Project Proposal

Research problem/challenge statement:

As the human race has developed over the years, a great deal of information has been acquired. Some of this information is considered useful for individuals to know so that they can better understand the world, make informed decisions, solve problems, and generally have an improved chance of achieving their goals. The challenge is that this knowledge is not easily transferred from one individual to another. A person cannot simply download information into their brains. Instead, people go to school to learn facts, principles, and techniques related to a variety of subjects such as mathematics, science, and history. While there is an education system in place to facilitate this information transfer, the general principles at work are still largely a mystery. What changes take place in the human brain while viewing educational material? Why do some students understand a concept after the first explanation while others require many repetitions? There are still a lot of challenges to be addressed in the domain of education, but our project specifically focuses on the following challenge: Suppose that there is a specific concept that a specific person desires to understand. How can a textual presentation of that material be custom generated for that person so that they can most efficiently reach an understanding of the concept? An ideal solution to that problem would allow any concept to be explained to any person interested in learning that topic. If a machine existed that could generate such individually optimized material, then the effort required to learn would be greatly reduced. People could spend less time learning, avoid the frustration often associated with learning, and more easily pick up new concepts as they are needed.

In order to address the stated problem, there are a few different areas that require investigation. *Intelligence Unleashed*[1] describes a framework for understanding the process of education using three models: domain, learner, and pedagogy. A teaching tool, such as the one proposed in this project, must combine the information from all three models in order to teach the learner. The domain model encodes an understanding of the subject matter and is the source of knowledge used to generate material to present to the learner. The domain model is a knowledge representation and may include specific facts and ideas as well as connections which organize those fact and ideas into a comprehensive understanding of the concept. The learner model encodes an understanding of the person seeking knowledge. This includes a breakdown of what the person already has learned and what preferences they have for receiving new information. Developing an accurate learner model requires collecting data from the learner. By assessing the learner's knowledge before and after presenting them with information, the tool can evaluate the effectiveness of various techniques to discover which ones the learner prefers. That assessment may be done by comparing the learner's responses to what is represented in the domain model. Additionally, data can be collected while the learner is viewing the educational material. This can provide information about how engaging a learner finds specific techniques. Finally, the pedagogy model describes the various approaches that can be taken to transfer knowledge. This can include how to present an individual segment of material and also how to organize a lesson plan for the concept as a whole. The teaching tool can combine these three models to decide how to best present information to the learner. The specific information from the domain model is presented using techniques from the pedagogy model which require information about the prior knowledge and preferences that are encoded in the learner model. Thus by updating these models as the learner interacts with the tool, the learner can receive increasingly customized content and learning efficiency will continue to improve.

Any format of interacting with the learner can fit into the three model system just described, but our project focuses on presenting textual information. Most people have had the experience of reading a textbook in order to learn about a particular topic. The content to be produced by the learning tool would be similar to what is typically seen in textbooks. Paragraphs of prose would be the primary content. Tables, lists, and possibly figures can be interspersed where appropriate. While the output will be similar to textbook content, the goal is to improve upon textbook learning by addressing key issues that limit the efficiency of textbook based learning. When a textbook is written, the author must have a target audience in mind and the content is presented in a manner that is understandable to that audience. A person with a background that differs from that target audience may find the material difficult to understand. Even learners within the target audience may encounter issues when reading the textbook. This is because the contents are written once and targeted to a group of people rather than an individual. A related issue with existing textbooks is that they are written to cover a large topic in detail. The individual sections typically reference content from other sections and fully understanding the contents may require a cover-to-cover reading. Our project seeks to avoid these limitations by generating content that is tailored for a specific learner. Thus all the material for a topic does not need to be presented in a general way; instead the exact information sought by the learner can be presented in a format that they can easily comprehend. Additionally, the progression from one sub-topic to another is in the control of the system, and can be another source of individualization.

By providing individualized textbook style content to explain a topic, the efficiency of learning is improved. The learner receives material presented with their preferred techniques and in a way that takes into account their existing knowledge. There may also be an efficiency gain on the part of the textbook authors since they are no longer tasked with the layout and presentation of the information. The authors can focus on encoding their expertise in the domain model and rely on the tool to handle the details of presentation. As a result, learners can obtain a more complete understanding of the topics that they are interested in with less effort, and along the way, some insight into the learning process may be made.

