User Modeling and Personalisation in Search for People with Autism

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Abstract

The current proposal presents my objective to research and build a user model and web application, for individuals on the Autism Spectrum, within Search. The model will be built around the core features of Autism, and applied to search results returned from a synthesis of three leading existing search engines. The web application will also be integrated with motion-controlled user interfaces (UI). The project will provide novel insights into the needs and wants of individuals with Autism within search, and enable future development and interventions within these information streams and communication channels.

Contents

*This proposal is substantially the result of my own work, expressed in my own words, except where explicitly indicated in the text. I give my permission for it to be submitted to the JISC Plagiarism Detection Service.

Abbreviations

API	Application Programming Interface
ASD	Autism Spectrum Disorder
DSM	Diagnostic and Statistical Manual
GCS	Google Custom Search
HCI	Human Computer Interaction
JSON	JavaScript Object Notation
KWIC	Key Word In Context
TDD	Test Driven Development
UI	User Interface
UX	User Experience
VR	Virtual Reality

1 Introduction & Background

1.1 Problem Statement

People with Autism are less context-sensitive and prefer a more detail-focused processing style [32], and they form web-search queries very differently to the typical population. Individuals with Autism are also less likely to engage in a relational (hierarchically organized) style of processing [29] suggesting that relating information in a hierarchically organised framework is less likely. Hierarchical organisation implies a great deal of flexibility and mental-shifting, as a simple example, in a search for 'apple', it would imply awareness that the word is related to 'pear' but also to 'fruit'. Awareness of this latter relation also suggests awareness that 'apple' is related to 'pomegranate'. This is of course, a simple example, but these associations can get very complex very quickly. Generally speaking, individuals with Autism prefer, and are more likely to engage in an item-specific processing style, and, whilst intelligent cognition is definitely possible, web-search queries are more likely formed of first-order associations[1].To address this issue, the current project aims to build a user model within Search for individuals with Autism.

1.2 The Role of Context Within Search

It is unlikely that any given page on the web will contain a word or phrase that means exactly (or nearly) the same as another word or phrase in that language (e.g., shut and close). How is it then that your search engine picks these phrases to mean the same thing, and returns them synonymously in the results of your query? Well, quite simply put, it is by virtue of the fact that each of their neighbouring words and associations are similar. These are indirect, higher-order associations, and provide the context in which the search engine index keywords.

Most search engines apply user models to refine user search queries. These models can often lack specificity for users/groups of users [2]. Although adaptive search engines have now become prominent (using search history, locale, and demographics to guess the user's intentions) these models make several a priori assumptions about users from specific subgroups. Based on the Psychology literature, general user models and the needs of the user with Autism differ. Despite Autism being amongst the most common neurodevelopmental condition (1/68 children meet criteria for Autism Spectrum [9]), no user model has yet been developed for Autism.

According to the Diagnostic and Statistical Manual (2013), Autism is characterized by persistent and early deficits in reciprocal social interaction, so interaction with computers is prominent in this group. It is also well established that individuals with Autism are more engaged when using technology that is receptive and interactive (e.g., games, responsive consoles, motion controlled devices) compared to technology that is not [3], this project will combine interactive, motion recognition hardware with Search to also improve the UI (user interface) of Search for individuals with Autism.

1.3 The Downfalls of Current Search Tools for People with Autism

The Internet is one of the largest resources of information. Search engines allow users to collate hundreds of links on a single topic, using only a few words or phrases. The typical user sorts the returned results into 'relevant' or 'irrelevant' categories, flexibly shifting (mentally) between one result and the next, to determine the relevance of each page returned by the search engine. Search allows the user to assimilate the information on the page into their knowledge and is an important learning tool. For people with Autism, the requirement is no different; search is an important tool for learning. However, current search is not adequate because the requirement to 'mentally shift' between results is far harder for people with Autism [18]. The information is therefore harder to assimilate and learn for them.

