment cost [10]. The EpiHelp online community has the potential to significantly contribute to an evidence-based approach. Users will be able to rate their treatments and offer this information to other patients on the site. With a growing user-base it is possible to derive statistically meaningful data from this user input, especially when combined with contributions from professionals. For example, the current prototype of the EpiHelp website applications has the possibility of patients specifying if their diagnoses have been confirmed by medical professionals and further information like the type of diagnostic tests used can be entered.

1.3 The Informed Patient

The above definition of EBM already pointed out a stronger involvement of the patient in medical decision. This is the cornerstone of another concept that is gaining increasing popularity in health care - the informed patient. The objective of giving patient adequate information and involving him in treatment decisions is present in both Germany and the USA. Giving patients help with decision-making can improve the quality of these decisions, especially in areas where there is a choice between preference-sensitive treatments. These

Figure 1.2: Increasing health care cost in Germany showing yearly health care expenditure per capita in euros [26].

treatments do not have a clear ratio of benefits over possible harm caused by the treatment itself. It has been found that when supplying patients with decision aids, which are documents created to help the patient with deciding about treatment options, overuse of surgical treatment could be lowered by 25 percent [15], [27]. Here, EpiHelp can assume an important role first of all with informing patients. A community website is an ideal means toward this goal as a high amount of information can be concentrated in one place. By asking users about the treatment options they have received for a condition before, it is possible to compile a detailed list of all available procedures. Additionally, the patients' own evaluations can be taken into account, processed and presented in a statistically meaningful way. While having this kind of information is the basis for a decision, additional social community functions like chats, messaging or user profile comparisons can further support informed patient choice.

1.4 Current Health Information on the Web

Several websites offering health information or health services are already on the market. These can generally be classified into the following categories:

- Content Providers

These websites simply offer information about medical conditions, symptoms or other health care related topics. Usually there is little or no added benefit over conventional offline information sources. One example is Wikipedia [1], which is among the most significant websites that users go to for medical information [20].

- **Chats, Message Boards, etc.**

  In contrast, these sites offer their users various interaction possibilities - mainly for exchange of information either between patients or medical staff. While they provide a valuable tool in helping users to find opinions about treatment options and other issues, they often lack structuring and deliberate collection of medical information from users. This data is usually obscured in unstructured text input. Sites offering these possibilities are often created by support groups or foundations. For example, in Germany the "Borreliose und FSME Bund Deutschland e.V.", a lyme disease support group, has set up a website that offers features like a message board and chat to lyme disease patients [2].

- **Health Data Stores**

  This refers to storage of user health records that mainly keep track of patient data including personal information received during doctor visits, etc. While this approach may help raise efficiency in health care it does little in order to help users become informed patients. Examples for this type of services are Google Health [3] or Microsoft HealthVault [4].

- **Structured Community Websites**

  These are sites that combine several aspects of the previously mentioned websites to offer a structured approach to collecting user information. Examples for community sites are PatientsLikeMe [5], who offer structured input restricted to certain diseases, or Sermo [6], a web platform intended for doctors. A limiting factor for this approach is often the insufficient processing of information or too strong reliance on official diagnostic data from medical personnel.

EpiHelp sets out to create an online health community that satisfies various needs both from patients and health care professionals. Naturally, the functions previously mentioned for online health websites are integrated into this approach. What sets EpiHelp apart from already existing social networking sites for online health communities is a broader spectrum of data collection. In addition to the information provided by doctors to patients - which is usually input by the user - EpiHelp offers the possibility of specifying further information about patient lifestyle and environment. Furthermore, past medical events like surgeries or infections that have since been cured can be added into a patient's profile. As a consequence, this method creates new ways the data can be analyzed and conclusions drawn. For example, users can look for diagnoses that occur with similar symptoms to theirs in order to help in preventing possible misdiagnoses. And probable impacts of their lifestyle on the course of

[1] http://www.wikipedia.org
[2] http://www.borreliose-forum.de/cms/html/index.php
[3] http://www.google.com/health
[4] http://healthvault.com/
[5] http://www.patientslikeme.com/
[6] http://www.sermo.com/

a disease could be detected by the system. With sufficient high quality data, it would be possible to gain statistical information to help advancing EBM. Combining such a system with a broad range of medical information for the patient could then contribute to bringing the ”informed patient” as outlined above into existence.

The next section discusses the general architecture and functionality that social community websites can use in order to improve the users’ likeliness to continue coming back for further visits. Then, the added value of Games With A Purpose, a novel kind of computer games, for such a site are discussed.

Chapter 2

The Architecture of a Social Networking Site

2.1 Advantages of Social Networking Sites

First of all, it is necessary to pinpoint what precisely a social networking site offers that brings advantages over standard websites with little or no networking activity. Due to the active involvement that users can take in site participation, for example user-generated content, it is possible to create huge collections of data which otherwise would be impossible or extremely costly to produce. Additionally there is the possibility of adding further value to existing data by having users generate information like meta tags for it. This is generally known as generating ”folksonomies” with the name reminding of taxonomies, which are classifications created for various domains of knowledge. The first part of the word, ”folk”, implies that these meta tags which can be used to find and categorize objects are - unlike normal taxonomies - created by site users which are not necessarily experts in the field relating to the object [41]. Examples like the photo sharing site flickr [1] show how value can be generated which would not have been possible with other means. The open-source software scene is driven by similar aspects [35].

Next to the creation and management of various kinds of information or data, social networking sites also realize new communication possibilities and thus making it easier for people to organize themselves and share knowledge. The later has gained increasing importance for crowds of people because these have an inherent way of intelligent decision making which has become known as the ”wisdom of crowds” [40]. Tapping into this wisdom has been popularized by James Surowiecki in his book with the same title. Actually making this potential available for use in various fields is one of the strengths that social sites can make use of. Social features that can be implemented in a network site are discussed in the next section.

[1] http://www.flickr.com/

2.2 Social Features

2.2.1 Comments and Ratings

An essential component of the site's user interaction systems are participation functions for commenting and rating various site content. This is necessary to realize group tasks like collaborative decision making [37]and in turn generates new content for the site. Comments and ratings can relate to general site content, user-generated content or even the users themselves which gives rise to special functions. For example, users could mark content that is especially interesting to them with "I would like to learn more about this" or similar statements and thus signal a need for the site administrators or other site users to provide more information about the topic in question. Regarding interactions between users, a community website could make ways of rating users by other users available. This could be described using the label "equity functions". Possible applications are site users that rate the objectivity of a contributing person towards a certain topic.

2.2.2 Group Building

One important feature of social networking sites is the possibility of users creating their own groups for information and message exchange. In his book "Here Comes Everybody" Clay Shirky stresses that with the Internet and new forms of communication so-called "ridiculously easy group-forming" [37] is possible. Long distances are no longer a hindrance which leads to the creation of special interest groups that before the rise of new media like the Internet would not have been possible. Shirky calls them "latent groups" [37]. Thus, a website will greatly benefit from having a tool in place that lets users easily create new groups.

There is no need for deciding which groups to offer as this is a task usually best left to site visitors themselves [37]. However in the first phase of building a community it might be helpful to offer a few groups that might have a potential for popularity as well as open discussion boards. The reason for this lies in the fact that most people are not inclined to start something themselves but rather contribute to existing creations. An example are Wikipedia articles where there are only a few active users adding substantial amounts of information while the wealth of users restrict themselves to small additions or corrections [37].

Functionality that can be offered with groups can be:

- Broadcast messaging of all group members (maybe up to a certain group size).
- Group messaging board.
- Group blogging where users can write articles on the groups' topic.
- News feeds displaying recent group activity, like additions to the blog mentioned above or relevant news from media sources.
- Optional moderation through users, either the founder or another user collectively selected by group members.

It might be useful to implement a feature, as offered in platforms like Xing, that evaluates group activity and marks groups for deletion after a certain amount of idle time [1].

2.2.3 Invitations

Another essential feature are invitations to become community members. Individual users should be able to send invitation requests to non-members. To foster usage of the group functions it is advisable to implement a group invitation function so users can encourage other members to join groups that are likely to be of interest to them.

2.2.4 Messaging Functionality

Typical messaging services available to members in a community should include the various forms of online communication, both in respect to synchronization as well as the number of participants. The following are the standard messaging functionalities characterized according to their software implementation:

- **One-on-One**

  One of the most basic forms of user communication is one-on-one messaging. Subclasses according to synchronization are either asynchronous messages similar to email but contained in the platform's own communication infrastructure or instant messaging between individual users.

- **Message Boards**

  Another form of users exchanging information with each other are classic message boards with an arbitrary number of participants as either senders or receivers.

- **Realtime Interaction, Chats**

  Furthermore users should be able to log in to various chat rooms. These can either be topic- or group-based. Additionally, a general chat room should be offered, too. Users might benefit from additional features like switching to One-on-one messages with selected others.

2.2.5 Polls

Another valuable functionality is offering polls on the website. These can either come from site administrators, other companies wanting to to make use of the users' knowledge or users and user groups themselves to help foster identification with the site. Polls can also be considered useful in respect to the "wisdom of crowds". Groups of people often prove to be a valuable source of information or important factors in decision making with a high probability of good results [40]. With polling, this knowledge in user groups about various topics can actually be accessed.

2.2.6 User Profile and Pages

To maximize user contribution and bind users more closely to the website, a social community website can integrate user-specific services like blogs or photo galleries. This way, the user is given a free space to present his profile and interests to other users as well as possibilities to link to other relevant site content. Elements that can help with structuring the page can be a blog functionality, contact or group lists.

2.3 Conventional Features to Compliment Service Offers

Finally, next to all the functionality associated with user interactivity, it is advisable to integrate standard features as found in non-community websites in order to help provide a complete web experience and broad information to potential site users. This can play an import part in keeping people on the platform.

Features can be:

- **Information Aggregation**

  Collecting information from various sources and aggregating it in a meaningful manner is a valuable service that can easily be offered to potential site users.

- **Wiki**

  Going further than pure information aggregation, putting in place a wiki related to the topics the website is dealing with in detail can be a powerful tool to gain specialized knowledge through user contribution.

- **Moderated Link Collection**

  Most sites can profit from linking to other providers and sources of information related to them in order to present a balanced view of topics. Having a good collection of links also constitutes a useful addition to site services.

- **News**

  This helps keep the site up to date and thus sustain user interest. Furthermore, news articles can themselves again serve as a basis for user-generated content in form of content or ratings.

- **Real World Services**

  Going further than simple online services is the integration of real world services like offering offline support from professionals or contact information for referring important questions to people with necessary credentials in a certain field.

- **Regular Content**

  High-quality content produced by professional web journalists naturally presents added value for a site. Content can both be full articles as well as news or editorials.

- **Site Search**

  A standard feature provided by most websites so that information is not buried under several layers of pages without the user being able to find it.

- **User Profile Search**

  This contributes to providing a sense of community and aids people in contacting others with, for example, similar interests, issues or other information valuable to the user.

- **User Profile Comparison**

  Comparing profiles is an interesting application especially for websites with user health profiles as it is possible to directly compare, for example the effectiveness of measures taken by different users. In other, more general contexts, user profile comparison can be used to generate scores for example about user knowledgeability in certain topics. Information from user profiles can also be processed to gain statistically significant data.

- **Web Search**

  Integrated web searches can provide a quick means of getting information to users that is not available on site while not forcing them to leave the website and use other information providers like standard search machines for it. Often it is possible to integrate custom-made search bars from popular search engines seamlessly into the existing site layout.

Figure 2.1 shows a diagram displaying all the possible features of a social networking site with attribution to the respective content providers. The wiki, user profile information and profile comparisons symbolize content that is produced in a joint effort between site administrators and site users. It is important to note that the above lists of features by no means constitute an exhaustive compilation of all possible features for a given website. Especially with social features there are frequent developments of new types of services. For example, the micro-blogging service Twitter [2] created a new and very different way of communication for users. Another very popular service is the group scheduling service Doodle [3]. Often it is easily possible to integrate these types of services into an existing site and thus offer the users additional value. With the ongoing experimentation regarding user interaction on the Web 2.0 new user communication features are frequently popping up and can gain significant popularity in a short amount of time. Any site owner should be aware of these developments to make sure that his website is up to date and on par with the competition.

[2] http://www.twitter.com
[3] http://www.doodle.com

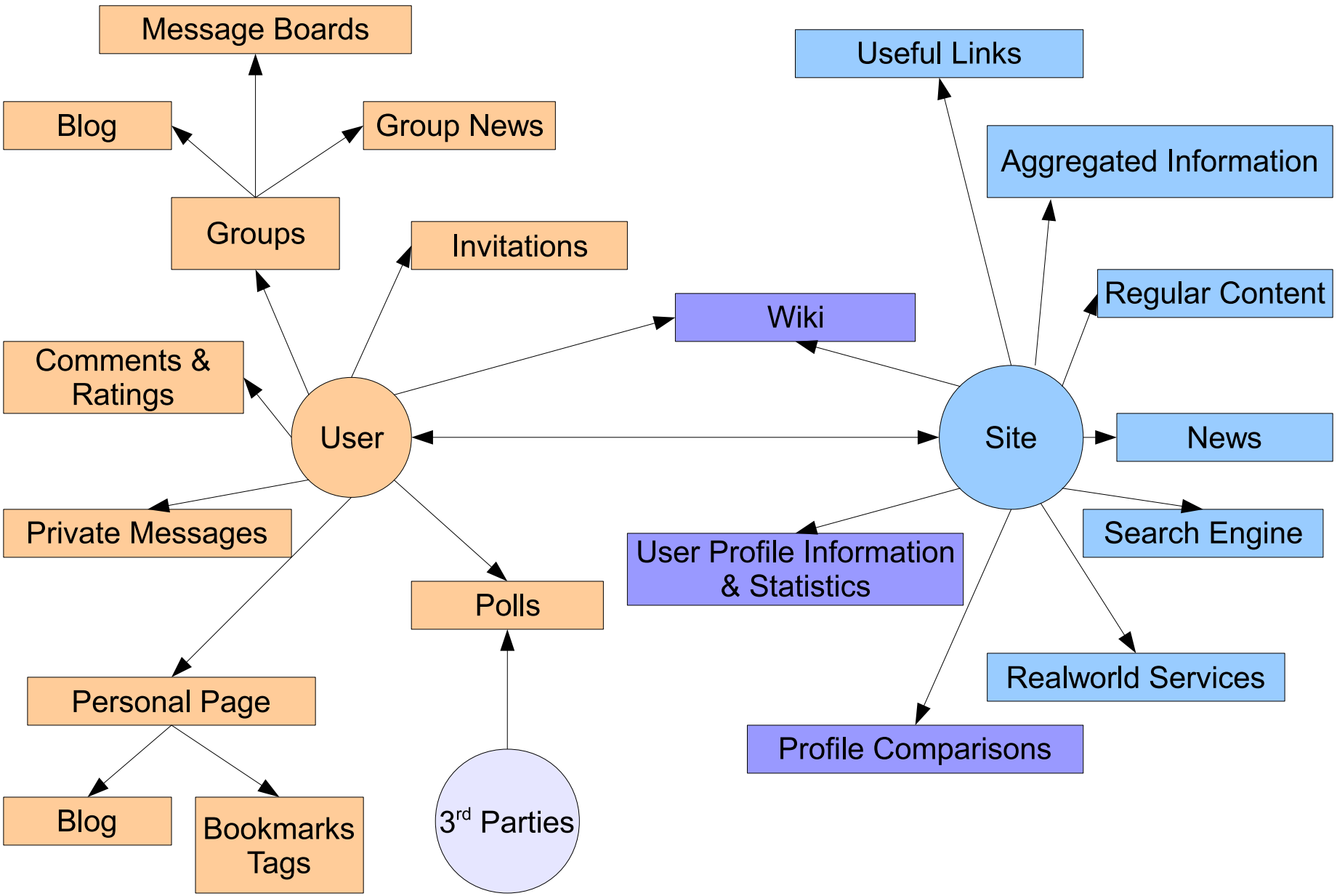

Figure 2.1: Potential features of a social networking site.