Idea:
As stated previously, the education system attempts to teach a group of people about a topic, often failing to address the differences between how these individuals learn. Through our research, we intend to determine what approaches to machine learning could aid in the personalization of the education system, particularly with how it relates to text that people must read to gain knowledge on a subject. By researching how text on a subject may be personalized, we hope to achieve a better understanding of how the brain is able to memorize knowledge, so that we can utilize this information in presenting the knowledge to the individual.

One particular aspect of our system that would make our approach to this problem unique, is that we will not need to rely upon questions alone in order to determine which approaches to knowledge presentation are yielding the most fruitful results. For many years this form of testing has been a source of contention, as it has become under fire for not testing the student's knowledge, and instead testing them on how good they are at taking tests. While for some this can be a good source of determining how much knowledge a student has retained, it fails to address those who understand the material, but are simply poor test takers. Instead, we hope to collect data on the users knowledge through a wider means, such as allowing them to highlight concepts or words which they do not understand, or even simply allowing them to state that they don't understand the presented information even after reading the generated material. A key piece of our project will be determining alternatives to simply questioning the users knowledge, in order to gain a better understanding of what they have retained.

Other attempts at such systems, which will be covered later, have failed to accurately test student's knowledge, as they rely upon questionnaires alone in measuring success. They failed to address the fact that knowledge is often not white and black; it is possible for me to have a partial understanding of a concept, even if I do not answer a question correctly. By giving the user a greater ability to point out gaps in their knowledge, we are allowing them to guide their own education, all the while adapting our system so that these gaps become less frequent. As such, our research will be based in that of other such systems, but we attempt to gain the upperhand by better understanding the cognitive aspects of knowledge acquisition and retention so that we may better tune our system to accurately create a model of how the user learns the information.

Relevance:

The primary goal of our project is to build a system designed to assist in the creation of material tailored to the educational needs and requirements of individual students. Because of this, the ability to represent what a student knows would be absolutely necessary. This ability would very likely require the ability to represent information in the same way as the student would - which is part of the definition given in the class for cognitive computations. In doing so, our system would be able to more accurately simulate the learning process of the student using these cognitive computations, while applying statistical methods to search through the concept-space of possible informational formats to maximize the efficiency or ease in which the simulated student learns.

From the syllabus, this course is about learning a general approach to developing and applying models of cognitive processes to improve intelligent systems and interfaces from scientific, engineering, and application perspectives. While our project does not intend to cover every aspect of the course, an educational program which must maintain a model of the student's cognitive processes to improve the human-computer system (by teaching the human and training the computer model) is an application of many of the core principles discussed. The more complete our understanding of learning, the exemplary cognitive process, the more complete our design can become, because of the aforementioned need to represent human learning as realistically as possible. Further, because we are attempting to generate understanding from a textual source rather than external experiences, a method for a more complete model of deriving semantics from syntax alone may be necessary, which ties into several possible resolutions of Searle's Chinese Room problem.

This proposal suggests an improvement on existing intelligent systems, as there exist other techniques used in the education field to attempt to increase the ease in which a student learns material, though our proposal is to create a feature that none of the existing systems have implemented, to the best of our research.

Methodology:

One particular route that is likely to be worthy of investigation is the currently known means that individuals learn information. In the field of education, it is widely believed that there are seven learning styles: visual, aural, verbal, physical, logical, social, and solitary. By investigating why these learning styles have been singled out to be the main styles that people learn through, we can perhaps shine some light onto how the brain is able to retain knowledge. Further, if we are able to determine a way in which we can pinpoint which of these learning styles are most prominent in an individual, we can better generate content which is tailored specifically so that the individual using the software would most easily learn the information. One possibility in learning this is to present information to the user in a variety of different ways, all of which correlate to one of these learning styles, in which we could then extract information of how the user is interacting with our system. Through the data collected from the user interactions, it would be our hope that we are able to learn which methods are resulting in the best knowledge retention with the user, and allow our system to adapt accordingly when presenting new information.

As one route of success may lie in learning how information can best be presented to a specific user so that they may retain it, one aspect that we must investigate is how the brain stores this information. While it is vital to our system to learn which style of presenting information is the best for any given user, another question we must ask ourselves is why that user learns from that style best. For instance, we cannot simply learn over time that a user retains presented information best when our text is generated with an example of the concept being presented, but we must also learn why the user learns from an example better than an abstract definition of the concept. If we are able to pin down why certain learning styles appeal to certain individuals more so than others, we should be able to tune our system and the means in which it generates content in a way that can more quickly and accurately tune the model for each user.

