Adaptive Conversations for Adaptive Learning: Sustainable Development of Educational Chatbots

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Abstract. This paper moves from the assumption that conversational interfaces will become an important ingredient for learning environments. We propose a specific role for chatbots: assisting tutors, helping the learner through a complex body of content. Main original contributions: i) a framework for adaptive learning; ii) focus on configuration of chatbot and adaptivity of learning. The main benefits are reduction of the effort for creation and maintenance of chatbots; empowering authors and instruction designers to directly design their chatbots; the possibility of deploying adaptive conversations. The advantages stem from the fact that most of a chatbot behavior is obtained by configuration data, rather than by (re-)programming it.

Keywords: Educational Chatbot · Adaptive Learning · Conversational Agents · Adaptive Conversations.

1 Introduction

Our assumption is that conversational interfaces could play an important role within the realm of ICT-supported learning environments. Although the idea of “educational chatbot” is not new, this paper provides an original contribution in a few directions: i) assigning a specific role for conversational interfaces in education; ii) proposing an original effective architecture that makes the development of educational chatbots sustainable; iii) empowering authors and instruction designers to directly shape and monitor the learning experiences of learners; iv) emphasizing the opportunity of adaptive learning, and the role that chatbots can play for it.

We believe that this lack of direct involvement of chatbots in learning activities could be due to several factors, among which: a) conversations are mainly perceived as “playful and entertaining”, such as learning \[3\] and not completely useful for complex tasks. b) Development of new chatbots, except for the very simple ones, requires ICT specialists, high costs and too much time. Teachers and instructors have problems at directly controlling the features of the chatbot. c) conversations are very often intended to satisfy requests by the user; this can be a part of learning, but only a marginal part.
We propose for the chatbot in education a specific role: assistive tutor. Assuming that there is a possibly large body of content, the chatbot can help the learner to go through it. The chatbot, in addition, can help in an “adaptive consumption of content”, i.e. a proper selection of content items, arranged in a suitable manner. Items of content for a chatbot could be derived from pieces of an online course, slides and accompanying text, etc. The medium of an item could be a video, audio, a pdf, an exercise, and a quiz. A full course consists of several items; we call it learning pathways. Learning pathway is the combination of the selection of items and their arrangement. Adaptivity of the learning experience comes from different aspects: 1) selecting a suitable pathway; 2) allowing further selection within the pathway according to learner’s requests or perceived problems; 3) adapting the feature of the conversation to the preferences of the learners and to context situations (e.g. running out of time). Let us now examine a few relevant requirements, guiding our research effort.

**Separating conversation from content**: Content has its own organization. The conversation helps the learner through the content and speaks about the content; the organization of the conversation, however, is a different matter, and it is independent of content. It implements a “conversation strategy” which is independent of the content being subject to learning.

**Adaptive learning experiences**: Learning experiences often need to be adaptive. For various reasons, the user may want to get only a portion of the body of contents and properly organized to her needs. A student may wish to consider only the easy part or the difficult part of a course or go through only specific subjects; a student may want (for the time being) to skip exercises and to consider them later. A manager accessing a MOOC may want to get a basic understanding of a new technology skipping details; or at the other extreme of the spectrum, she would like to get only the new advancements in the field.

**Designing adaptive learning experiences and conversation**: In our vision, several actors may be involved. Authors may wish to create specific ways to use their materials, designing possible pathways for different needs (e.g. core material, recommended material, optional material) and properly tagging items (e.g. elementary, basic, advanced). Tutors, dealing with a specific group of learners, may further adapt the pathways to local needs: They could delete some items, introduce a few new items, change the arrangement of items, and modify some tags of items. Learners may further adapt the learning experience to their specific needs and contextual situation. The day before the exam, for example, the learner may want to skip the demonstration of theorems or just go through exercises.

For adaptive conversation several features of a chatbot could be “adapted”: how many turns the chatbot is taking? Is the style and the wording of the conversation appropriated? Adapting these features could attune the chatbot to the user profile. Moreover, Elsholz et al. explored how adding different style to chatbots can be used to increase user satisfaction [2].
Empowering authors and instruction designers: Our goal is to allow authors, instruction designers, and tutors to design their solutions directly, with little intervention of ICT specialists. Using current design approaches and technologies authors and instruction designers need substantial help from ICT specialists. But for very simple chatbots, extensive reprogramming is often needed; also, the intertwining of content structure and conversation, make it difficult to operate on one without modifying also the other. With our approach and architecture: content and pathway adaptability is made very easy for non ICT experts; simple conversation adaptability (e.g. modifying the wording) is considerably easy; modifying conversation strategy requires a conversation specialist and little programming).