Individuals with Autism have poor attention [17]. The static 2-dimensional interface of many current search engines are unlikely to maintain adequate (sustained) interest levels. Individuals (and especially teenagers) with Autism spend a substantial amount of their time using computers, web, portable or console devices [10], as they find these more stimulating and attention-grabbing. For these individuals, computer-based technologies provide a stable, consistent learning environment that can be customized [4]. Furthermore, motion recognition devices can be programmed to make consistent responses to environmental triggers. These controlled and interactive environments have shown promise for improving social communication skills and

[1] Of course there is a great deal of individual variability in the Autism Spectrum.

reducing repetitive behaviours [1]. For the current project a motion-controlled learning environment will be bolstered to improve attention within search for people with autism.

Current search is text-ridden and extremely verbal. This is a problem for people with Autism because they have a stronger visual memory [15] than verbal memory. A more visually-oriented approach to search (reducing the 'verbal working memory' load [5]) is a more appropriate way to bolster the strength of visual memory in people with Autism.

Many search engines are Adaptive or Personalised, and associate each user with a HTTP-cookie containing information such as login (gender, age), preferences (languages, interests) and previous search history. This allows the website to remember what buttons the user clicked on, or sites visited, and allows the search engine to return results that are highly related to pages that the user visited through previous searches. Although adaptive search seems to have significant user benefit in terms of relevance of returned pages to the user, it decreases the likelihood that the user encounters new information, biasing the results towards the users location and previous site traffic. This has the unwanted effect of creating a filter bubble [14], which is argued to close us off from important and relevant information. It creates a personal ecosystem of information for one user, giving the impression that their self interests are all that exist [2]. Unfortunately the filter bubble may positively reinforce restricted interests in Autism as the user constantly receives feedback about their previous (idiosyncratic and personalized) searches without being able to break out of that repetitive loop.

Research has suggested personalization also increases background noise relative to the search results [7], with a carry-over effect in personalized search, where prior search influences the results from subsequent searches [3]. This carry-over may be particularly disadvantageous for people with Autism (some of whom already have restricted and repetitive interests) as it muddies their search space. To produce a search tool specifically tailored to reduce the filter bubble effect in Autism, widen the information gateway and reduce the possibility for restricted and repetitive searches, the weighting on previous search results will need to be reduced. This is something I will investigate in the project, particularly for individuals who identify restricted or repetitive interests. For these users, it would limit the possibility that they get trapped in a spiraling loop of ever-narrowing user-relevant information and over-personalization of self-reinforced information ecosystems.

1.4 Existing Combination/Advanced Search Engines

I will first synthesise results from a combination of search engines, before appling my user model of Autism to filter them. Existing solutions for the synthesis of search results already exist, and the ones of note include **'Bing vs. Google'**, which presents search query results from Bing and Google side-by-side, allowing the user to make a comparison, and providing the experience of navigating both search pages simultaneously. Alternatively, **'Qrobe'** combines three search engines results (Google, Bing and Ask) on one page, but the user can also search web, images or popular. **'AskBoth'** combines both Google and Bing results, integrating a section in the middle, dedicated to a twitter feed. **'Spectra'** attempts to include user preferences by combining results from Google, Bing and Yahoo and allowing users to assign 'weights' to each engine. However, the number of personal preference options is very limited. In addition, there is often double (or triple) the amount of verbal information on the results page, resulting in verbal (and cognitive) overload for users with Autism, as well as redundancy (near-duplicates). Furthermore, where an RSS-feed such as twitter may add to the aesthetics and user experience (UX) for a typical user, for individuals with Autism who prefer rigid routines, continuous updates are distracting and sub-optimal. I will therefore synthesise the results from search engines using their individual Application Programming Interfaces (API) (which I discuss later, in Section **??**)

