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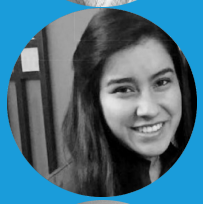

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CHECK(CHatbots in Education and Cultural Knowledge acquisition)

Executive summary

The CHECK project (CHatbots in Education and Cultural Knowledge acquisition) aims to bridge the gap between raw unedited teaching material present on the web and its easy conversational fruition, by developing a reusable chatbot architecture (iCHAT), able to adaptively guide students even when they cannot count on the guidance of a teacher. The novelty with respect to current approaches lies in the fact that the chatbot rather than being an expert on the subject is an expert on a body of content covering a subject. In other words, the chatbot is tasked with efficiently (and empathically) interacting with the learner while being backed up by a complex system, powered by instructional intelligence, that adaptively provides the most suitable items of content when needed. We named this novel approach Content-Oriented Learning Assistant (COLA).

Key Words

Chatbot, IBM Watson, Education, Intelligent Tutoring Systems

Project description written by the Principal Academic Tutor

The use case of developing a chatbot to help the secondary school's students recover learning gap about equation (math chatbot), had driven the research, the design, and the development of the iCHAT architecture. This real-world application is based on real contents edited by real teachers, and thus stand out as a proof of concept for both the architecture and the COLA approach. A working demo of the math chatbot was developed through an iterative design approach, and helped understand the main limitations and strong points of the overall approach. The supporting technology was created in cooperation with IBM, partner of the project. The COLA approach can be exploited by different education providers to reach a guided scalable access to big corpus of educational material. In fact, the advantage of adapting the content's index to the user inclinations by a conversation flow is more evident on large corpora like for example university Massive Online Open Courses (MOOCs). As a matter of fact, COLA is now being deployed in the frame of a European project to create a chatbot that supports students enrolled to a Coursera course on Recommender Systems. The research effort aims at being a step on the path towards educational chatbots' "industrial production", to inexpensively give a second life to the educational material, sometimes forgotten, that populates the web.

Team description by skill

Andrea Belli An enthusiastic management engineer that has also a technical background complementing his leadership skills. He coordinated the team while developing the Watson-based conversation engine.

Damla Ezgi Akçora A computer engineer working on Computer Vision and Artificial Intelligence. Being the team leader, participated both in the technical development and the organization of the project as interface with the board.

Luca Lodi A technology lover with the interest in other disciplines and the knack for simple but elegant solutions. Main architect and implementer of the proposed solution, as well as interface with the professors.

Filippo Vannella A telecommunication engineer with a passion for Artificial Intelligence. He took part in the technical development and in the editing of the content.

Marina Berardi An energetic, passionate, and hard-working management engineer. She took part in the analysis of the linguistic formulations as well in the organization of the content.

Daniela Nossa Systemic designer that participated on the analysis of the user, understanding the linguistic features of the student and professors.

Stefano Falletta A physicist with passion for complex systems and their technological applications.

Goal

iChat was designed considering several expectations in both the technical capabilities and user sides. To cite the most significant goals that also challenged the entire process could be listed as follows:

- *Creating a generalized technology*: The idea is to build a combination of tools resulting into a unique data driven system capable of driving conversations (rather than being a passive system) and be easily re-usable in other contexts. The tools support the front-end (e.g. proposition of contents conversation itself) and back-end activities (e.g. preparing the content).

- *Creating a framework for the modular architecture of data driven chatbots*: The chatbot has to be based on a modular architecture where a few key actions are always executed in series and continuously. If we think how a conversation between humans takes place, we could design a conversational process. First, there is the exchange of information among the individuals, who, secondly, store and interpret the data received according to their backgrounds. Finally, the response flow is produced and delivered. - Providing a valid user "experience" The objective is to stimulate users' interest. Usually, other educational solutions, such as MOOCs and other online courses, do not either catch the attention or keep teenagers interested since they are based on non-interactive media. The chatbot makes the user live an out of the ordinary experience. The key is to drive engagement and interest.

- *Creating an effective interaction:* The chatbot should be effective in delivering contents and adapting to the faced user. Students have different learning capabilities from each other, thus, educational solutions must consider this constraint while designing content paths. What our projects aims at is to supply a flexible solution that is, at the same time, aware of students' difficulties, capable of identifying their areas of interest and using them to engage students more in the conversation.