2.4 Building a User Base

Of course, as for any other project, a website without users - especially a community based site - will not work and deliver the value expected from it. Thus, an appropriate strategy has to be devised for steadily building a user base for the site so that actual user-generated content and user communication can happen.

2.4.1 Identifying and Motivating the Target Audience

First of all a site's probable audience has to be identified, which can be aided by surveys. For example, a health community site is likely to not only address patients and health care professionals but as well their family and friends or people with general interest in a certain medical topic. After the target audience has been determined, its users have to be invited for participation. One the one hand there are common possibilities like distributing vouchers or gift certificates for users who are willing to spend a certain amount of time on the site. On the other hand it is advisable to even directly pay users to generate traffic on the site as this alone can incite other users to do so, too. James Surowiecki refers to this as an "information cascade" where the popularity of something gets relayed from one person to another [40]. An historic example of this is the introduction of shopping carts. First they faced little acceptance, however, after its inventor hired people to push the shopping carts around a store and fill them with products, other people followed this example and the shopping carts became popular [17]. In this context it makes a lot of sense to try and find those users who are highly connected in terms of their social network because these people will spread news about a website much faster than others. In his book "The Tipping Point" Malcom Gladwell refines this user identification further into three different types of people that play part in starting a trend and thus something very desirable for a social networking site: "mavens", "connectors" and "salesmen". This adds mavens and salesmen into the equation. Gladwell sees the mavens or "market mavens" as people who have a natural tendency to collect a lot of information about various topics which could become useful at some point, while the "salesmen" help persuade others that an offer or service is worth getting.

2.4.2 Sustaining User Interest

Once a sufficient number of users have been motivated to view a website, it is necessary to sustain their interest over more than one site visit. As has been shown in 2.3 and 2.2, there are a lot of potential services that can be offered to users so that they gain a positive experience from their site visits. While it is possible to generate some of this content automatically, it remains crucial to have qualified personnel overlooking all the information offered on a website. First of all because these professionals, for example specially trained journalists , can create more sophisticated material from user-generated content, but also because any problems on the site have to be identified and solved quickly. Any bad experience a user gets from a website constitutes a potentially devastating issue. The reason for this is that especially any of the highly connected users can spread negative news just as fast as positive experiences. Nevertheless, a good part of content generation and processing can be left to the users themselves. It is possible to involve site visitors into content management and site administration. Very active users can be given moderator status on message boards which yields several beneficial effects. On the one hand they help in regulating the commu-

nity and preventing site misuse and on the other hand they are more closely associated with the website and its community and thus more likely to spend additional time on site. Furthermore, costs can be saved when tasks are outsourced to the users themselves. Often they can also do a better job, for example when it comes to spam detection. In accordance with the suggestions by Clay Shirky for group building as described in 2.2.2, it is advisable to not split up a message board into too many predetermined groups in the beginning but rather have users come up with suggestions. Apart from getting moderator status, users could also be rewarded with premium membership accounts that offer some kind of added benefit over standard users - for example access to information that is usually not free.

2.4.3 Importance of the Social Model

In general, the outlined measures will only work if the social model of the website is sufficient to sustain user interest over a long time. Shirky states that such a model has to satisfy three different things in order to work correctly: ”the promise”, ”the tool” and ”the bargain” . ”The promise” refers to the advantage people can gain through site usage - with a health community website this could be help with treatment decision making or even attaining a better status of health. The functionalities and technologies a site offers for people to contribute are seen as ”the tool”. A site should perform efficiently and with a usability high enough so users can easily get the information and communication options they need. Finally, ”the bargain” is about the expectations people need to have about participating in a community, this means what tasks they will have to fulfill and what they can expect in return during usage of the site. That could be translated to entering a user profile and communicating on the site while receiving compassion and social support from others who are in similar situations.

2.5 Benefits of GWAPs for Social Community Sites

While much of the possible and easily implementable options for social networking sites have now been described, so-called Games with a Purpose (GWAP) [43] are another more sophisticated feature for implementation in a site. These games are set apart from standard computer games because next to being enjoyable and entertaining they are indirectly using the users’ brain power to get a variety of tasks done. For example, it is easily possible to collect or validate information through GWAPs. This makes them an ideal tool for an online community site because they can not only improve user experience and sustain people’s interest in a site but also help solve other problems pertaining to the site’s content. Additionally, a game can also attract users outside of the typical audience for a website if the game is well-done and enjoyable. These users can in turn, if they have no interest in the remaining site content, attract other potential site users - for example, if they are one of the well-connected people who have been described in 2.4.1.

Considering the problems that GWAPs can solve for a website there are three different issues that can easily be covered: collection of new information, enriching existing information and validating existing information. In case of an online health community, new data like layman terms for medical conditions or symptoms could be collected. Getting hold of this kind of data can prove difficult otherwise both due to a lack of availability but also the frequent changes in everyday language - getting the input directly from the target audience is an efficient way to receive quality data. Existing information can be enriched

in various ways, too. For example, there are various classifications of medical information available like the SNOMED classifications [4] or the ICD for diseases and other health problems [5]. However not all the data is semantically connected even though a relation between diseases and their characteristic symptoms or standard treatments is highly desirable. Employing professionals to work on this data is an expensive and slow way. For example, in August 2008 the SNOMED clinical terms classification, which consists of terms used in health and health care that are structured and associated with codes, contained of 283,000 concept codes, 732,000 terms and 923,000 defining relationships. Taking only one minute to examine a single description and spending 40 hours per week on this, it would take a single person about 6 years to look at all descriptions. Thus, it is almost impossible to manually manage information like this [39]. GWAPs could be a possibility to process some of the associated issues like data validation in a faster way.

In the next chapter, GWAPs will be described and discussed in detail.

[4] http://www.ihtsdo.org/snomed-ct/
[5] http://www.who.int/whosis/icd10/

Chapter 3

Games With A Purpose on the Web

3.1 The History of Games With a Purpose and Related Work

3.1.1 Human Computation

Games With A Purpose (GWAP) are based on the concept of Human Computation, also called human-based computation. This type of computation, as the name already implies, makes use of humans to process certain computational steps in an algorithm. Usually such tasks cannot be solved completely or sufficiently by computers. Examples include so-called CAPTCHAs (Completely Automated Public Turing test to tell Computers and Humans Apart) that were invented by a team at Carnegie Mellon University [47]. These now very popular security measures on the web are used to decide if a site is viewed by a computer or a human. Snippets of scanned, distorted text are displayed which the user has to type correctly into a box before being granted authorization for using a certain function on a website. Consequentially, a computer is not able to give the correct answer. Due to this it is not possible to, for example, start a brute force attack with a software tool that is trying to login into a user account by trying all possible combinations of chars because the software would have to solve the CAPTCHA box for every login attempt. At some point, Luis von Ahn et al. later extended these CAPTCHAs with text that was not recognized during optical character recognition (OCR) because of issues like warping and distortion which are often present in very old printed works. The user then types two words, one where the solution text is known - for verification usage - and a second one to help with finding the correct digital representation of a scanned text. This way, in addition to the security function, the CAPTCHA contributes to completing a text where all the letters could not be correctly determined during OCR.

Another well-known example for human computation is Amazon's mechanical turk, a "marketplace" where people can both request or process individual tasks, also called Human Intelligence Tasks [1]. Naturally these tasks represent tasks that cannot be done with computers like writing reviews or compiling summaries about a topic. The name is derived from "The Turk", a chess playing automaton invented in 1769 that turned out to not be an automaton because its secret was an actual human hiding inside, playing the chess game [3]. Picture 3.1 shows an engraving taken from a 1783 book by Karl Gottlieb von Windisch.

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

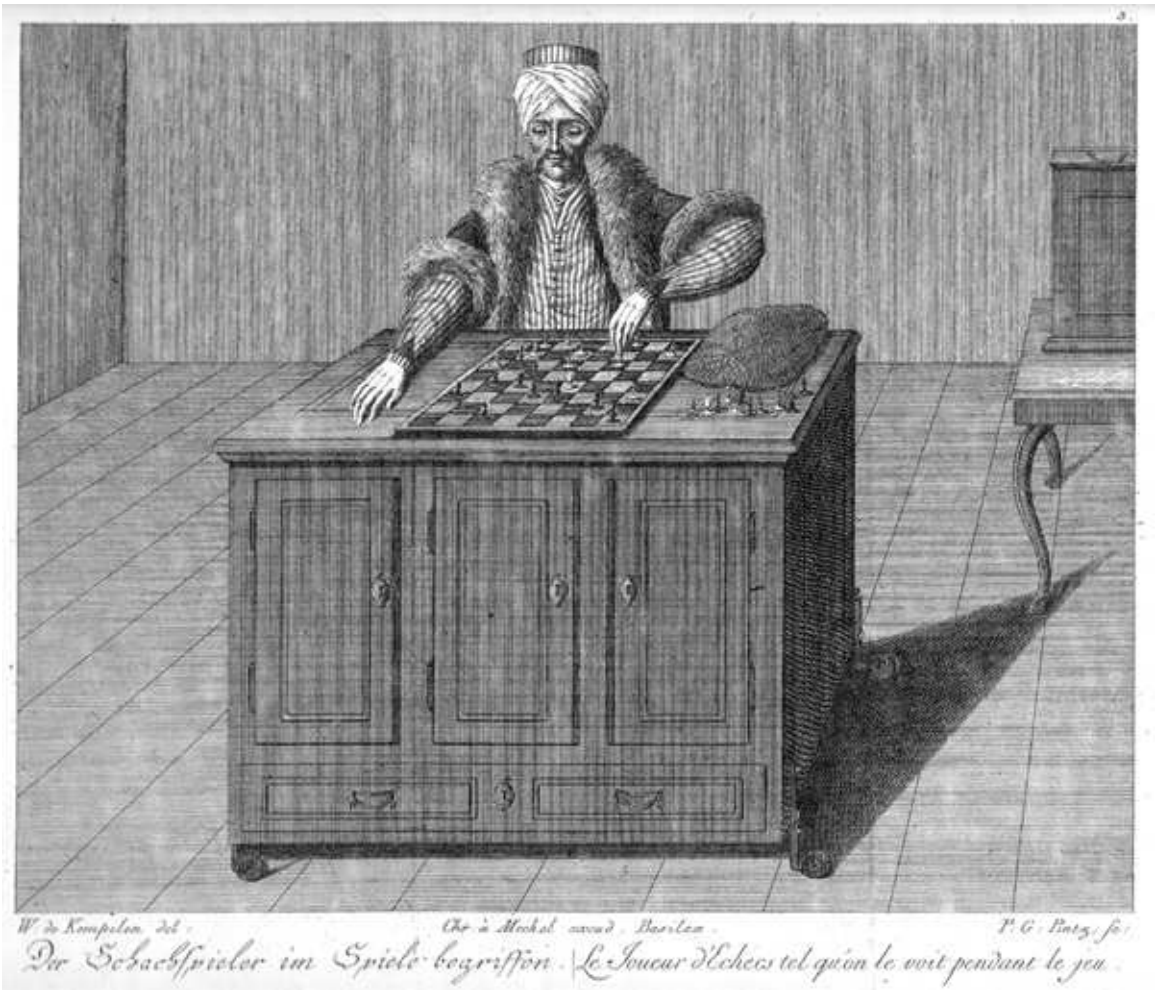

Figure 3.1: Engraving of the 1769 chess automaton ”The Turk” [5].

3.1.2 Combining Games with Human Computation

In 2008 a total of 68% of American households played computer or video games with about a fifth of adults playing daily or almost every day [2]. Because of the significant amount of time people spend with computer games it seemed only natural that instead of offering money as an incentive, as done for Amazon’s mechanical turk, or requiring people to do a task like CAPTCHAs, it should also be possible to present people with an enjoyable game. This way, while people are having fun and getting entertained they can, even when not conscious of it themselves, help solve problems [43]. Luis von Ahn and his team have created several games which are very popular with game players while being able to gain significant benefits from the game plays. For example with their ESP game, which will be discussed in the next section, they managed to collect more than 50 million labels for images available on the web [45]. After this success, further games were created for tagging music or collecting human knowledge in a computer-processable format.

The GWAP idea has since been taken up by other researchers, too. Katharina Siorpaes and Martin Hepp have been using games to provide incentive for contributing to the Semantic Web. In the OntoPronto game, users determine the ontological role of a Wikipedia article, for example if it is about an instance or a class of objects [38] as seen in figure 3.2.

David A. Shamma and Bryan Pardo are the creators of ”Karaoke Callout”, a game that challenges users to sing karaoke versions of selected songs. The data gathered from this game is used to train a query by humming (QBH) system which enables people to find the artist and title of a song by humming its melody [36]. The very different applications shown in these examples demonstrates the versatility GWAPs have.