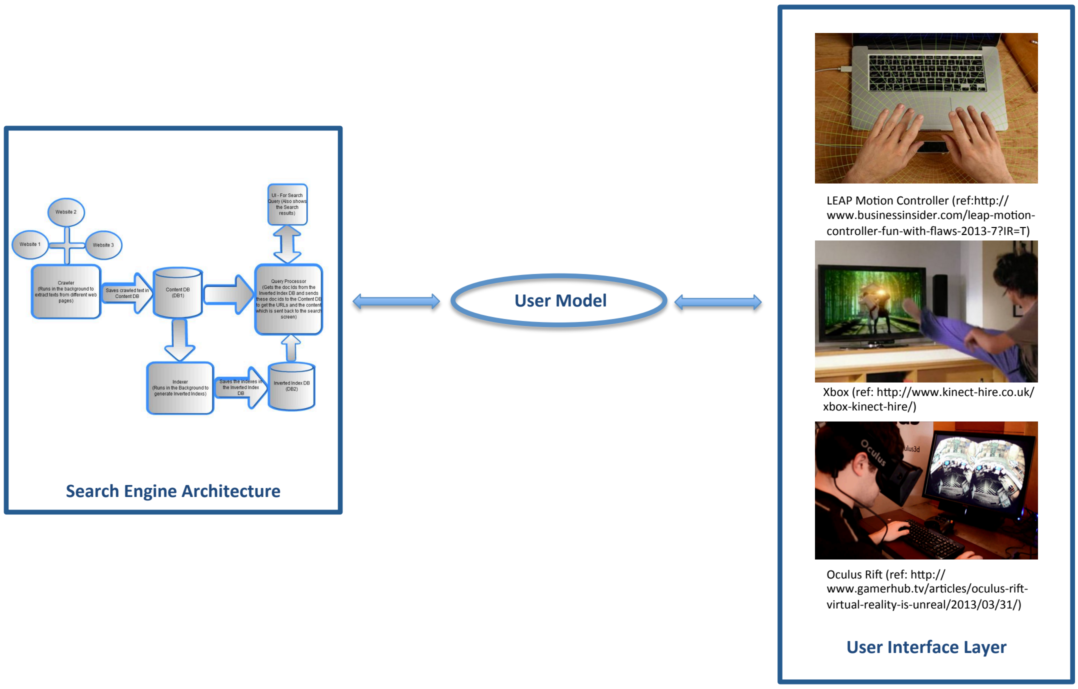
2 Aims and Objectives

I propose to build a user model of Autism, for a motion-controlled, web search. The core and non-core features of the application are given below. I elaborate on each of the key features in the following sections.

[2] The filter bubble also has potential privacy problems, as the user may be unaware that the search has been specifically tailored towards their interests and they wonder why things that they have previously searched for have become more and more relevant. There are search engines that have attempted to address this unwanted effect, by not tracking or saving user information (e.g., DuckDuckGo.com). As users are not linked to their search queries, it limits them being targeted by adverts related to their previous searches.

[3] It should be noted that personalization of search results generally takes a lower priority for the ranking algorithms than the URLs ranked top in terms of their relevance for the search query.

2.1 Proposed Application



Proposed application: The User Model will be applied to existing Search Engine Architecture[19], and be integrated with a Motion Controlled interface.

2.1.1 Core Features

1. **A combination search (web application) that synthesises the results from three of the largest and most popular engines (Google, 67.5%, Microsoft Bing 18.4% and Yahoo 10.3%) [28].**

2. **The design and implementation of a stereotyped user model of Autism to filter user search results.**

3. **Key Word In Context search; returning query terms in context, within small snippets (not verbally-overloaded).**

4. **Prioritisation of results which have first-order semantic relations to the query words (see Section 1.2), i.e., they appear in matched context to the search query.**

5. **Motion controlled UI (see Section 3.5).**

2.1.2 Non-core Features

1. Implement a higher ranking for pages with most images.

2. Use of WebGL and the three.Js library for 3D UI .

3. Compatibility with other motion controller devices (e.g., head-mounted devices).

3 Plan for Developing the Solution

3.1 Building the Combination Search Engine: Core Feature 1.

I selected the three most popular search engines (as calculated using an average of the unique monthly visitors) are Google (1,100,000,000), Bing (350.000.000) and Yahoo! (300,000,000)[25]. Google is the goliath question-answering system (query volume = 64.5%)[28], and is often considered the most innovative and dynamic. It is popular amongst users worldwide (using global traffic rank figures, in March 2015). Yahoo (2003) was the first ever web directory service; it has stronger advertising and e-commerce partnerships and has a query volume of 19.8%. Bing was officially launched in 2005, and has a query volume of 12.8%, which is substantially less than Google, but nevertheless, is within the top 3 search engines. Other search engines were not included, to limit redundancy of the search results returned (see Section 1.4).