- *Keep the student interested:* The human span attention is the ability of a person to focus on a task without being distracted. It can vary according to age, physical health, emotional status, degree of interest in the topic and type of attention required. As regards long-term attention, researchers estimated an average of 20 minutes for deep concentration in teenagers with no apparent health problems. The attention span resulted higher when the task to be performed was enjoyable and enough challenging to feed self-determination and perceived capabilities. In iChat design, we focused also on understanding how to keep the student interested during the interactive session. This idea applies also for other domains since all the chatbots aim to engage the user to get involved in the conversation.

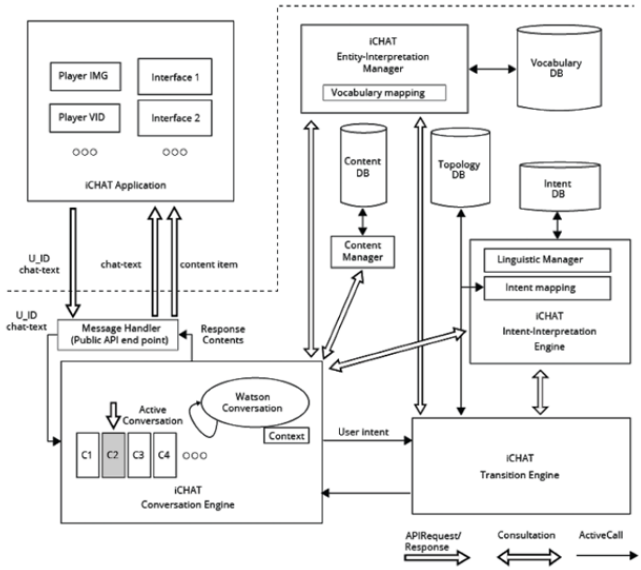
Understanding the problem

Chatbot interfaces simplify the user interaction with information systems, by exploiting the machine natural language understanding capabilities developed in recent years. In fact, they let the user express intentions and receive information through the natural flow of a conversation, improving the overall user experience, steeping the learning curve and better fitting the user needs. However, most of these technologies are tailored for specific conversation scenarios and thus intrinsically coupled with the content (knowledge base) of the conversation. This characteristic jeopardizes the code re-usability in different contexts (topics), independently of their similarity. Nowadays, chatbots are mainly forged through an artisanal, rather than industrial, process. Everyday, a huge amount of learning objects and resources are created and stored in the web, but they are poorly accessible due to the limits of the "search oriented" nature of the web. Educational content must wait to be edited into books or websites (time and cost hungry operation), before it can be properly used. The CHECK project (CHatbots in Education and Cultural Knowledge acquisition) aims to bridge the gap.

On one hand, we had to face the difficulties of interpreting and understanding the natural language, in order to deliver an emphatic and simple-to-use chatbot. But on the other hand, we also had to tackle the complexity of education strategies, in order to adapt the conversation to the student's needs. These challenges extend

to two main research fields: The Natural Language Processing, to empower the chatbot to "talk", and the Artificial Intelligence / Machine Learning, to enforce the student's adaptativity. There are technologies and frameworks to address these problems, but many of them are business-oriented (eg: booking interface for a restaurant), and thus are user-centered and do not present any form of proactivity. In education, this is a limitation that need to be overcomed, since usually the student need guidance and is not expert of the whole corpus of content. On top of this, we needed to work under some simplifying assumptions.

The COLA approach involve a chatbot that is expert in the body of content, rather than on the application field. Thus, we need to organize this corpus, splitting into "items" (atoms of informations), organized into topologies (possible paths of items). From this emerges that both choosing the right item's granularity and devise some mechanism to navigate and generate these topologies are problems of paramount importance.



iCHAT architecture.