The next section discusses the various steps involved in creating a GWAP. First, the initial templates, which describe the basic layout of certain tested GWAPs, created by Luis von Ahn and his team are presented along with guidelines for game design that were derived from their research. Finally, new templates that allow the collection of various types of data are presented.

Figure 3.2: A screenshot of the OntoPronto game showing players defining the ontological role of a Wikipedia article [38].

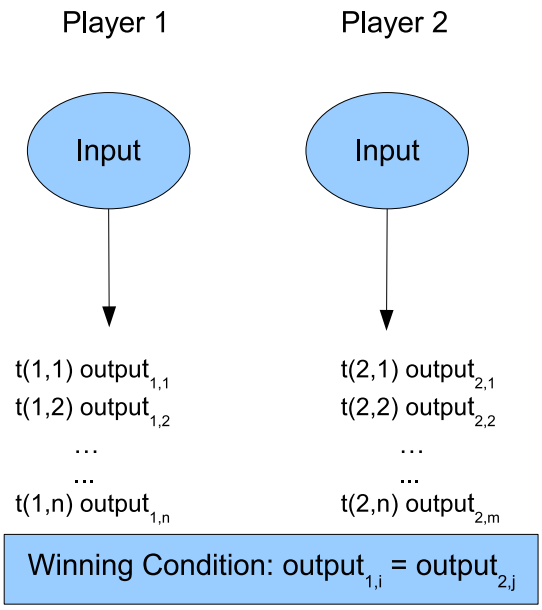

Figure 3.3: Graphical representation of the output-agreement game template.

3.2 Existing GWAP Templates

3.2.1 Output-Agreement Game

The Output-Agreement-Game template is a generic description of the well-known ESP Game [45]. In these types of games, two players are randomly assigned to each other and given the same input object. In the case of the ESP Game this is an arbitrary picture or photo. The players are then instructed to think of terms, which the corresponding other player is likely to come up with, too, in order to describe this input. While they make guesses, each player's input is not revealed to the other. As shown in figure 3.3, the players win if they both type the same term to describe an input.

One of the most famous types of GWAPs is the ESP Game, which is based on the output-agreement-game template. It was conceived as a tool to help in labeling images as this task is one where current software technologies, for example computer vision, often yield unsatisfactory results [44]. Designed as a two player game, the ESP game is played online with each player guessing the terms the other one is likely to come up with for a given picture. Luis von Ahn et al. call this process "agreeing on an image". This is also where the name stems from with ESP being the abbreviation of extrasensory perception purporting a deeper "connection" between the players.

During a game, the players continue to agree on terms picture after picture until a preset countdown has run out. If one of the players has difficulty in finding a term to describe a picture he can choose to suggest passing the picture. In case the second player agrees, the current picture is skipped and the next one is shown with the agreement process starting over. As to make sure that the game is also playable at times when no second player is connected to the server, prerecorded games from previous plays are saved and used to simulate a second player. Along with IP address filtering this feature also helps in making it more difficult for cheaters to misuse the game mechanism.

Evaluations have shown that the ESP game yields very good results with high-quality

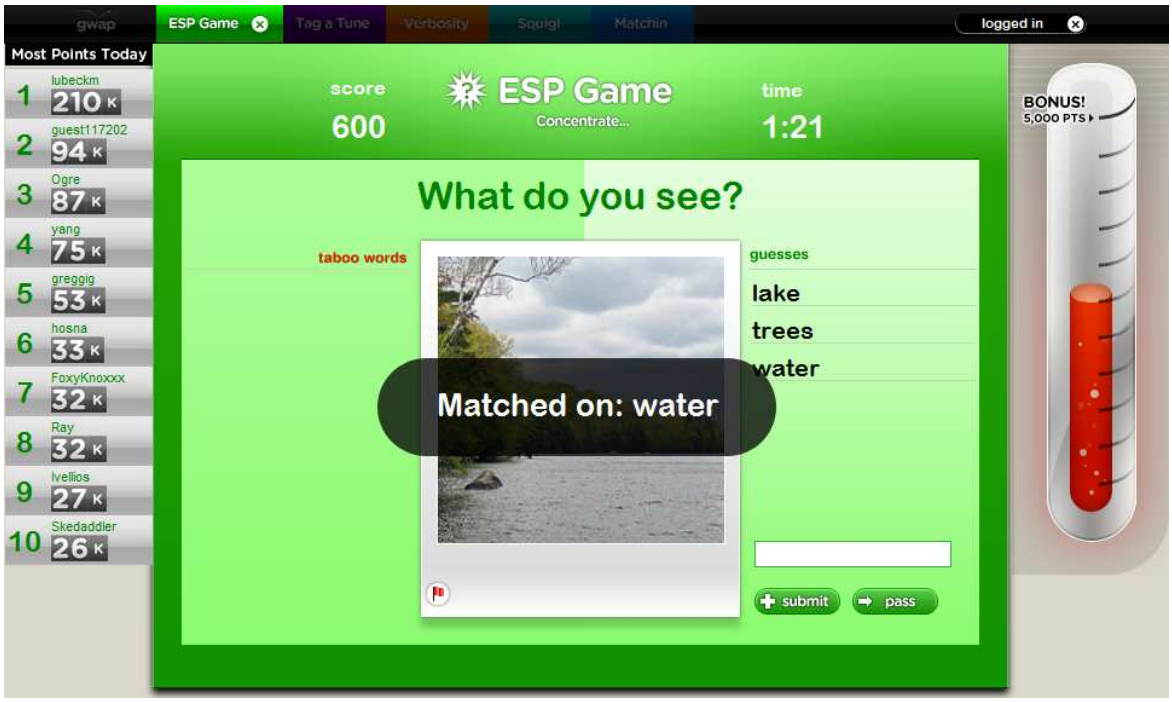

Figure 3.4: A finished ESP game round where no taboo words were given.

labels that can, for example, be used to improve image searching on the web. In figure 3.4 a screenshot of a typical ESP game round is shown where two players have just agreed on the keyword ”water” to use for a picture showing a lake or river. In general, output-agreement games are an excellent way of gather meta tags for various kinds of objects.

3.2.2 Input-Agreement Game

The Input-Agreement-Game is a kind of reverse edition of the output-agreement game. Here, the players, again randomly assigned, have to find out if they have been given the same input. To do this, the participants in game are shown each others output, i.e. the terms describing each player’s input. They win in case both of them correctly agree on having received the same or different input. As a way of ensuring correct output and thus reducing so-called guesswork, it is advisable to penalize incorrect answers through reducing scores or changing the rules according to which points are distributed. Figure 3.5 shows the steps of an input-agreement game.

On the official GWAP homepage [2], the input-agreement game template has been realized as a game called ”Tag-A-Tune” which is intended to collect meta tags about audio files - in this case various musical excerpts. The players each hear an audio track playing while they have to type terms they associate the music with. During typing, the players’ input is displayed for both, thus they can guess according to the tags if the other player is listening to the same track or not. After both players have given their guesses, the result is evaluated and they receive points if they have guessed correctly. The more correct guesses have been made in a row, the more points per audio track are distributed to the players’ scores. However this

[2] http://www.gwap.com/

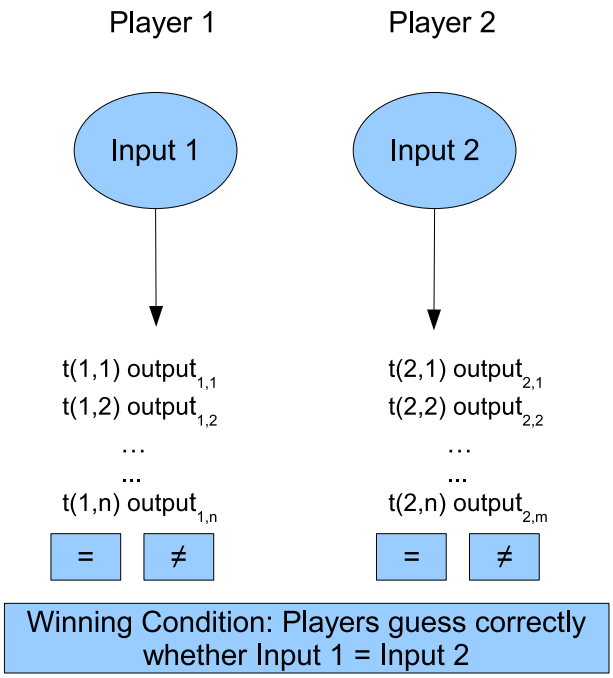

Figure 3.5: In the input-agreement game players guess if they have received the same input.

steady increase of points per track is stopped and reset to the initial amount once there has been an incorrect guess by one of the players.

Screenshot 3.6 shows a Tag-a-Tune game being played. The different input options for entering tags, guessing if the input is the same and suggesting to pass an image are visible. In this case 340 points are given for the correct guess due to the 2 correct previous guesses as displayed on the upper right of the screen. Next to the game action screen on the right, a thermometer is displayed to indicate the number of points missing in order to play a bonus round. The bonus round allows players to gain even higher scores by having them pick the most different track from 3 given audio samples which is naturally a more difficult task to give correct guesses on. This example shows that input-agreement games are - just like output-agreement games - powerful tools for collecting meta data about objects.

3.2.3 Inversion-Problem Game

In this game two players are again arbitrarily assigned to each other. These game players are either the ”describer” or the ”guesser”. The ”describer” receives an input not known by the other player. He then goes on to try and find words or other output in order to describe the input while the second player is guessing the actual input. The players win when the ”guesser’s output”, i.e. the guessed word, is the same as the input originally given to the ”describer”. Figure 3.7 illustrates the aforementioned game steps.

Luis von Ahn et al. suggest further extensions to improve game enjoyment, namely transparency and alternation. In this game’s context, transparency means that the individual guesses of a player are shown to the ”describer”, who is then able to indicate if a guess is close to his input or not (”hot” or ”cold”). It is seen as a possibility for increasing the ”social connection between the players” [45]. The second extension, alternation, refers to switching the players’ roles after each round. This can raise enjoyment, because the different

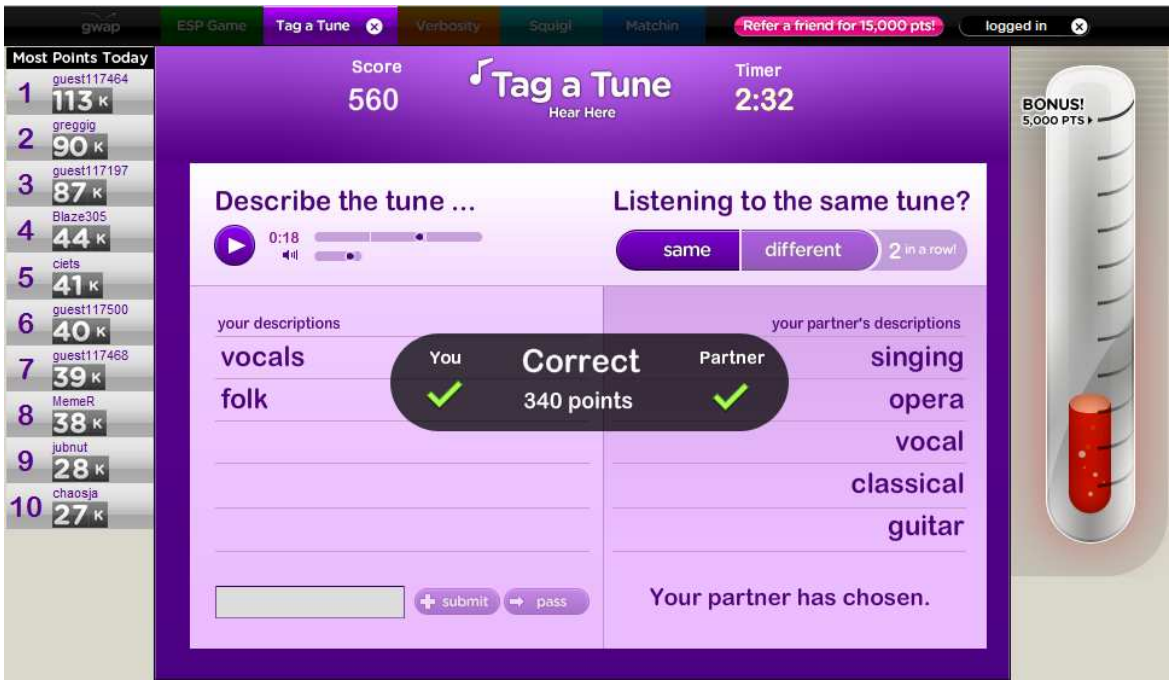

Figure 3.6: A Tag-a-Tune game in action with a round finished by a correct guess.

roles often demand different levels of user activity.

Verbosity is an implementation of the inversion-problem game template available on the GWAP website. The motivation behind the game is to gather a large collection of common-sense statements [46]. Similar approaches often work with paid users or volunteers. Verbosity on the other hand stresses the enjoyment players receive due to the interaction process being similar to games like Taboo. In the game, the roles are attributed as described for the general template above. However in this case, the ”describer” is called ”narrator”. He receives sentence templates like ”___ is a kind of ___” or ”___ is the opposite of ___” with which to describe the input given by the system. The guesser then tries to find out what the input given to the other player was. The concepts of transparency and alternation with the players switching roles have been implemented, too.

A typical verbosity round with the player being the narrator can be seen in screenshot 3.8, however the example also shows potential problems when the input-output-matching only compares the actual characters of the players’ input. In this case, the guesser is using British English while the game implementation is using American English and thus not interpreting the guesser’s input correctly.

The verbosity game shows how the inversion-problem game templates lend themselves to the accumulation of semantic statements and thus the relationship between objects or their characteristics .

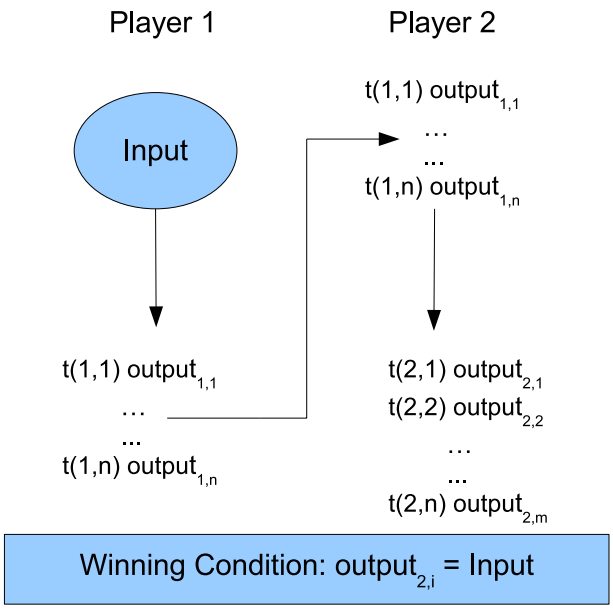

Figure 3.7: For the inversion-problem game one of the players has to guess the other's output about the original input that he was given.

