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Argument Analyzer: Visualizing and explaining logical arguments in context

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Abstract: This paper describes the design, development and preliminary evaluation of a visualization tool, the Argument Analyzer. This interactive online tool aims to help students understand applied logic by visualizing logical features in context. Multimodal bilingual explanations can be revealed on demand using toggle buttons. The two main sets of digital artefacts, namely annotated texts and explanations were student-created. Users can view preloaded texts or submit their own texts that have been annotated according to the guidelines. Users decide which logical features to reveal and hide. On revealing logical features, users can see more information by hovering over the visualization. When users want a fuller explanation, they can click on the hyperlinks to multimodal explanations. Thus, users are able to direct their own learning, and follow their own learning path of discovery and exploration. Preliminary evaluations of accuracy, usability and efficacy are positive.

Keywords: teaching logical thinking, visualization, argumentation, digital artefacts

1. Introduction

Japanese students of applied logic in a credit-bearing university course display difficulties analyzing arguments logically and critically. In an elective course named *Logic and Language* learners develop their ability to apply logical and critical thinking. Some of the participants have already taken a foundation course in logic and/or a course on logic for programming. The course is delivered in English, but some examples are provided in Japanese as well. This course differs from the other two logic courses in that the focus is on the application of logic to natural language texts written in English.

The credits from this course count as part of the English language graduation requirement, but the course focuses on teaching logic through English rather than English through logic. This course consists of approximately twenty-four teaching hours and is delivered over an eight-week quarter. The course is divided into three blocks: identifying arguments, identifying fallacies and evaluating arguments. Most of the logical concepts and terminology are introduced in the first half of the course, creating a steep learning curve that tapers off as the focus moves to application rather than acquisition, allowing students to consolidate and extend their learning.

In most classes delivered in English within the Center for Language Research at the University of Aizu, Japanese students appear to focus on the grammar and meaning of individual English words rather than considering the real-world meaning. The question below illustrates the problem. This question was presented as part of a reading quiz to three classes of computer science majors taking compulsory English language classes.

Question:
    Why do polar bears eat penguins?
Relevant extract from longer text:
    Due to global warming, polar bears rely on penguins as their primary source of food.

Of the 92 student responses, not one pointed out that polar bears do not eat penguins, which should be obvious because they live in different hemispheres. The Japanese term for polar bear is *hokkyokukuma*, which directly translates to “arctic bear” making their habitat even more obvious. Almost all students, however, gave “global warming” as the answer. This apparent uncritical acceptance of information is worrying, particularly given the rapid growth of fake news (Lazer *et al.*

2018) and the rise in the reliance of algorithmic-curated social media news feeds (DeVito, 2017) and a growing preference for opiniated rather than objective news (Marchi, 2012).

To analyze arguments, readers need to be able to pinpoint conclusions and related evidence, and evaluate the truth value and validity. Evaluation of validity necessitates knowledge of the five forms of valid arguments and at least nine formal fallacies that invalidate arguments. In addition, readers need to be able to identify whether deductive, inductive or abductive reasoning is used to discriminate sound and cogent conclusions from unsound or uncogent conclusions. Moreover, at the bare minimum, students are expected to understand twenty-four informal fallacies that may impinge on arguments. Language difficulties exacerbate the problem of identifying and explaining arguments as students study in their second language.

An extensive search of the Internet and published literature failed to discover any interactive pedagogic online tool that visualizes logical arguments in context. There are a number of teaching-focussed websites that explain example arguments, but none of these are interactive. Cutting-edge research automatically identifying claims and evidence within texts (Rinott *et al*., 2015), causality relations (Dasgupta, Saha, Dey and Naskar, 2018) and so forth exist, but none are deployed online or designed for pedagogic purposes.

To fill this niche and ameliorate the difficulties faced, an IT artefact (Oates, 2005) was designed and created by the author. The Argument Analyzer was developed to provide contextualised examples of arguments. The Argument Analyzer detects annotated arguments and executes scripts to control website behaviour, revealing emoticons, colour-coded labels and displaying further details on demand. Links are also provided to bilingual multimodal explanations created by previous cohorts of students.

This paper is organized as follows. The following section details the creation of the digital artefacts, namely the database of annotated argument texts and the explanatory materials available in text, image, audio and video formats. Section three describes the design and development stages of the software. Section four describes and evaluates the beta version of the Argument Analyzer while the final section identifies future work.

2. Digital artefact creation

The first set of digital artefacts comprises annotated arguments. These are plain text files containing an argument that is annotated for logical features using html-like tags. The second set of digital artefacts consists of multimodal explanations. These are stored in plain text, rich text, image, audio or video files depending on the specific content. Both sets of digital artefacts are created by students. The final artefact is the delivery system, i.e. the backend and the frontend of the web-based interface. The student-created artefacts are described in this section. The software development is described in the following section.