Exploring the opportunities

We tested many possible alternatives throughout the project, from a completely proactive chatbot, able to mimic the teacher's behaviour to a solution that enhances the user's agency. The design of iCHAT has been a significantly challenging task since all the functionalities have been researched from scratch and there was not clear path to follow. The design path shown in the figure on the right was updated incrementally every time we discovered a problem. The first idea that we came up with was implementing a proactive, content-driven chatbot architecture which can be used in several fields. The prototype architecture was meant to be tested on two use-cases, namely mathematics and cultural heritage. We explored the tradeoff between degree of specificity of the content, that degrade reusability, and its performances with the support of some of the best IBM cognitive tools, such as Watson Assistant, to produce a novel approach to chatbot generation. Also, we started to test the limitations of the system by writing conversations. To be able to gather all the improvements and see how the system so far works, we prepared the first version of the cultural heritage demo. Analyzing the performance of the chatbot at this demo, we came up with one the key idea of the whole project: the creation of different engines to manage the conversation flow, namely the Transition Engine (TE) responsible for the transition to the next item, the Interpretation Engine (IE) that propose contents in the best way possible according to the user profile given some input variables, and the Conversation Engine (CE) responsible to manage the conversation. Despite these components never changed in the name throughout the project, their role and importance changed a lot to explore the previously

introduced tradeoff between reusability and performances. It is possible to split the "smart/logic" element of the chatbot between these components, to achieve a better proactivity (complex Interpretation Engine), or an improved adaptivity (complexity in the Transition Engine). For a relevant part of the project duration, one of the primary goals was to mimic the didactic proactivity of a teacher, inside the Interpretation Engine. This lead to an increased complexity of that component. In the end, it was almost impossible to check the correctness of the Interpretation Engine rules, and thus it was decided to partially drop the goal, to focus on a simpler didactic strategy, based on the superposition of simpler heuristics. We tried to figure out how we could dynamically adapt the current situation of the user. The team agreed on using a set of variables which are updated according to user input. Following this, linguistic formulations were studied in order to give more flexibility to the model and interpret the expressions. At this point, we prepared an online survey to evaluate the public expectations of a chatbot to improve user experience in the design of iCHAT.

Generating a solution

Through an iterative design, supported by agile development methods, we developed a chatbot architecture that is mainly reusable, and thus is able to cut costs. This solution exploits the hierarchy of knowledge to modify the minimum amount of knowledge from one application to another. The supporting technology was created in cooperation with IBM, partner of the project. It consists of four engines (components) that take care of different aspects of the conversation. A Conversation Engine, built on top of IBM's cognitive platform Watson, profiles the user understanding the natural language (intention and mood) and adapts the style of the replies to the user. Explicit reference to the conversation's object are resolved by an Entity Interpretation Engine, exploiting a hierarchical vocabulary. An Interpretation Engine manages the flow of the conversation deciding the best dialogic action to perform according to the dynamic profile of the user status. It is driven by a hierarchical set of rules. Finally, a Transition Engine decides which one of the "items" (atom of the content corpus, e.g: videos, texts, html pages) to propose to the user, based on the history of previous feedback and on a "topology" (graph that semantically organize the

items in some paths). On the one hand the author has still to split the material into items (choosing the right granularity) and organize them into topologies, even though assisted by machine learning tools. But on the other hand, due to hierarchical nature of vocabulary, of language expressions and of educational choices (taken into consideration in the engines' design), most of the components can be reused in a similar application context or easily adapted in a modular way. This enhances the scalability and the re-usability, improving thus the economic feasibility of the approach. The research effort sustained during this project aimed to provide an abstract reusable architecture (iCHAT) to develop COntent-based Learning Assistants, as well as a proof of concept for its flexibility and reusability, necessary to enable an chatbot development "industrial process". A chatbot to assist secondary school students in bridging their gaps about math equations was developed up to the stage of fully functional demo, through an agile development process that involved many iterations. This chatbot implemented a subset of the iCHAT architecture, but was anyway able to deliver many of the required functionalities, proving the feasibility of the architecture for real-life applications. A side output of this iterative development process is a constellation of tools that aim to support and speed up the editing of the contents, as well as enhancing the configurability of the developed chatbot and boost a continuous improvement of its configuration by interpreting the usage feedback. In fact, a fundamental characteristic in order to create an industrial process is the presence of a tool ecosystem, supporting the authoring process, and enabling of the monitoring and improvement of the performance on the product after the interaction with the users.

Main bibliographic references

Bourdeau R. Nkambou, R. Mizoguchi. Advances in intelligent tutoring systems. Springer, 2010

P. Foltz et al. Preliminary evaluations of a dialogue-based digital tutor. C. Penstein Rosé et al. (Eds.): AIED 2018, page 480–483, 2018.

R. Budde T. Leimbach B. Jost, M. Ketterl. Graphical programming environments for educational robots: Open roberta - yet another one? International Symposium on Multimedia, 2014