3.3 Rules for Designing GWAPS

In their article about designing GWAPs Luis von Ahn et al. specify additional design guidelines derived from their experience in implementing these games [45]. These can be attributed to two general categories that concern different aspects of the game. On the one hand, changes in the games can be applied in order to raise game enjoyment. This is useful to avoid having game players lose interest in a game too soon and abandon playing. On the other hand it is also necessary to make sure that the game output, usually valuable information describing the objects used in the game and intended for further processing or usage, is kept at a continually high accuracy.

3.3.1 Increasing Enjoyment

The following are some possibilities to raise game enjoyment for GWAP players, they are usually focused on increasing the challenge a game represents to players which is a key factor of enjoyable games.

- **High Score Lists**

  Lists with players having achieved the most points can be implemented at various levels ranging from hourly to daily or all-time high score lists and contribute to motivate players to get onto these lists.

- **Player Skill Levels**

  Having different levels of player skills incites game players to try and reach a higher skill level rank in the game, e.g. graduating from "novice" to "experienced player". For the ESP Game it was found that many players keep playing mainly because of their desire to reach a higher rank [45].

Figure 3.8: A verbosity game round showing the weakness of simple input-output-matching algorithms.

- **Randomness**

  This is another very important factor that can be employed to raise game enjoyment. Randomness means varying different aspects of the games like the objects that are input to the players or the players that are connected to each other for a game. The variation of the objects is especially important as players receiving, for example the same pictures in the ESP game over and over again, will probably lose interest soon.

- **Score Keeping**

  Scores can be a positive reinforcement for player motivation as it directly rewards the players' efforts.

- **Timed Response**

  This aspect refers to setting timers so that players have to complete certain tasks within a preset time span

- **Word Filtering**

  Another function that is implemented in Luis von Ahn's GWAP games is the filtering of certain words that cannot be entered by the players. The filtering can refer to two kinds of processes. On the one hand it is a good idea to filter swear words and other bad language so that players do not get put off by some site users that want to disrupt game play by using these words. And on the other hand, for example in the game Verbosity, in order to assure meaningful output, the words that can be entered are restricted to words from a preset dictionary.

3.3.2 Ensuring Output Accuracy

The next list of design suggestions refers to keeping the accuracy of the players' output at a sufficient level so that high quality data can be derived from the games.

- **Player Testing**

  Testing a player refers to occasionally assigning players to prerecorded games with all correct outputs already known. In such cases, a player may be considered suspicious and his outputs should be disregarded as they are very likely to not be valid.

- **Random Matching**

  When players are not randomly matched but allowed to choose with whom to play, they could easily find a way to trick the system and receive points without giving adequate output. Thus it is mandatory to always have players assigned to each other in a random way to make sure that output quality is not compromised.

- **Repetition**

  Even though players' outputs are inherently validated through normal game play it is advisable to have two or more rounds played with the same object before output specified by both players is considered accurate.

- **Taboo Outputs**

  In the case that there are many descriptions available for an object it can prove to be difficult to collect all possibilities. Taboo outputs can restrict the data that can be entered in such case. For example a photo in an ESP game showing the sea can be marked with the taboo tag "sea" and thus let people only use other words like "beach" or "ship", etc. to describe the picture. To reduce the influence of taboo outputs on player output they should be randomized.

3.3.3 Further Guidelines

- **Prerecorded Game Sessions**

  Especially when a game is first introduced, the audience might often not be big enough to assign each player another one at all times. For these cases it is essential to have data from older games saved with which to simulate another player. This is an easy task for input-output-agreement games, however, more complicated games like the ones based on the inversion-problem-game template need to have more sophisticated mechanisms to implement virtual players. With prerecorded games, it is possible to raise player scores asynchronously, for example when a tag is only validated in a later single player game by another user. This could help in keeping users interested in the game as their scores can change overtime without their own participation.

- **More than Two Players**

  The templates lend themselves to extensions like adding more players. This is an easily implementable change but can have great impact on the way the game is viewed by players. For example, giving points to the one who comes up with the correct guess before other players in inversion-problem games introduces a factor of competition instead of cooperation as with two players.

3.4 Evaluating GWAPs

Luis von Ahn and Laura Dabbish have also come up with means to evaluate GWAPs in order to find out if they satisfy the requirements demanded from them regarding output and playability.

- **Game Efficiency and Expected Contribution**

  If a game is viewed as a kind of algorithm it should be possible to measure its efficiency for a given problem, for example finding labels for an image. However, as it is difficult or impossible to define the notion of an atomic step for GWAPs, the notions of ”throughput”, ”average lifetime play” and ”Expected contribution” are introduced. Throughput is defined as the ”average number of problem instances solved per human hour”. Average lifetime play refers to the time an individual is likely to spend playing the game. This is important to consider game enjoyment in the evaluation. Expected contribution is throughput divided by average lifetime play. Luis von Ahn et al. advocate using the ”expected contribution” as a good indicator for the usefulness of a game.

- **Correctness**

  Apart from the mere number of problems successfully solved by a game, it is also necessary to look at the output quality. This can refer, for example, to the appropriateness of labels given to an image or tags used to describe an audio track played in the game. Among the possibilities to rate output quality are having paid volunteers work on the same task as the game players and compare the output or have experts, who are familiar with the type of data produced, judge the quality of the game’s output.

3.5 Novel Game Templates

The existing templates as discussed in the previous sections do not constitute all the possible approaches a GWAP can take, as pointed out by Luis von Ahn himself [45]. One of the notions that guide these templates is the concept of ”cooperation” or ”agreement” between the players. The following novel templates try to approach GWAPs either from an opposite angle, stressing ”disagreement” between players as a way to produce valid output or constitute a substantially different output in that players take on different roles with various tasks during the same game. It is important to note that these templates have also been created with regard to their use with medical information. It is highly probable that the existing game templates might not work for a game that is intended to collect medical information. On the one hand the users might not be interested in a game that is too focused on medical topics and prefer a more subdued approach. On the other hand it is also possible that the audience for an online health community is not the same as the one for medical GWAPs. For example, people afflicted with a certain condition are very unlikely to want to play a game relating to it. When an audience outside of health community users has to be attracted it is crucial for the proposed games to be very enjoyable for their players.

3.5.1 Cadavre Exquis Game

In this type of game, three players are taking turns in constructing semantic relationships between different terms, preferably entities. According to their current position in the game, the players take on different roles that deal either with creating a semantic statement or the evaluating one. The template name ”Cadavre exquis”, ”Exquisite corpse” in English is derived from the French game invented in the early 1920s in the surrealism movement. In the game, a drawing or a text is produced collectively by having each participant contribute part of the drawing or text according to a set of rules or starting from the previous participant’s contribution. Picture 3.9 is a typical example of the output produced by these games. In this game template, players act in a similiar way with part of the input always coming from the previous player’s turn.

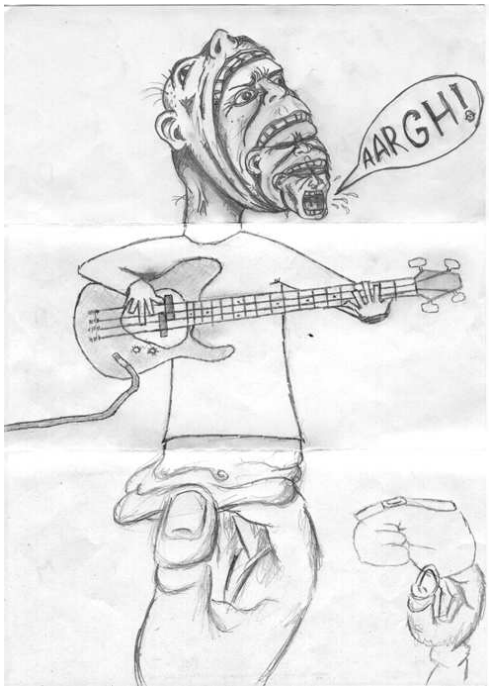

Figure 3.9: Example image of a typical cadavre exquis or exquisite corpse drawing game [6].

The first round advances according to the following steps as illustrated in 3.10:

1. Player A receives a random keyword and has to fill in a blank in a statement to relate this keyword to another term (e.g. KEYWORD looks like).
2. Player B and Player C judge independently if the term given by Player A is correct AND/OR evaluate the quality.
3. Player B has to complete another statement starting with the term given by player A.
4. Player C and A repeat the 2nd step for Player B’s result.

For the following rounds, steps 2 through 4 are repeated during a certain amount of time while always choosing the next player, rotating clockwise.

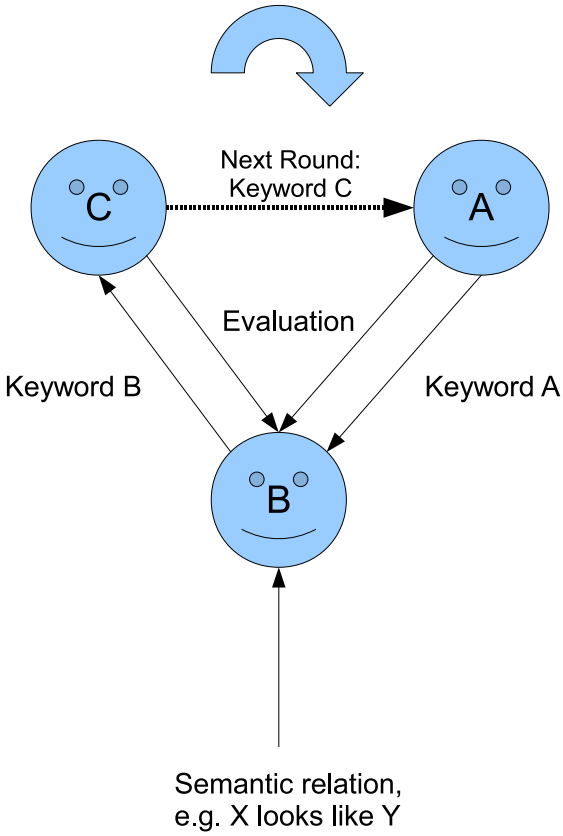

Figure 3.10: One round in a cadavre-exquis game: player B receives the keyword from Player A, constructs a statement with A's keyword and the given semantic relation and submits it to independent evaluation by Players A and C.

A general example of a game using this template while determining semantic relationships on arbitrary objects could be this:

1. Player A is given the keyword "cards" and the semantic relation "are used in ". His solution is they keyword "games".
2. Player B judges the quality of the relation "cards are used in games".
3. Player C receives the keyword "games" from Player A as well as the semantic relation "have" and produces the solution: "games have rules".
4. Player A judges the quality of the relation "games have rules".
5. Player B has to build a new semantic relation using "are the opposite of" with they keyword from Player C. His solution is: "rules are the opposite of anarchy".
6. Player C judges the quality of the relation "rules are the opposite of anarchy".
7. Player A continues with the keyword "anarchy" ...

The game can easily be adapted for various situations and has multiple options for further extensions. These can either be used for increasing game enjoyment or trying to raise the quality of the players' output. Some possible options are:

- **Arbitrary Number of Players**

  Another possibility of game variation is breaking up the rule of having 3 players in order to open up the game to a multiplayer environment.

- **Bonus Round**

  Special bonus rounds can be implemented which might yield surprising results like the transfer of the complete amount of points from one player's score to the other's.

- **Choice of Statements**

  The players can be given a choice of statements to use with the keywords. This choice can again be group-wide or even extend to giving one or several of the other players the right to make up a statement of their own.

- **Evaluation Options**

  Several evaluation options can be implemented. For example if both evaluators rate a player's output as bad, his score will be lowered If both judge it positively, the score will be raised. In case they are of different opinions no points are given. Finer evaluation scales like "very good", "good", "average", etc. with different point distribution can be used, too.

- **Order of Advancement**

  Instead of rotating clockwise between players, rules could be implemented to, for example, have several players constructing statements with their output speed and quality deciding about who receives the points.

- **"Pass" Option**

  In case a player has problems filling in the blank of a statement a pass option should be available. The other players can be given the choice of letting the player pass or not. Additionally, these passes should be recorded in the database in order to mark statements that are passed too often and thus are too difficult to use in the game.

The number of semantic statements that can be used for this template is more or less unlimited. Some suggestions are included in the list below, however the author suggests customizing the list for the actual task the GWAP should be used for or having players determine the statements.

- is a part of
- is like or is similar to
- is located in
- is often encountered together with
- is the opposite of
- looks like
- often occurs with

- usually has

Of course, as with any other GWAPs, this game type can be compromised by various attacks. To counteract possible manipulations the author suggests additional measures to the ones discussed in the general design rules for GWAPs. Two possibilities to reduce game misuse are:

- **Automatic Manipulation of Evaluations**

  The semantic statements should include negative statements that contain words like NOT, NEVER, etc. To stop players from collaborating, the semantic relation expressions are hidden from the others players until evaluation. Before evaluation, statements are randomly manipulated by inserting or removing the negations mentioned above. Evaluation results are produced accordingly.

- **Relying on Player Input**

  Another possibility is to offer players in a game with more than 3 players the possibility to remove another player from the active game or reset his point count to zero. Further options in this case could also be a transfer of points.

If the game is working correctly it can produce either arbitrary or predetermined relationships about random terms. Of course it is possible to evaluate the results using another game. Due to the flexible nature, this template can be introduced and customized accordingly for various contexts. An application for medical information is shown in the next chapter.

3.5.2 Input-Output-Agreement Game

In this game type, two or more players work together and help each other get acquainted with each other's knowledge in a certain area in order to complete a round. The players do not only agree on the input, i.e. what object they are shown but also on their output, what they would call or how they would describe the object. The actual idea stems from so-called "language tandems" a popular method for learning foreign languages where two people from different countries collaborate in order to teach each other their respective native language. A general template might be applicable to various domains of knowledge exchange.

The game rules are as follows:

1. The two players are shown a random object. Player A tries to give the correct description for the object as it would be expressed in B's knowledge base.