2.1 Annotated arguments

One cohort of students taking the elective course created a database of 400 annotated arguments as part of their coursework. The tailormade annotation tagset comprises 57 items divided into five broad categories, namely arguments, reasoning, formal fallacies, informal fallacies and causality. These tags were selected for pedagogic purposes rather than to adhere rigidly to a particular school of logical thought. Arguments includes elements (e.g. premises, conclusions), valid propositional forms and assumptions. Three types of reasoning are currently included: deductive, inductive and abductive. Formal fallacies are divided into three subcategories: invalid arguments, syllogistic fallacies and invalid references. Informal fallacies are broadly divided into red herring fallacies, *non causa pro causa*, vagueness and ambiguity, and weak analogies. The final category of causality comprises proximal, distal, root, common, rival, sufficient and necessary causes.

An indicative extract of the complete tagset is given in Table 1. Each item within a specific category is assigned an opening and closing tag. The content of the tags uses abbreviations of the item and relevant category to make it easier for students to use. Students use the text editor of their choice to insert tags. Each annotated text was manually double checked and added to a database. The database consists of letters, teaching texts, extracts from research articles and books. The majority of the texts, however, are letters to editors. This genre was chosen because of the high incidence of argumentation and the use of fallacies to support claims. Figure 1 shows an extract of the annotation coding document, showing some of the annotation tags that can be inserted into texts containing fallacies.

Table 5
Extract of Annotation Coding Document

Category	**Item**	**Opening tag**	**Comment displayed on hover**
Invalid argument	Affirming the consequent	< IA-AC>	Invalid argument: affirming the consequent
	Denying the antecedent	< IA-AD>	Invalid argument: denying the antecedent
	Undistributed middle term	< IA-UM>	Invalid argument: undistributed middle term
Syllogistic fallacies	Fallacy of four terms	<SF-fourterms>	Syllogistic fallacy: fallacy of four terms
	Illicit major	<SF-major>	Syllogistic fallacy: illicit major
	Illicit minor	<SF-minor>	Syllogistic fallacy: illicit minor
	Affirming a disjunct	<SF-disjunct>	Syllogistic fallacy: affirming a disjunct

<inductive></inductive><conc>Professor X is an efficient and effective teacher.</conc> <prem> <redherr>All his students enjoy his classes </redherr>according to the feedback given on the student feedback questionnaires.</prem><prem><misstat>Every student who attended the course in full received a grade A which is testimony of his expertise in teaching.</misstat> </prem> <prem><redherr>The professor not only holds a doctorate in physics but is also a polyglot and a polymath.</redherr></prem> <prem><bandwagon>His course is always popular with students.</bandwagon></prem> <prem><misstat>Every course offered in the previous two years has seen enrolments meeting or exceeding the minimum number of students.</misstat></prem> <prem><redher>To ensure he has enough energy, he always brings a cup of coffee to the classroom.</redherr></prem> This is yet more evidence of his dedication to his students. <prem><bandwagon>Finally, the Facebook page of Professor X has received thousands of "Likes", a clear indication of votes of confidence in his teaching.</bandwagon></prem>

Figure 1. Screenshot of submission interface of the Argument analyzer

2.2 Multimodal explanations

Interviews with focus groups of students revealed the demand for an online tool showing logical features in example texts accompanied by explanations. Preferences were expressed for video and audio rather than textual explanations, which is in line with Hafner, Chik and Jones (2015). Teacher-led creation of videos was an option; but following Chewar (2016), student-created materials were selected. The decision to enable students to create digital materials for future cohorts stems from the Latin proverb *Docendo discimus*, i.e. the best way to learn is to teach. Typically, this is realized synchronously in class, but given the current ease of creating digital artefacts using smart phones, teaching can now be conducted asynchronously online.

Ohashi *et al.* (2018) provide a detailed comparison of methods for educational video production, and noted that when used linearly throughout a course, there was initial enthusiasm, which waned as the course progressed. This tool, however, does not present videos in a specific order, but users select the video that is of relevance as and when they need it. Hansch *et al.* (2015) detailed a typology of eighteen types of videos including talking head, conversation, screencast, webcam capture and green screen. The videos created so far are presentation slides with voice-over.

Students created audio and video explanations in English and Japanese for sixty technical terms as part of their coursework. Over two hundred explanations were contributed, from which the best quality versions were selected for inclusion.