To combine search results, I will use APIs provided by Google, Yahoo and Bing, as this is more efficient than inspecting the source code for every query result-page. For Google search results, the **Google Custom Search** (GCS) API (available in Java) will be used to create a personalised search engine. GCS requires a domain name and server at configuration, and provides a consumer key and secret, which are hardcoded in the application. Using the API I will extract image search results, page dates, formatting dates, custom snippets, and sort and filter the results. For Yahoo search, the **Yahoo BOSS** Java API will be used. The API offers similar functionality as the GSC. Lastly, for Bing, the **Bing Search** API can produce results for Web, Images, News, Videos, Related Search. It also includes spelling suggestions based on the query entered[4]. Each costs $0.01/search (max 5000 searches/month).

3.2 Building a User Model of Autism: Core Feature 2

A user model is a collection of information associated with a particular user (usually a data structure), with which a system can adapt/customise its behaviour in line with user needs. User modeling has strong implications for human-computer interaction (HCI); by creating a representation of the user, the system can be better informed about how to behave in various circumstances. In the current case the user will be required to set up a Google+ account, where their basic information (demographics, needs, preferences, likes, dislikes, goals, plans, knowledge, and skill), will be gathered. They will authenticate their Google+ account with the web application to start the formation of their data model. I will access these data via the **Google+ API** (see Section **??**), which includes methods to access 4 resource types; People, their Activities, Comments and Moments. A person is represented with many fields in Google+, including name, gender, title, occupation and so forth. I will asked users to save diagnostic information (Autism, Asperger, and high/low functioning) in the 'about me' section on their profile. This information will be parsed at a later stage and fed into the user model. Information about web-search history for any individual user can be obtained from the browser history.

User models can be static/unchanging (i.e., no algorithms update the model about the changing preferences of the user/ no new information is fed into the model), or dynamic (representation of the user with their up-to-date changes in interests, and interactions with the system). User models may also be stereotyped, where the system infers or assumes characteristics about a user from data gathered from other users within that distinct subset. Or, a user model can be highly adaptive and model the user on their own, without stereotyping, however this requires a large amount of data before implementation. Stereotyped user models are the most advantageous in the current case as they can be built quickly using clusters of characteristics of groups of individuals. I will have limited data to work with at the start of the project (only basic information gathered via a registration process, and diagnostic information). So, to address core feature 2, I will build a stereotyped user model, around a cluster of characteristics of well-researched cognitive aspects of Autism (see Section 2.1.1).

3.3 Key Word In Context Search: Core Feature 3

To identify results which contain the Key Word In Context (KWIC)[16], outlined by core feature 3, the **Apache Lucene Library** (hereafter referred to as 'Lucene') will be used. Lucene is a text-search library (written in Java), providing powerful, scalable, accurate and efficient algorithms to search textual data. The API offers the possibility to carry out phrase, wildcard, proximity and range (distance-of-words) queries.

[4]The APIs alone may not be comprehensive for textual-search (KWIC), and an addional library may be required (see Section 3.4).

Using the library it should be feasible to ascertain whether the key word appears in context, with reference to the user's search query, parse the text to extract the key word in a small snippet, which can be returned to the users results page.

3.4 First-Order Semantic Relations: Core Feature 4

I will filter the search results to those that contain at maximum a first-order relation to the search query words. The Lucene library affords ranked searches, which could help acheive this goal.

3.4.1 API for 'LEAP' Motion Controller

LEAP Motion SDK offers an API to get tracking data from the LEAP Motion Service. A WebSocket interface, allows LEAP Web Based applications, and a WebSocket server listening in on http://127.0.0.1:6437[5]. The server sends tracking data in JSON messages and an application can send configuration messages back. This library will be used to establish connection to the server and consume the JSON messages [6].

3.4.2 ThreeJs Library (Non-Core)

This Javascript library enables WebGL-3D in a web browser. WebGL brings hardware-accelerated 3D graphics to the browser without installing additional software. This library may be used to better integrate the application with the motion controller, and improve the experience of embodiment, UX, and UI of the application.

3.5 Motion-Controlled UI: Core Feature 5

3.5.1 Hardware Selection Process

Two options were available; the Oculus Rift Virtual Reality head mounted display, and, the LEAP motion controller. The hardware was selected as follows:

1. Accurate timing of the device correlates a good UX. The LEAP has options to poll frames at a constant rate (to keep timing of movement accurate).