2. Player B verifies if A's solution is correct.

3. Player B now tries to find a description for the object as expressed in Player A's knowledge base.

4. Player A verifies Player B's input.

5. The correct solution is displayed and points are distributed accordingly.

These steps can be repeated as desired.

To come back to the ”language tandem” idea, the following are the steps for one round in a language tandem game:

1. The picture of a chair is shown.
2. Player A, who wants to learn English, is asked ”Que es esto en ingles?” He gives the answer ”A chair”.
3. Player B, whose native language is English, is then given Player A’s answer and has to indicate if this is correct or not. If yes, player A receives points.
4. Now Player B, who wants to learn Spanish, is asked ”What is this called in Spanish?”. He responds with ”Una silla”.
5. Player A, whose native language is Spanish, evaluates if Player B’s answer was correct. If yes, player B receives points.

As with the previous template this game can be extended in various ways to increase game enjoyment, for example by

- Having a ”pass option” if player can’t find an appropriate description or term for an object-
- Allowing players to give each other hints, e.g. keywords or similar sounding words, to help with finding an output.
- Using the same object for several rounds and asking different questions about it, in case of the chair in the language tandem game this could be ”What material is this object made of?”.

The language tandem version shows a promising application of the input-output-agreement game in the domain of knowledge exchange.

3.5.3 Evaluation-Agreement Game

The game is played by two players. One of them makes statements (possibly aided by blanks in sentences that describe relationships between two objects) about a given object, i.e. a picture of something. The statements are afterwards randomly manipulated on purpose by inserting the word NOT into some of them. These statements are then put out to the 2nd player who has to guess which one of the statements were not originally formulated by the 1st player.

A round progresses as follows:

1. Player A receives object and enters statements.
2. Player B receives Player A’s statements, gives evaluation.
3. Points are given for correct guesses about truthfulness of statements.
4. Player B continues with step 1.

An actual example round with one object and three statements could look like this:

1. Player A is displayed the picture of a chair.
2. Player A makes statements about this object:
    - object IS MADE OF wood
    - object OFTEN OCCURS WITH a table
    - object IS USED FOR sitting
3. Player B is displayed the same picture and these statements:
    - object IS NOT MADE OF wood
    - object OFTEN OCCURS WITH a table
    - object IS NOT USED FOR sitting

    Player B decides which statements could have been made by Player A, and which not.
4. Player B receives points accordingly

Possible options to extend this type of game can be implemented in the form of:

- A ”pass option” if a player can’t find an appropriate term for filling in the blanks.
- ”Joker options” that can remove some of the statements to make the game easier.
- Further statement manipulations like ”VERY” ”A LITTLE” in order to raise difficulty compared to the mere negation of statements.

Just like the Cadavre-exquis template, the evaluation agreement template can serve - as evidenced in the example game - for the collection of semantic statements or common sense facts. In the next section, the collection of medical information through the use of GWAPs will be discussed. For reasons of brevity, the focus will be on finding symptom information which is only one example of the kind of health data used on the web.

Chapter 4

GWAPs for Medical Information

4.1 Symptoms in the Context of Health Community Websites

4.1.1 The Definition of a Symptom

In order to collect information about medical symptoms it is first of all necessary to define what a symptom actually is. However defining a symptom is not a straightforward task. A page on the website Wikianswers shows a listing of a total of 24 symptom definitions that have more or less in common with each other [8]. The following is a selection of some of these definitions:

- ”Something that indicates the presence of a disease” [28]
- ”Anything that accompanies X and is regarded as an indication of X’s existence” [42]
- ”Subjective evidence of disease as perceived and reported by a patient” [30]
- ”Subjective evidence of a patient’s condition, such evidence as perceived by the patient” [14]

It is also necessary to note that often there is no clear distinction between a symptom and a disease. For example, torticollis or wry neck is both a symptom and a disease at the same time [16]. The SNOMED classification directly sidesteps this issue by listing both symptoms and diseases under the category of ”clinical findings” with diseases being a subhierarchy of clinical findings [31]. In general, it can at least be derived that a symptom is usually reported by a patient and is connected to a disease. Starting from this notion, it is obvious that a symptom can be associated with various attributes. However, compiling this list is again a difficult task as shown in figure 4.1, which has been taken from a presentation about electronic health records [18]. Creating these records is challenged by similar problems where symptom definitions can both be too narrow as well as too broad and thus impair system usability.

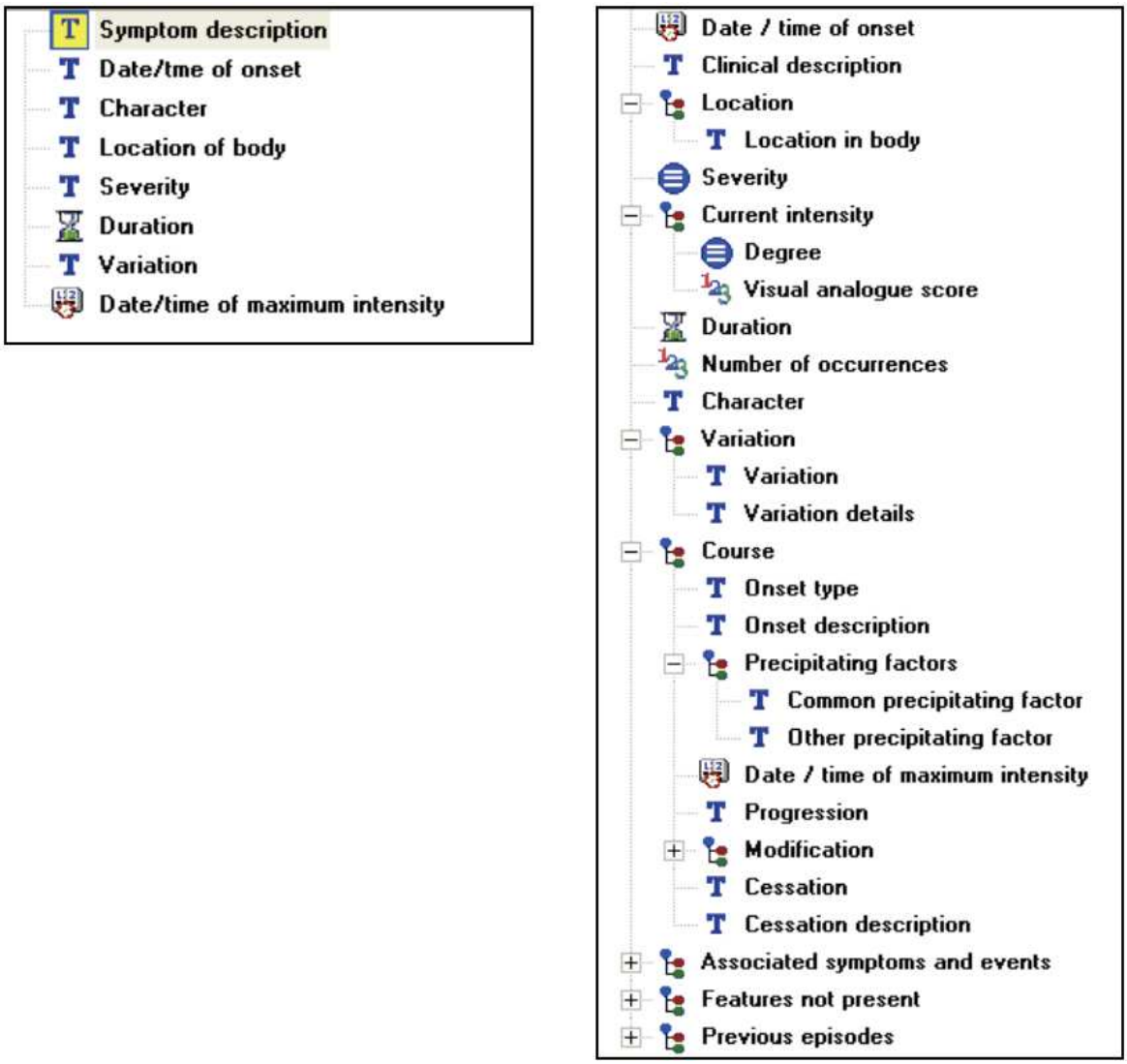

Figure 4.1: The challenge of defining a pain symptom for electronic health records - too narrow (left) or too broad (right) descriptions [18].

Attribute	ICD	ICF	ICPC	SNOMED CT	CTV3
Anatomical site	x	x	x	x	x
Morphology	x		x	x	x
Onset				x	x
Course				x	x
Episodicity				x	x
Severity				x	x
Occurrence (Temporal period)	x			x	x
Stage of disease				x	x
Number of lesions					x
Causative agent	x		x	x	
Pathological process					x
Abnormal location					x
Structural embryological defect				x	x
Associated function		x			
Associated activity	x	x			
External cause	x				
Place of occurrence	x				
Associated finding	x			x	x
Subject of information		x		x	x
Social factors		x		x	x
Environmental factors		x		x	x

Figure 4.2: Aspects of clinical findings as they have been included in various standards [48].

4.1.2 Symptoms in Medical Classifications

In the SNOMED clinical terms report-2 [48] an overview (see table 4.2) is given over the aspects of clinical findings included in medical classifications like the ICD [1] or SNOMED CT.

Based on this list, a standard incorporating most of these aspects - while admitting that it is not possible to cover every feature of a clinical finding in all circumstances - will be developed [48]. The standard incorporates the data as seen in table 4.4 with a graphical illustration including the categorial layout in figure 4.3.

[1] http://www.who.int/whosis/icd10/

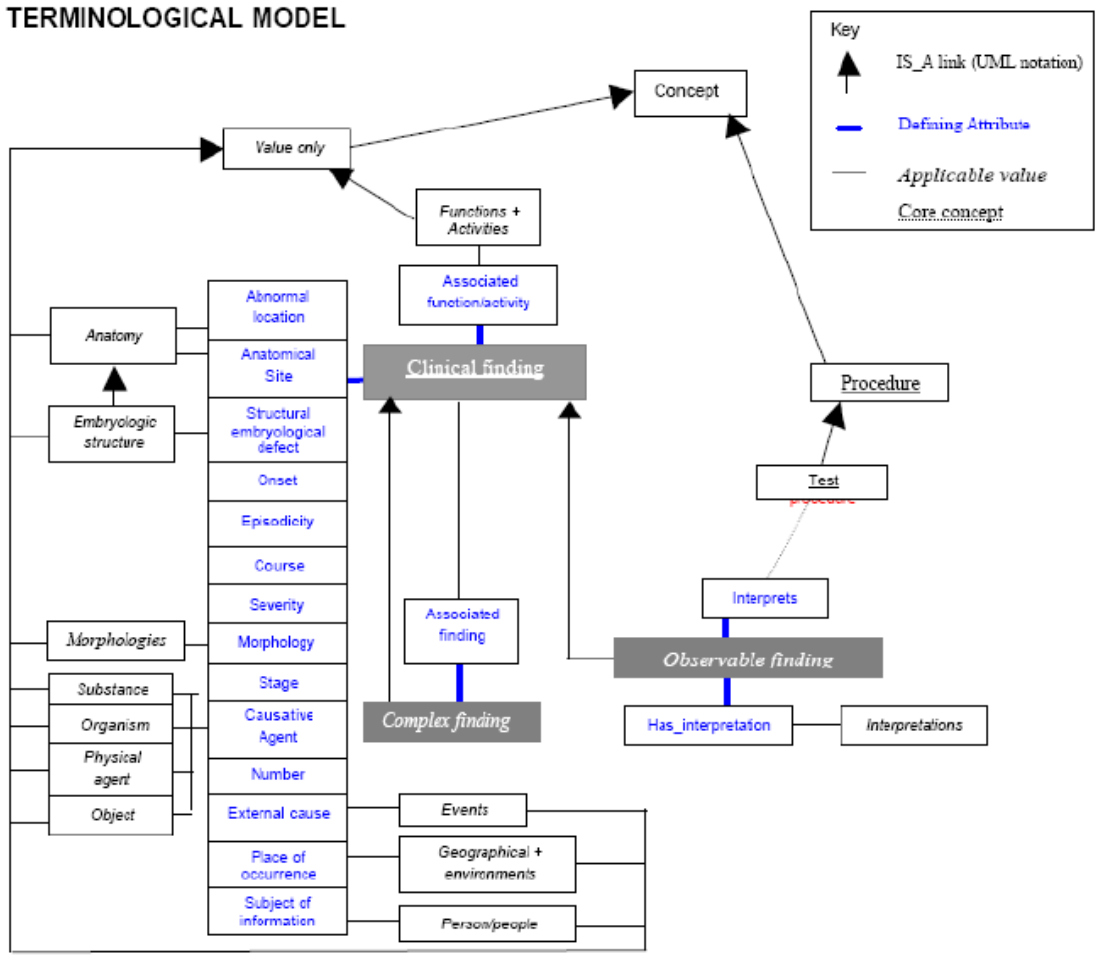

Figure 4.3: Graphical representation of a standard proposition for classifying clinical findings [48].

Attribute	Applicable value	Example
Anatomical site	Anatomical structure	Pleuritic pain
Morphology	Morphological structure	Adenocarcinoma of rectum
Abnormal location	Anatomical structure	Pelvic kidney
Structural embryological defect	Embryological structure	Meckel's diverticulum (Persistent vitelline duct)
Causative agent	Organism	Coxsackie pericarditis
	Substance	Alcoholic hepatitis
	Physical agent	Burn to foot
	Physical object	Plant thorn synovitis
Onset	Onsets (e.g. Sudden)	Sudden stoppage of urine flow
Course	Courses (e.g.Paroxysmal)	Chronic mastoiditis
Episodicity	Episodicities	Old CVA
Occurrence	Temporal periods	Morning nausea
Severity	Severities	Mild pyrexia
Stage	Stages	Membranous glomerulonephritis -stage 2
Number	Numbers	Fracture of three ribs
Has interpretation	Interpretations	Tinnel's test positive Walking ability normal
Associated function/activity	Function or Activity	Walking ability normal
	Test or Sign	Tinnel's test positive
External cause	Events	Whiplash following road traffic accident
Place of occurrence	Geographical or environmental locations	Found lying on the floor
Associated finding	Other findings	Left cerebral infarction causing right hemiparesis
Subject of information	Person/people	Fetal bradycardia

Figure 4.4: A proposed clinical finding standard based on SNOMED CT [48].