Sustainability of design, implementation and maintenance: Sustainability, in general, means that the time and effort needed are relatively limited. In the field of education, we have a few hundreds or thousands of users per year, for each course. If developing a chatbot to support learners is expensive in most cases, it will not be done. Moreover, revisions of courses (especially for higher education) are often required. If we want to achieve large diffusion of chatbots in education, the cost of their production and deployment must be strongly lowered, still achieving complexity and effectiveness of conversations.

2 Related work

2.1 Chatbots in education

The concept of educational chatbots has its origins from intelligent tutoring systems, which address the idea of building a learning tool that is “intelligent” enough to understand learners’ needs and proceed accordingly [7]. Since chatbots are becoming popular every day and chatbots in education are not new, and several proposals exist. From the broad application of conversational agents in education over time, In 2008, Kerry et al. worked on using conversational agents for self-assessment in e-learning [4]. Chatbots [1] are often applied for organizational support to perform specific tasks. Tegos et al. worked on a configurable design of chatbots for synchronous collaborative activities in MOOCs in university setting [8].

According to Hwang [3] the definition of a smart learning environment relies on three key features (context-aware, adaptive support, and adaptive interface). To the best of our knowledge concrete solutions for adaptive learning have received more attention by industry compared to academic research. Industry efforts recently have considered chatbots suitable for direct involvement in learning. Work in [6] highlighted the use of chatbots to train new employees about digital transformation.
3 A novel architecture for chatbots in education

In this section, we describe a novel architecture for designing and implementing educational chatbots. The architecture provides a clean separation among different concerns (see Fig. 1): interface, conversation, interpretation, and content. We have different components, dealing separately with each one of them.

- **Interface Component**: This is the “interaction” component. It can be text-based, or audio/voice-activated. It conveys both the conversation and the delivery of content.
- **Conversation Engine**: It performs three tasks: it generates the conversation turns of the chatbot; it understands the user turns of conversation, and it organizes the flow of turns. When it is necessary takes instructions from the interpretation engine.
- **Interpretation Engine**: It analyzes data (e.g., the conversation flow, the user interaction, the user performances), and it decides how to proceed according to the state machine. For a learning environment, for example, it takes the didactic decisions. It provides instructions to the Conversation Engine (for continuing the conversation) and to the Action Engine (for accessing new content).
- **Action Engine**: It manages the content of the course, and the “pathways” (trails traversing the content). It controls the transition from the current item of content to the next one. A pathway could be as simple as a linear playlist, or, more generally, could be a graph with colored nodes and colored arcs. The user may need a simple “next” or she may require specific adaptivity (e.g. skip demonstrations of theorems).

Let us examine now some of the configuration data, and describe how they work:

- **State machine**: The state machine is the core of the configuration for the conversation. It describes the various possible states of the conversation; which transitions can determine a state change for chatbot. The state machine can be modified at will in order to design different conversation strategies, but for a family of chatbots, it does not need any change. An example of the family could be “tutors for STEM course at junior high school”, or “tutors for history at higher education”.
- **Conversation categories**: To generate dialogues we are using a several categories such as greeting, support, and feedback messages. These categories are attached to the states and arcs of state machine to describe the chatbot dialogues in the conversation with user. Also, these categories are used in the unsolicited turns to understand users and provide them the response.
- **Master table**: It defines a set of basic utterances of the chatbot. They also determine the rule for transition in the state machine. In the master table transitions are associated with utterances of the chatbot.
4 A first prototype based on the architecture

The testbed for the development of this architecture is a graduate computer science course about “Advanced Computer Architecture”. From the content of the course, we selected a module about “Cache Memory” with 32 content items, for a total time of 38 minutes and 56 seconds of video. The fragments were traditional videos with the teacher speaking 10%, while 90% were generated from images-slides coupled with audio, generated from text using Watson text-to-speech technology. Fig. 2 is a snapshot of this course attached to the chatbot. This production method, with respect to traditional video taking lowers cost and time for maintenance, since modifying text is much simpler than editing video.
5 Conclusions and future work

Below are the main contributions of this work provided towards the field of education and from the technological point of view:

- Authors and instruction designers can control directly the main features of the learning experience, without the need of recurring to ICT experts.
- Our chatbot is proactive, leading the conversation and following an instructor defined agenda and offer adaptive conversations, in the sense that the style and the wording can be tuned to specific needs, taking into account the profile of the learner and the context of usage.
- An original overall architecture, clarifying the differences between the various components: interface, conversation, interpretation, content and a generalized “meta-solution” for generating conversation, controlled via a number of configuration data.

Future work will focus on the following areas and directions:

- In the future we intend to focus on developing the capabilities of the interpretation to make to take better pedagogical-didactic decisions.
- Working at embedding of this architecture in the context of a general conversational environment. This will make e-Learning as a part of general experience, with the possibility of blending serious tasks with entertaining and relaxing activities.

References