2. Cognitive lag time. Each of our senses operates with a different lag time. Hearing has the fastest sense-to-cognition/understanding time; sight is the slowest. The device should therefore work with the combinatorial configuration of the senses.

3. As this is a tool to be used with individuals with Autism, the sensory experience (imposition) of the device cannot be overwhelming.

4. Cognitive-load should not be high (operating the device should not require a great deal of cognitive effort).

5. The device should integrate with concrete behaviours, e.g., drop or grab.

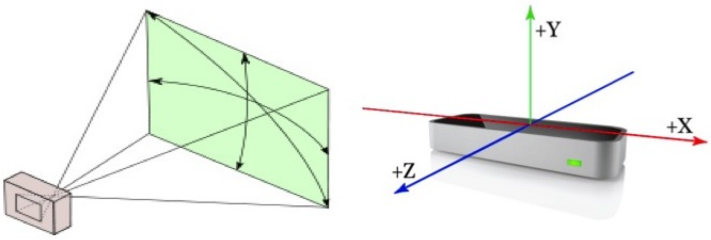
6. Affordability for users.

The two main reasons to persue the LEAP before the Oculus VR were, (1) it's non-imposing nature (no head mount), and (2), the affordability of the controller.

3.5.2 LEAP Controller

The LEAP can recognize and track hands, fingers, finger-like tools, positions, motions and gestures using infrared light and optical sensors along the x, y and z axes (cartesian coordinate system). The controller has a 150-degree field of view, and can operate in a range of 1 inch to 2 feet. The API works with distance in millimetre resolution. Time is measured in microseconds, speed in mm/s and angles in radians.

[5]The user can enable or disable the WebSocket server as they choose to do so, in the device's control panel.

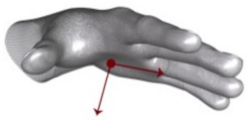


The LEAP controller, with 150 degree view [6].

The LEAP uses frames to represent tracked entities such as hands, fingers, tools or gestures. Motion data is recorded as a set of frames (stored, read-only) containing the detected information. Frames can be created by calling the Controller.frame(). Up to 60 can be held in the history buffer. Frames may be 'dropped' if there are resource contrainsts, or, they are missed.

3.5.3 Hands

The Hand class, returns information about the position of fingers, and arm (left/right).



The Hand palmNormal() method and direction vectors define the orientation of the hand [6].

The software uses parts of visible hands, internal models and previous observations to form a model of the hand. There is a Hand.confidence() method that provides a rating of how well the observed data fit the internal model [6].

3.5.4 Arms

The Arms class can return information about orientation, length, width and end points of movements. The LEAP controller software bases these return measurements on previous observations of the user, and using typical human proportions.

3.5.5 Fingers

These characteristics are based on the anatomy of the hand, and recent observations.

Finger tip position and direction are given as vectors. [6].

3.5.6 Tools & Pointables

Tools can represent any real object (noun), but are longer, straighter and thinner than fingers. Tools must be cylindrical.

3.5.7 Gestures

The LEAP recognises certain movement patterns (CircleGesture, KeyTapGesture, ScreenTapGesture and SwipeGestures) allowing the user to indicate an intent.

3.6 Project Plan

3.6.1 Project Timeline

The start date of the project is June 5th 2015, and end date is September 13th 2015. 'COULD' / non-core features will only be completed, time permitting.

Table 1: Project Stages

Dates	Task	Priority
Jun 05 - Jun 12	Configure relevant API's & Libraries to domain name/server	MUST
Jun 13 - Jun 19	Synthesise search results	MUST
Jun 20 - Jul 05	Research & build user (and data) model of Autism	MUST
Jul 06 - Jul 13	Work on configuration with Google+ API	MUST
Jul 14 - Jul 20	Apply user model to Search	MUST
Jul 21 - Jul 27	Develop UI	MUST
Jul 21 - Jul 28	Develop questionnaire and eye-tracker set up	COULD
Jul 29 - Aug 05	Integrate motion controller tools	MUST
Aug 06 - Aug 13	Test the model and ask for user feedback	COULD
Aug 14 - Aug 21	Revise the user model and UI	MUST
Aug 14 - Aug 21	Develop UI with other motion controllers	COULD
Aug 22 - Aug 29	Develop UI using WebGL/threeJs library	COULD
Aug 22 - Aug 29	Write up project report	MUST
Early Sep (tbc)	Present findings to supervisor	MUST
Sep 13	Submit report	MUST