4.1.3 A List of Symptom Characteristics for Social Networking Sites

The standard proposition shown in 4.1.2 serves as a basis for devising a list of symptom characteristics necessary or useful to a social community health website like EpiHelp. A symptom specification intended for a health community website has to be balanced between between too narrow and too broad symptom specifications, as shown above. Additionally user motivation for entry of health condition details has to be taken into account. Having too many fields to enter before a possible gain from adding data to an on-site profile could scare off potential site users. The following list of symptom attributes presents a compromise between the varying requirements as well as sufficient information for further data processing after enough user profiles have been added:

- **Associated symptom**

  This refers to other symptoms that usually or often occur together with the main symptom.

- **Causative agent**

  A causative agent can, for example, be a viral or bacterial infection.

- **Circumstances**

  The circumstances under which a symptom occurs can give valuable clues for diagnosis.

- **Description**

  This item gives a user the possibility of further describing his symptom or adding notes about it.

- **Duration**

  The amount of time a symptom is present.

- **Gender specificity**

  This item indicates if the symptom only occurs or most commonly occurs with a certain gender.

- **Location**

  Often it is of paramount importance where the symptom is actually occurring in the human body. Many symptoms can occur in various body parts, for example an inflammation can be present anywhere like the sinuses, joints, etc.

- **Name**

  This is the name a symptom is usually addressed with. It is essential to have the database structured in order to save all possible synonyms.

- **Occurrence**

  Describing how often or when a symptom appears, for example ”every morning”.

- **Onset**

  When the symptom actually started to appear.

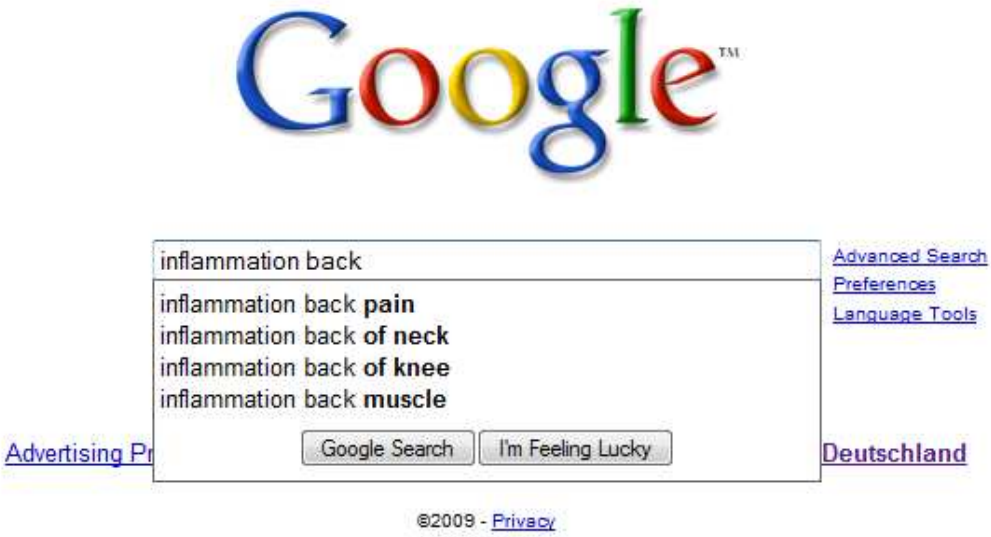

Figure 4.5: The autocompletion feature as it has been integrated in the popular search engine Google.

- **Severity**

  Rating of the severity of a symptom on a preset scale like ”very strong” or ”weak”.

- **Side Effect**

  Indicates if the symptom is a side effect of medication taken at the same time.

Certain parts of a symptom definition should offer predefined values as a basis for user input on the website. For example, when entering his health profile, a user should be supported with auto-completion or alternate suggestions in order to help preserve database integrity. Autocompletion has been popularized by the search engine Google which routinely features this function on their main search engine entry mask 4.5. When a user starts to enter for example the word ”torticollis” with autocompletion turned on, the system will present him with the desired entry before he finishes typing so that the user can directly choose the appropriate entry without the risk of committing a spelling error. This is of high value both to users by making form entry easier as well as database administrators by reducing duplicate entries of the same concept.

Thus, when considering the collection of medical information useful for a health website it is important to take into account what kind of data can add in raising site usability and which data is negligible in this respect. Information corresponding to the later category are attributes like ”onset”, ”severity” or ”duration” - these entries usually either do not have a big amount of possible values or are easily standardized to a user-friendly input form.

Certain attributes lend themselves especially well for collection using GWAPs. For example, it can be considered relatively easy to collect possible names (synonyms) or locations for a symptom. The next chapter will present the GWAP approach for some characteristics.

4.2 GWAPs for Collecting Symptom Information

4.2.1 Symptom Names and Synonyms

The first game that can be used for collecting symptom names as well as synonyms is the symptom finder which is based on the output-agreement game template that has been described in 3.2.1. Two randomly assigned players are shown the name and possibly a picture of a human organ for every round of the game. Then they are asked what symptom of a disease related to the organ in question the other player might find. A countdown is running while they are playing. The round ends either when both players type in the same name of a symptom or when time is up. Then they are shown the next organ and continue as above. After they have completed a certain number of rounds, the game ends.

In addition to the mere collection of symptom names and synonyms, which can be used for input validation when users enter symptoms on a website or to offer correction for typical spelling mistakes, the game is - by virtue of its input - also able to collect additional semantic information. In this case, for example, the symptom named is directly linked to the organ in the body and thus all the information connected to an individual organ and its location. Such data can be extended by changing the input object served to the players. Possible alternative input could, for example, be the name of a disease in which case the symptom could be linked to the disease name.

A more sophisticated version of this game can be created by feeding not one but two different objects to the players. The two objects could describe a certain situation, for example one picture of an organ or body part and one of a typical everyday situation. Players are asked what symptoms they think the other would ascribe to a certain situation. A possible combination is shown in figure 4.6. After a round is ended, pictures change to a new situation.

However, it is also possible to just vary one of the pictures and thus focus on collecting symptoms for mainly one type of situation or for certain body-parts or organs as shown in figure 4.7. This scenario game could also help to make a medical GWAP open to a broader audience of non-health care professionals who are not interested in playing a game that is solely based on medical pictures and information alone. For this, additionally game changes like changing the posed question to a more subdued way as in ”How do you think the other game player could feel in this situation?” could be made. Naturally, further objects can be added for the players to see which will increase the detail of collected data. Unfortunately this can also lower game enjoyment and data quality if taken too far.

Figure 4.6: Two input photos to describe a situation in which symptoms can occur [13], [12].

Figure 4.7: Another round with only one situation photo changed [13], [21].

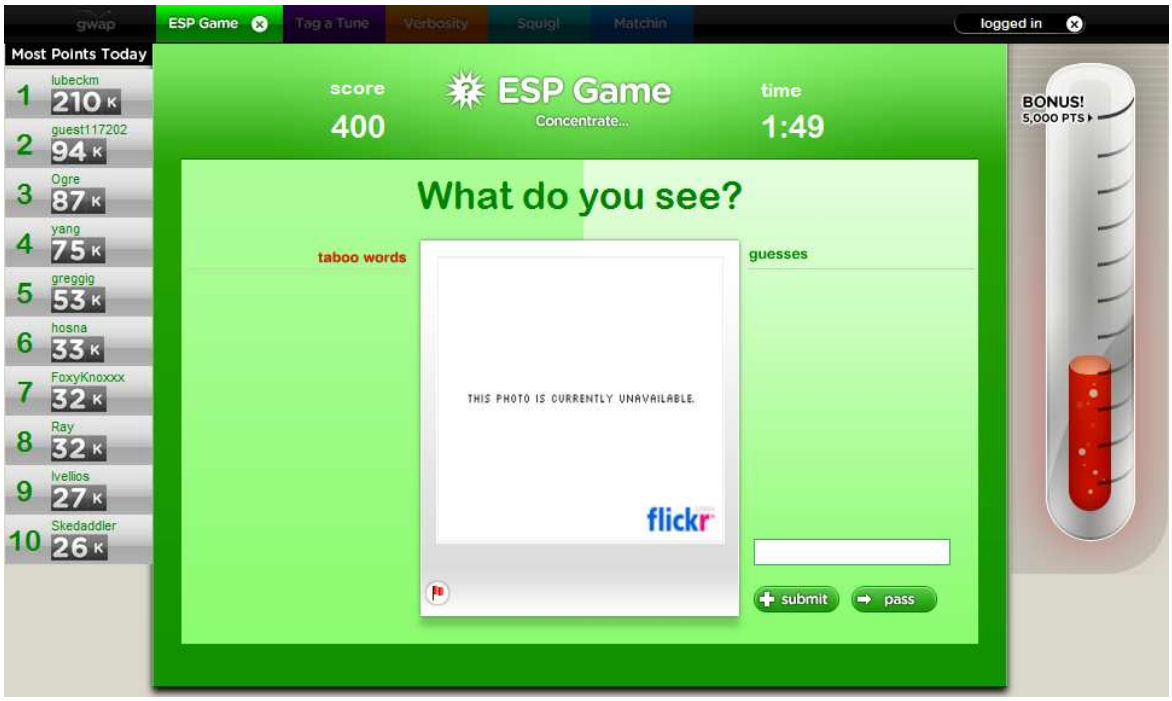

Figure 4.8: The ESP game gets its photo input from flickr as can be seen from the flickr error message in this screenshot.

The photos used in such games can be taken from online resources offering photos in the public domain or with licenses that allow use in such games in either an academic or commercial setting. One example is the photo sharing site flickr which is also one of the sources for Luis von Ahn's ESP game as evidenced in screenshot 4.8.

With the described games it is possible to collect symptom names as well as synonyms like laymen terms. For example, torticollis is usually referred to as "wry neck", and as such probably the more common input a site user would enter as a symptom name on a medical website. This game type also lends itself to easy extension to other types of medical data like disease names or treatments. Disease names could be collected by displaying a list of symptoms or the description of a disease and asking for the most likely disease fitting to the list or description.

4.2.2 Finding Arbitrary Information Related to Symptoms

Another possibility for finding various kinds of symptom-related data is based on the inversion-problem game template. In contrast to the previous games it is possible to find many different symptom characteristics, which have been described in detail in section 4.1.3, with the same game. As directed by the game template, one of the player takes the role of the narrator while the other is the guesser. The narrator is given a number of sentence templates as well as the name of a symptom. Then he has to describe the symptom by filling in the blanks in the sentence templates. At the same time the guesser starts to guess the symptoms that could fit the narrator's description. In case the guesser arrives at the correct symptom the players have won the round and advance to the next one where their roles are changed. Some possible sentence templates that can be used in this context are:

- is usually treated with ___ (can be used to find treatments associated with a symptom)

- often occurs in conjunction with ___ (for finding associated symptoms)
- can be caused by ___ (indicates the causative agent or disease)

With semantic associations like these, it is possible to collect a lot of the symptom information that is necessary to support website users during form entry or to evaluate existing medical data. A game can be made easier by permitting several possible answers by the guesser through the use of symptom synonyms as collected in the previous game. It is also important to note that this type of game is not confined to symptoms, it can also be used for disease information or - depending on the game audience - to find the possible side-effects of common drugs.

4.3 Further GWAPs for Medical Information

The symptom games that have just been presented are only one small part of the information that can be collected with medical GWAPs. Game versions based on all the different templates, both the ones developed at Carnegie Mellon University [45] as well as those presented in this thesis, should be possible. The cadavre-exquis game template, for example, can be used to create games that have users associate various medical concepts with each other. For example: X is used to treat Y, Y usually has the symptom Z, Z is a common side effect of A, etc. It might be necessary to confine the possible semantic relations to a certain number of statements that can be used in a medical context. Furthermore, restrictions could be placed on the keyword topics that can be entered. For example, in the previous example X could only be a treatment option while Y would be restricted to the names of medical conditions.

Another interesting template for further exploration is the input-output agreement template which can be used for knowledge exchange. It might be used for knowledge communication between experts of medical fields that work on the same condition, for example radiologists and cardiologists. Additionally, applications of this game template in student teaching or tutoring are an option.

Naturally, the templates presented by the author are likely to be only a small part of game types that can be created as GWAPs. Further research is necessary to reveal other templates, both for general and health care use. An approach to implementing a GWAP in such a way that changing templates and adding functionality does not entail substantial modifications of the implementation is presented in the next section.

Chapter 5

Implementing GWAPs

5.1 Objectives for a Generic Approach

Starting from the templates and architecture of the GWAP games as presented in previous sections, an approach towards a generic GWAP implementation has been developed with several preset goals in mind. This approach tries to supply programmers with as much detail as possible regarding structure of data storage, business logic and presentation while preserving as many options for later extension as possible.

Considering further extensibility, care was taken in order to keep all requirements and definition at the most general level so that any kind of specialization or customization can be introduced easily. For example, the database design was realized in such a way that additional tables can be introduced seamlessly for most requirements. The controller has been designed using tools in order to make extension with additional functionality only a minor change. Compatibility with other common formats has been preserved as far as possible. Due to the separate handling of application logic, it is possible to recombine parts of the business logic referenced by the application logic for quick development of new application variants.

Furthermore, both the design process as well as the actual software deployment should be possible using freely available open-source software. Next to the cost aspect, open-source software offers several other benefits over closed software [35]:

- **Peer Review**

  As the software is developed and tested by anyone interested, bugs and errors can be found out and fixed more quickly than in traditional software projects.

- **Propagation of Standards**

  With the wide availability of open-source software it is especially conducive to introducing standards.

- **Higher Quality**

  Due to a theoretically unlimited number of highly motivated contributers, software quality can be significantly improved over closed software.