Another area of research we must investigate is that of adaptation, as many approaches to machine learning attempt to quickly converge on an answer, and once a believed solution is reached they become rigid. When learning, it is clear to us that the style that an individual learns can adapt over time, or even vary depending on the type of information being presented. As such, we much investigate how a model can be created to converge on a solution but still be flexible enough to allow change when needed. One case worth researching more is that of Pavlov's dogs, in which classical conditioning was applied so that a perceived stimulus began to change the behavior of the dogs. In this experiment, Pavlov took a previously neutral stimulus and slowly converted it to be a positive stimulus. This indicates to me that there is some method in which repeated exposure to specific sensory input can alter existing behavior, which could prove vital in the case of adaptation for our algorithm. In Pavlov's case, how many times did the bell need to be ringed in order for the dogs to have an altered reaction? If the stimulus was changed again, such as changing the now positive stimulus to a negative stimulus, how quickly do the behavior change, and at what level of change would it do so? These are all questions worth considering so that we may propose a system that is able to continuously adapt to a users preferred means of knowledge acquisition.

Prior Work:
With our project specifically centralized on generating textbook contents adapted to an individual's learning tendencies, we have only uncovered related projects that are loosely similar to both these aspects. Brusilovsky et. al. [2] elaborate an approach to constructing web-based textbooks that are adapted to different groups of users. Firstly, this method develops a domain model that is a mapping of all the concepts of a given topic. It also constructs a user model that keeps track of the user's knowledge of these concepts, which is then overlaid upon the concept model. Doing so enables the framework to compute the ideal way to structure the concepts in the webpage to exemplify the user's learning experience. However, this is quite different from our approach. While it is beneficial, this framework is only rearranging the textbook's structure to help the user follow through the concepts more easily. In addition to rearranging text for clarity, our approach seeks to extract the semantics of the textbook and generates new content with the same meaning that enables the reader to better understand the concepts. Being able to reconstruct the actual knowledge at hand will be more beneficial for the user and differentiates our approach to that of Brusilovsky et. al.

From an author's perspective, our proposed system is beneficial since the writer does not have to generate any new versions of a textbook for different target audiences. Stewart et. al. illustrate that with the MOT authoring system and the WHURLE delivery system, one can create a single adaptive version of educational material that can be catered to many different contexts [3]. In a similar implementation to the Brusilovsky et. al.'s, the author constructs a domain concept mapping to piece together how the different parts of content should relate to one another. Goals and constraints can also be embedded onto this mapping such that the author can fine-tune how the content should be conveyed, whether through an image, text or sound. WHURLE can determine the user's characteristics through a small questionnaire and accordingly deliver the material in the best representation for the user. Once again, relying on domain concept mappings is limited because the actual knowledge of the material is never extracted. Moreover, WHURLE only considers a limited number of factors, all strictly related to learning style. The model proposed by El-Bakry and Saleh [4] targets this problem, where more intricate parameters such as health, psychological, economic and social are also taken into account. Just as in WHURLE, a student takes a brief questionnaire to evaluate their state along ten different dimensions, including the ones mentioned above. The model constructs a mapping that allows it to identify the best teaching style for the given results. Given the teaching style, the appropriate lesson plan can be developed that best caters to the student.

In both these implementations, using a basic survey to understand the user's learning behavior is quite incomplete. Determining complex characteristics with simple questions is not ideal. Furthermore, a user's attitude is constantly changing and relying on the fixed results of a survey will not be useful. To better account for the user's complex behavior, our system can detect the user's emotions, actions, and past history and create a mapping of these variables. This allows for our system to output the textbook contents to precisely match the individual's preferred way of learning. In addition, the observation process is continuous, as the system will constantly acquire data of the user. With this data, the system can further improve its model of the user's learning style and generate even more applicable textbook material. Thus, the system is able to constantly improve its efforts through this reinforcement procedure.

Division of work:

In terms of the remaining work for this project, we plan to split the effort as evenly as possible among the 4 team members. We have had, and plan to continue having, a weekly meeting in which we discuss recent progress, identify tasks, and distribute work. In this way, each team member will be assigned tasks that contribute to the final project report and presentation. Tasks include finding and reading research papers, proposing and elaborating on the ideas, goals, methods, and evaluations which describe our project, and preparing material for the presentation and report. While some tasks may be more focused on specific portions of our project (such as research methodologies or broader impact), all of the team members will have input into all aspects of the project.

References:

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