3.6.2 Methodology

There is a relatively short deadline in which a single developer will research and deliver a system prototype and report. The APIs, technology and areas of development are unfamiliar. As the final product depends on user feedback testing, there is an element of uncertainty about what the final product will be/should look like. These characteristics suggest that the most suitable methodology to deliver the application is an Agile-like Methodology. I will focus on early development and rapid feedback to make adjustments to the project's direction. This methodology offers the most flexibility and adaptability.

3.6.3 Development Languages

The Google, Yahoo, Bing and Apache Lucene APIs are available in Java. The LEAP SDK sends Frame information in JSON format to Web Browsers. As a non-core feature, I may use a 3D interface with the three.Js library which is also JSON format. I will use HTML5 for the development of the aesthetics of the Web Application itself.

JSON is light weight, language-independent data format, and a good tool for sharing data. Importantly JSON offers faster execution and server-side parsing by storing the data in arrays, so that the transfer of data is faster. Faster parsing is particularly important for sharing the LEAP motion controller data. Some of the drawbacks of JSON are that it only has limited support tools available, and little error handling capabilities. It is also vulnerable as it returns responses in wrapped function calls which are vulnerable to attack. Java is a platform and operating-system independent language. It offers a simple, dynamic, robust object oriented, and functional language. There is excellent documentation available for the language, with many third party, open source libraries.

I will use Eclipse text editor and attempt to make the application compatible with Google Chrome browser (as it is WebGL-compatible and useful for 3D interfaces). I will use Git for Version Control. For testing I will use JUnit, JSON Test and Mockito (for user/external dependencies).

3.6.4 Testing

3.6.5 User Testing

I aspire to test the application with a group of individuals with Autism. However this requires time to acquire ethical approval and it is not clear whether I will have time before the deadline to acheive this. Nevertheless, if time allows, user testing would include

1. Inviting people Autism to use the web application.
2. Obtaining their feedback (relevance/explicit feedback, and, implicit feedback, e.g., mouse clicks).
3. Designing and administering a questionnaire to gather qualitative data.
4. Use of the Tobii Eye-tracker TX300 (Department of Psychology, Birkbeck University of London) to gather high resolution eye-tracking data as users test the application.
5. Further revising the model and ideas. Choosing the best possible approach/tools to achieve optimization for this group of individuals.

3.6.6 Unit Testing

I will be implementing Test Driven Development (TDD)[6] with JUnit (version 4.12), and where there are external dependencies, these will be mock tested using Mockito [7]. JSON Test will be used to test JavaScript Object Notation [11]. I will run both unit and regression tests.

3.6.7 Challenges/issues, probabilities and mitigation of impact

The challenges associated with the project, their impact and how I will mitigate them, is outlined in Table 2.

Table 2: Challenges & Impact Mitigation

Liklihood	Impact	Challenge	Mitigation
LOW	HIGH	API's require significantly high payment	Find/use alternative
LOW	HIGH	KWIC library does not offer methods needed to achieve goals of contextual text search	See if I can implement the method, or find additional API
MEDIUM	MEDIUM	Google+ API does not configure a user persona/user model well	Use Facebook or alternative
MEDIUM	HIGH	LEAP does not integrate with web application	Investigate user forums, contact LEAP to source answers, adjust web application accordingly.
MEDIUM	HIGH	User Model lacks impact and power in Search	Plan further development. Modify weights of parameters in the algorithm. Revise the model.
MEDIUM	HIGH	Not enough turn around time to implement the userfeedback	Develop plan and prototype in time for report submission
HIGH	LOW	Cannot get research participants with Autism to take part in a usability test	1. Expand age range of interest in attempt to find participants. 2. Drop aim as it is a non-core feature.
[1ex]			

[6] The TDD process involves iterating through the write-test-then-write-code process. First writing a test for some functionality, and second, writing just enough production code to make the test pass.

[7] mockito.org

3.7 Concluding Statement

I hope these insights will assist with the forthcoming information-overload problem by exploiting user models to turn the masses of information available into a specific set of information goods.

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