- **Future-proof**

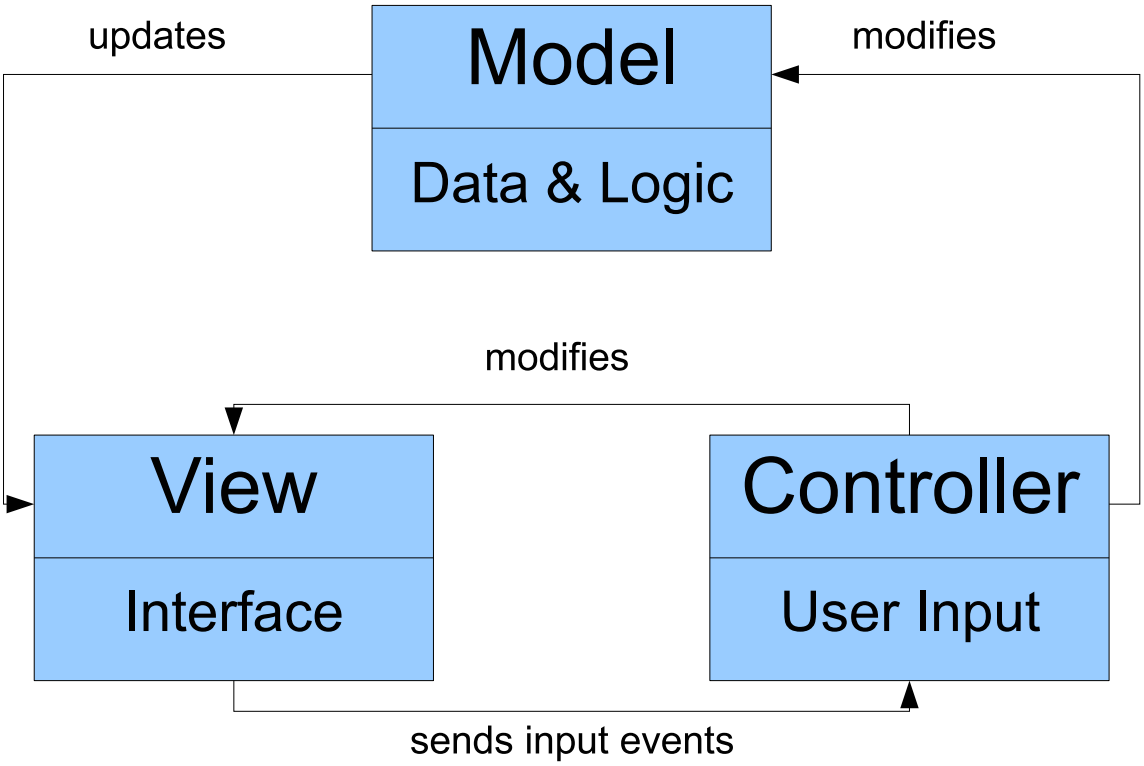

Figure 5.1: Communication between Model, View and Controller [24].

With the source code being freely available it can be changed by anyone and thus if the original developers of a project stop working on it, it can always be taken over by someone else.

The Model-View-Controller paradigm lends itself naturally for use under the circumstances outlined above as it inherently separates data access, business logic and user view. Applying this kind of separation can prove very useful for component reuse and help in software maintenance [22]. Considering the variety of GWAP game templates, it is crucial to make components available for reuse so that the implementation has to be changed only slightly to satisfy different requirements. Figure 5.1 shows the components of a Model-View-Controller architecture and communication between them. The model represents the actual data, often a relational database, and business logic being used by the application. If or how much of the business logic is included in the model or in the controller is a controversial topic [25]. However, a proper implementation of the MVC paradigm is usually considered using so-called ”skinny controllers” and ”fat models”, where the latter contain all of the business logic [49]. The controllers are then solely dealing with application logic [34] with the presentation logic being confined to the view. Data manipulation by the user, interacting with the view, does not happen in a direct way but is conducted through the controller. Thus, the view can be changed independently of the model or the controller. There are variety of open-source frameworks available which are based around the MVC pattern.

In the next sections, the different layers of a GWAP implementation will be presented in a manner corresponding to the separation needed for model, view and controller.

5.2 The Data Model

The data model that serves as a basis for the GWAP implementation was created with the overall goals for the GWAP implementation in mind. It should both satisfy the requirement of extensibility as well as genericity. Furthermore, in case of heavy usage, the possibility of splitting the database over several servers in a sever farm to reduce load should be available. As has been stressed in the first section, open source tools and technology are preferred over closed source commercial solutions. This makes relational databases the first choice due to their widespread usage and good open source software support. Consequentially, the database schema was created for a database running on a MySQL Enterprise Server 5.0. MySQL is a popular open source solution offering common features like compliance with ACID principles and crash recovery [1].

Furthermore, during the design process, close attention has been paid to common design practices in order to avoid mistakes that might prove hazardous to stability or scalability [7] [9]. For example, as during a game only taboo tags, blacklist words and the objects have to be displayed, this is unlikely to be a performance critical task. Additionally, any write actions can be postponed until the end of the game. Thus, normalization has been applied as far as possible in order to reduce database redundancy. Close attention has also been paid to naming standards in oder to make consistent reference to database items possible.

Figure 5.2 shows the structure of a generic database for GWAPs. The user entry is connected to both the object tags, which are collected during the game, as well as the game players entry. The reason for this is that both the connection between individual users and their entered tags as well as their participation in the individual game sessions has to be preserved after a game ends in order to realize score keeping and make sure that no game manipulation has occurred.

The database contains the following tables:

- **BlacklistWords**

  The terms saved in this table are words that should be filtered from user input and not be accepted. Usually this will be the case with swear words and other inappropriate language which could either be used to discourage other game players or even cause legal problems.

- **GameSession**

  The table GameSession represents one session of a certain game type that consists of several rounds and ends after predetermined timeout.

- **GamePlayers**

  A game player is a site user that has started playing and thus entered a game session. All game players are always attributed to the corresponding game session, their number is not restricted and thus it is possible to extend any game to more than 2 users.

- **GameType**

  The GameType table is used to save the type and description for a game in order to preserve information about what kind of game session was played. For example variations in game structure, timeouts, etc. can be kept track of in this way.

[1] http://www.mysql.com/products/enterprise/server.html

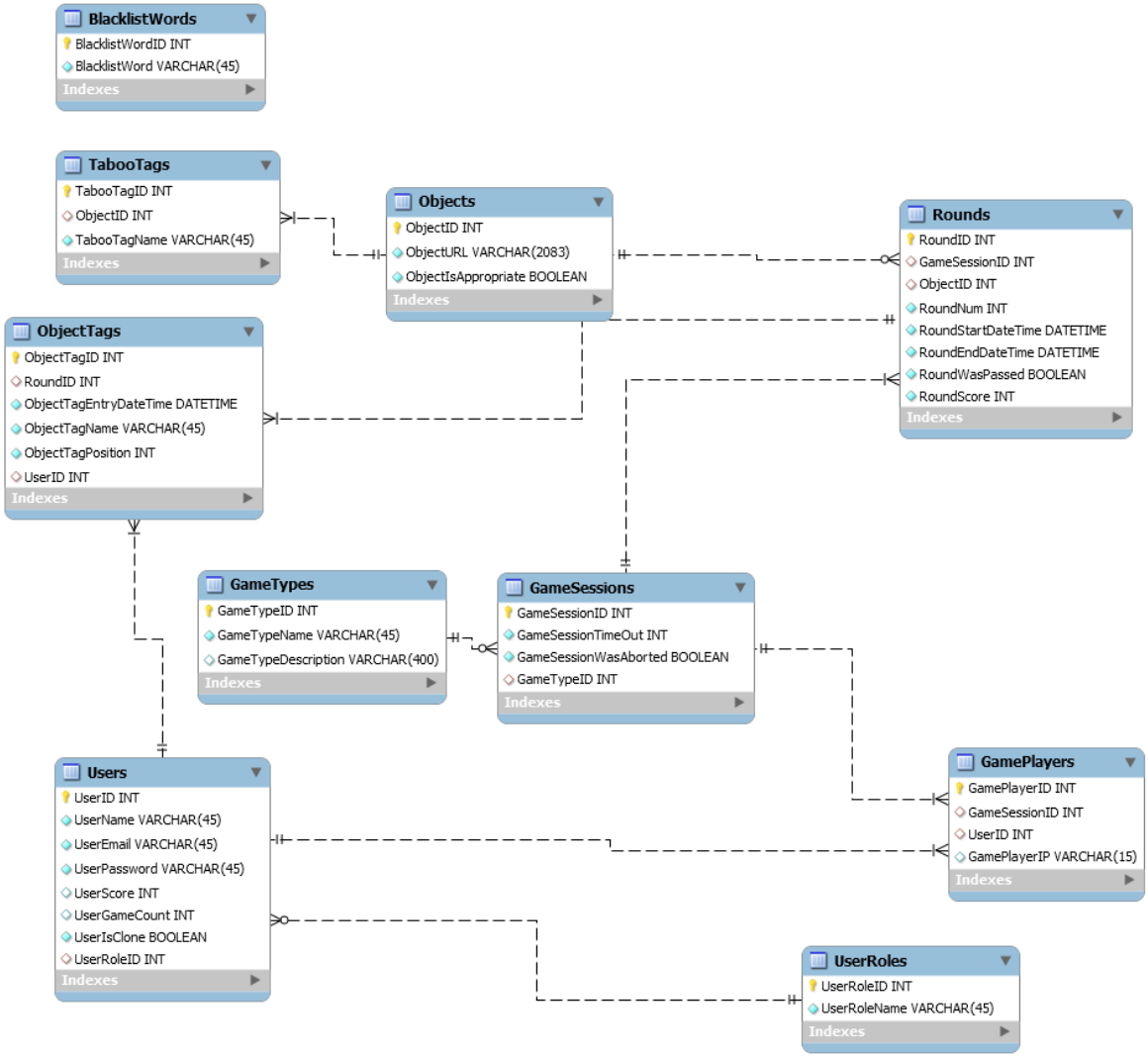

Figure 5.2: Database layout for a generic implementation of GWAPs.

- **Objects**

  This table refers to the objects that are input for game rounds and for which information like tags can be collected. In case an object, for example a photo, is deemed inappropriate for the game audience it is possible to mark the object by setting the flag accordingly.

- **ObjectTags**

  The terms entered by game players as a means to describe the object are associated with the rounds they were entered in as well as the actual user who typed them. The position and the date & time for the entry are saved to make realistic user cloning for game sessions with an insufficient number of connected users possible.

- **Rounds**

  A game session as presented above is made up of several rounds. Each individual round is associated with an object for which the terms input by the players are collected as tags. A round number is saved to mark the position of rounds in a game. Further information that is retained from a round is the start and end date & time, if it was passed or not and the round score. Most of this information is essential for replaying a round as a clone user (see Users table for more information about this).

- **TabooTags**

  TabooTags are terms that game players are not allowed to use for describing an object displayed to them. A typical application of this constraint is when certain words have been input so many times for an object, that no further validation is needed for them to be accepted as appropriate tags. In that case, these tags can be moved - either automatically or manually - to the TabooTags table.

- **Users**

  This table contains the users registered for website usage. As the table shows, typical additional user information like usernames, email addresses and passwords can be saved. It is also possible to keep track of the points users have scored in games as well as the amount of games played. Additionally, a column is offered to mark users that have been generated as a clone. These user clones are necessary if the number of connected game players is not sufficient for a certain game type and some players have to be computer generated. This will often be possible by copying the user interactions recorded from a player in an earlier game to a new user and marking this account as a clone.

- **UserRoles**

  This item describes the roles a site user can have in regards to privileges. For example there can be normal users or those that have administrator privileges. The database layout does not constrain the number and type of user roles, thus making more complex site user privilege management possible.

After creating the tables described above, an SQL create script was created directly out of MySQL Workbench. Various triggers have been included in order to keep consistency in the database. Some data can become obsolete when certain tables entries have been deleted.

For example, if a game session is deleted, it is of little use to keep the game players or rounds associated with it. If a user role or game type is changed, this should be propagated to the tables referencing these values. However, if a user role is removed from the database, it is still necessary to keep the users that had this role - albeit with the user role value set to null.

The database has been designed in such a manner that extensions can be integrated with little effort. Possible extensions can be applied in various areas like adding statistic information for game research or implementing further templates. Examples of additions are:

- **Asynchronous Score Keeping**

  Adjusting player scores can either happen directly after the end of a game session, or it can happen at some point later in time as described in section 3.3. Naturally, an option should be introduced to keep track of game types that are part of this asynchronous score changing, for example realized through a flag in the game types table.

- **Handicap**

  A handicap refers to a possible option that can change how points are distributed to player scores. For example, an experienced player could receive less points in easy games or other similar rules.

- **Normalized Tags**

  The layout as presented only saves the tags as entered by the users. However, as a more sophisticated algorithm for matching entered tags between users is desirable in the business logic, once such an algorithm is in place it makes sense to save its output to the database. This can then be helpful when analyzing data gained from the games.

- **Object Randomization**

  There are different ways for an application to retrieve random objects from the database. One way is to rely on the unique object ID, however in MySQL when one of the objects is deleted, its unique ID will not be reused. Consequentially, when an application is getting a random object based on the unique object ID and the object count it will then not yield random results anymore. Random functions in database management systems like MySQL are often too slow for a high count of entries [11]. In this case, other approaches have to be taken which can include adding a special column to the existing table.

5.3 The Application Logic

As explained in the first section of this chapter, using the MVC paradigm as a basis for the implementation, the controller is where the application logic resides. The objectives concerning extensibility and reuse imply using a formal way to define application logic. It is possible to do this with flow charts, but a more advanced way of application logic representation is using UML activity diagrams which are part of the UML standard [23].

The jBPM platform, a JBoss Enterprise Framework that offers business process management (BPM), is based in many aspects on the UML activity diagrams. Thus, it is a convenient way for defining the application logic. Its strength is that it can be directly integrated with JBoss SEAM, a powerful open-source framework supporting MVC, as well as

the popular Eclipse integrated development environment offering a graphical tool for defining business processes. A special process definition language, the jBPM Process Definition Language (jPDL) is available for this task [2]. It has several elements for describing business processes with the main ones listed below [33]:

- **Decision Nodes**

  Arriving at this node, several transitions are possible where the first one with a condition evaluating to true will be chosen

- **Forks**

  The execution of multiple process paths can be realized by using a fork.

- **Joins**

  At a join node, multiple execution paths are ended and process execution is continued once all child processes have completed.

- **Standard Nodes**

  A normal node is used when the execution of a task is automatic as soon as the node is reached.

- **Start and End Nodes**

  These nodes mark the respective beginning and end of a business process.

- **Swimlanes**

  A swimlane assigns a specific user or user group to a task in a business process.

- **Task Nodes**

  This node refers to tasks that are assigned to humans, thus the next node will only be executed once the user has fulfilled his task.

- **Transitions**

  Transitions mark the flow from one node to the next during process execution.

Figure 5.3 shows the activity diagram for a GWAP implementation created using the jPDL graphical process designer plugin in Eclipse. The game session process starts and directly forks to the user-assigned tasks of starting the game. Once both users have started the game the respective execution paths are joined and then forked again. This is necessarily to implement the timeout, so that after a certain amount of time has passed the game finishes automatically. Additionally, an exit function that ends the game when one of the users has quit should be implemented, too. If the game has not timed out and no user exits, one of the game objects is displayed for both users after which they give their input tags. These are then checked for blacklisted words or taboo tags which cannot be input. If the users' input passes this check, it will be subjected to the tag matching where a positive result will raise the users' score and the next object is displayed. Otherwise, the users continue to enter tags for the same object. In case one of the users decides to pass an object because he has difficulty in finding an appropriate tag, the pass is only executed when the other user passes,

[2] http://www.jboss.com/pdf/jb_jbpm_04_07.pdf

too. As described above, the game only ends when the timeout is reached or one of the user quits.

This process definition already splits tasks like blacklist and taboo tag matching up between the clients. This is important because most of the processing should be done on the clients so that the server does not get overloaded during times of heavy usage. Having a server crash, react too slowly or declining some users the possibility of playing could have negative effects on the users' opinion about the website and consequently lower site popularity.

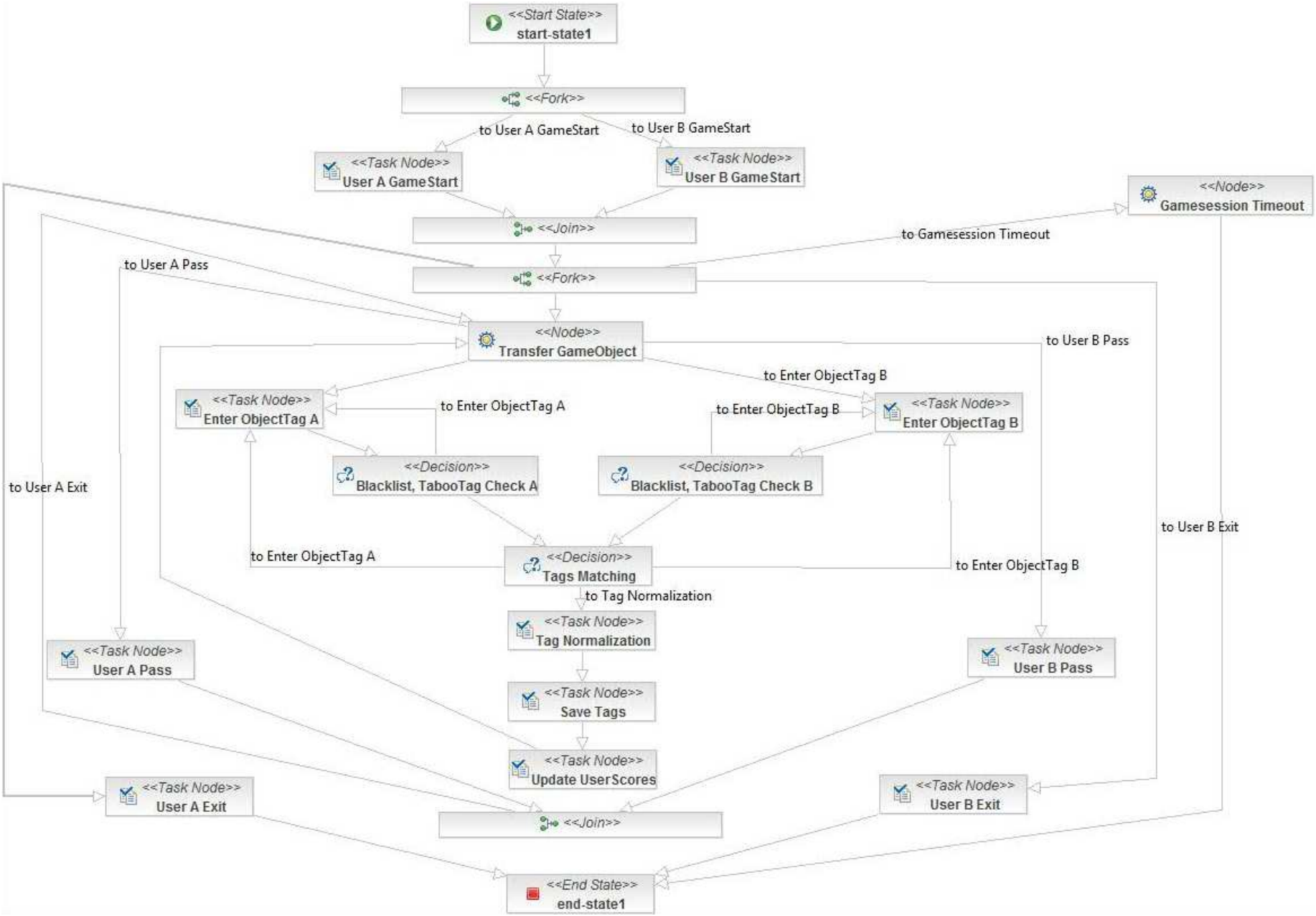

Figure 5.3: Application logic for a general GWAP implementation.

5.4 The View

The view for a GWAP is usually not very complex with only the following pages being necessary for a typical game:

- **Admin Page**

  For all the administrative tasks concerning the site and the game data contained in the GWAP database a site should be available to manipulate this data. Depending on the functionality and technology used for the webpage it can extend to one single page or link to several other admin pages.

- **Game Manual**

  This page is reserved for offering a user manual on a game with instructions and descriptions.

- **Game Session**

  Whenever a game is started, this page is called up. During a game the content changes dynamically along with the various game rounds. Usually this requires some technology like AJAX where parts of the page are updated through the usage of JavaScript and remote calls to the server.

- **Home**

  The starting page for the GWAP games which links to all the other pages related to the game.

- **Register**

  A page for registering a user account on the website in order to preserve game scores and identity for on-site actions.

- **View Account**

  The user should be given the possibility to view his scores and statistics from previous games as well as any additional information.

Figure 5.4 shows how the different pages are interconnected with each other. All pages are reachable from the home page of the games while a game can be started from both the start page as well as the game manual page. Individual instances of these two pages need to exist for every different game. Information like high score lists are best shown as part of the existing pages - for example on the home page or in the corner of the game session page.

The view can easily be extended further, but usually a GWAP will be embedded into a bigger site like a social community. Features like user presentation pages and communication widgets like chats are often part of the website integrating the game and do not need to be added individually for the games.

5.5 Possible Further Extensions and Actual Implementation

The process flow as described is only a basic layout applicable for standard templates like the input-agreement or the output-agreement game. Additionally it does not support multiple

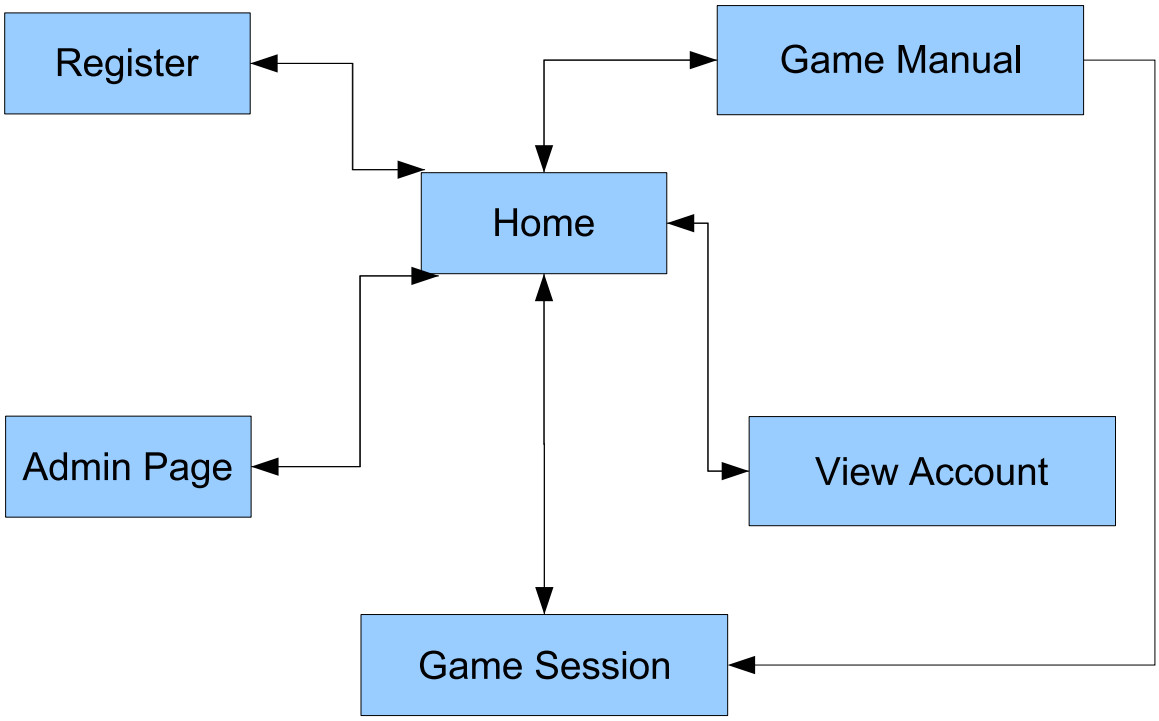

Figure 5.4: Screenshot of business process management information saved in a MySQL database.

users or single player games. These features as well as further extensions can be introduced into the application logic as well. In this case, the notion of process states as available in jPDL can prove useful [33]. It makes it possible to call subprocesses for execution and wait until a subprocess has finished for the superprocess to continue. Thus, for multiple users, subprocesses can be called from a super process where the single player game can be expressed as well.

Another interesting extension is the use of business rules with a rule management system like Drools [3]. This is especially useful when a potential game contains a lot of business logic that changes often or should be changed by personnel which is not familiar with the actual programming environment. Rules can be easily formulated in the following manner:

```
rule ShipOrder
  when
   InStock(value == Yes)
  then
   order.ship();
end
```

Having application logic implemented through a business process management also yields the possibility of long-running GWAPs. Business process states are usually stored in a database so that processes can span any preferred amount of time. Figure 5.5 shows the various information that is saved about a business process so it can be resumed again at any point of time. A GWAP could then for example have a group of players solve complex problems over the course of several days or even weeks.

[3] http://www.jboss.org/drools

jbpm
All tables of the jbpm schema

Table Name	Engine	Rows	Data length	Index length	Update time
jbpm_action	InnoDB	3	16 kB	144 kB	
jbpm_bytearray	InnoDB	0	16 kB	16 kB	
jbpm_byteblock	InnoDB	0	16 kB	16 kB	
jbpm_comment	InnoDB	0	16 kB	64 kB	
jbpm_decisionconditions	InnoDB	0	16 kB	16 kB	
jbpm_delegation	InnoDB	0	16 kB	32 kB	
jbpm_event	InnoDB	2	16 kB	64 kB	
jbpm_exceptionhandler	InnoDB	0	16 kB	0 B	
jbpm_job	InnoDB	0	16 kB	128 kB	
jbpm_log	InnoDB	0	16 kB	208 kB	
jbpm_moduledefinition	InnoDB	2	16 kB	48 kB	
jbpm_moduleinstance	InnoDB	0	16 kB	48 kB	
jbpm_node	InnoDB	17	16 kB	160 kB	
jbpm_pooledactor	InnoDB	0	16 kB	48 kB	
jbpm_processdefinition	InnoDB	1	16 kB	32 kB	
jbpm_processinstance	InnoDB	0	16 kB	112 kB	
jbpm_runtimeaction	InnoDB	0	16 kB	64 kB	
jbpm_swimlane	InnoDB	3	16 kB	32 kB	
jbpm_swimlaneinstance	InnoDB	0	16 kB	48 kB	
jbpm_task	InnoDB	1	16 kB	160 kB	
jbpm_taskactorpool	InnoDB	0	16 kB	32 kB	
jbpm_taskcontroller	InnoDB	0	16 kB	16 kB	
jbpm_taskinstance	InnoDB	0	16 kB	160 kB	
jbpm_token	InnoDB	0	16 kB	128 kB	
jbpm_tokenvariablemap	InnoDB	0	16 kB	64 kB	
jbpm_transition	InnoDB	23	16 kB	96 kB	
jbpm_variableaccess	InnoDB	0	16 kB	48 kB	
jbpm_variableinstance	InnoDB	0	16 kB	128 kB	

Figure 5.5: Screenshot of business process management information saved in a MySQL database

After the finalization of the data model, controller and view definitions, the author began work on a concrete implementation according to the objectives outlined before. However, due to the necessity of finding new templates for the collection of medical data, the time span of this thesis did not allow for the finalization of a full GWAP implementation. As has been mentioned in section 3.5, the standard templates have a high probability of being unfit for medical data. In addition to the work that was necessary for template research, the SEAM framework [4] designated for the reference implementation employs a wide range of different web technologies like JavaServer Faces, AJAX or jBPM. While it is easy to create standard web applications, the implementation of a GWAP necessitates a deeper familiarization with these technologies. This proved to be too time-consuming a task for full completion in the scope of this thesis. So far, the database and business process integration as well as part of the user synchronization has been realized. Christoph Wieser, who is currently a member of the teaching unit ”Programming and Modelling Languages” will continue the GWAP implementation based on the existing work.

[4] http://seamframework.org/

Chapter 6

Conclusion and Future Work

This thesis discussed the use of human computation for collecting and enriching medical information in the context of a social networking site. Next to other common social features used by this genre of websites, the Games with a Purpose that have been presented can serve as a valuable addition. With the creation and sustainment of a user base being one of the most important tasks in starting a website, these games can play an important part in contributing to a site's success. However, the enjoyability of GWAPs is not the only reason for their use. These games are commonly used to solve various problems for which a solution would otherwise be difficult or impossible to attain. In this thesis, several applications of them for use with medical information were presented. It is possible to generate new collections of interesting data as well as refining existing information - a task that often fails because of scalability, which is no or only a minor problem for GWAPs. The implementation outlined in the thesis can serve as the foundation for a multitude of games derived from both the existing as well as the new game templates presented.

These templates are only a small fraction of the games possible and still leave a variety of game types open for further exploration. Potential new templates might be based on existing traditional games. Maybe some of the social features of online communities can be integrated in novel game types. In addition to the creation of general templates, there are many different applications for the usage of GWAPs with medical data. While this thesis only extended to information related to medical symptoms, the vast amount of data about other topics like disease treatment or treatment procedures can greatly benefit from validation and semantic enrichment processes, too.

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