3. Software development

A requirements analysis audit was conducted to determine the operational specifications for this project. The audit comprised focus group interviews and observations. Focus group interviews were held with ten students taking the *Language and Logic* elective course. Students on the same course were observed analyzing both paper-based and electronic texts. In both cases students made extensive use of Google Translate, Weblio (a popular online Japanese-English dictionary) and Google images. Students frequently highlighted the paper-based texts using different colours for conclusions and premises. Students also wrote annotations in the margins of paper-based texts to indicate the types of reasoning (inductive or deductive), presence of assumptions. Fallacy types (formal or informal), fallacy classes (e.g. causal fallacies) or names of fallacies (e.g. *post hoc ergo propter hoc*) were labelled. In short, students hoped to see and immediately understand rather than struggle to decode spoken or written text. This explains the use of Google images when students were looking up unknown terms. A list of the required functionalities and the necessary operations for visualizing logic were created. Potential difficulties and obstacles were anticipated, and ways to overcome or remove them were determined. A software requirement specification (SRS) was drawn up. This included detailed information of the technical terms and concepts that students struggled with, including pairs of terms that students had problems discriminating between. Such pairs included: inductive/abductive, illicit major/minor, and affirming the consequent/antecedent.

Based on the SRS the specific architecture to achieve the required functionalities was considered. Google cloud server was selected to store and deliver the database of annotated texts, JavaScript used to highlight the logical features and links to the digital explanations were embedded. A graphical user interface was created to display the annotated texts. Users can select to input their own annotated text or view pre-loaded texts housed in the cloud database. Figure 2 shows the interface that users use to submit their own texts.

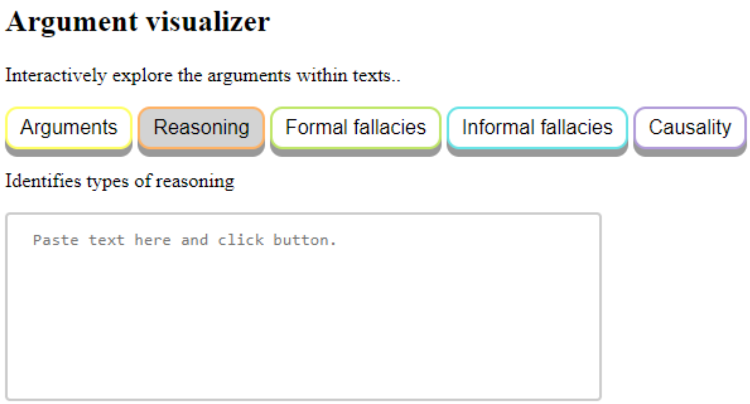
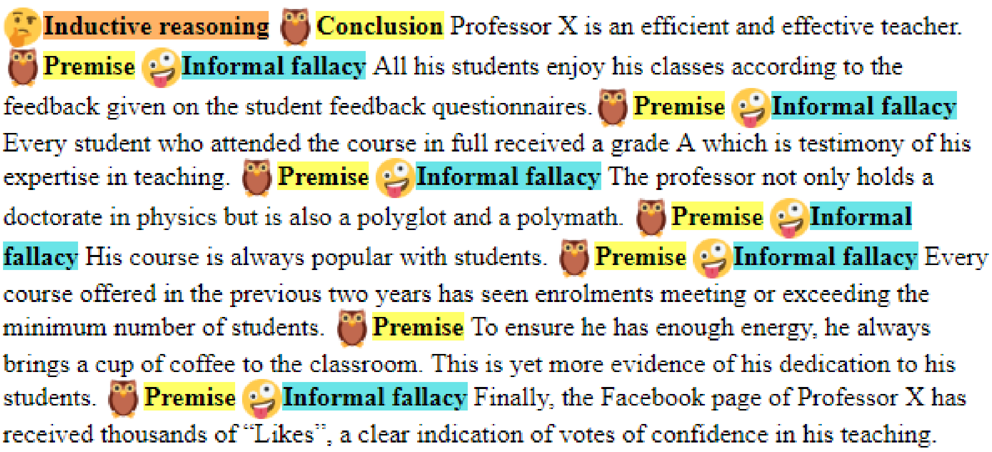


Figure 2: Screenshot of input interface for users to submit annotated texts

An agile approach was adopted in which usability tests were conducted *ad hoc* to gain early feedback on the user interface and user experience. The subjects in the usability tests were all Japanese speakers, who varied greatly in their knowledge of English and of logic. The feedback received informed the final design of this tool.

Five toggle buttons are used to hide and reveal logical features using rule-based parsing, giving learners full control of their learning, encouraging learner direction and discovery-based learning. The functionality of each button is explained on hover, and users click to reveal whichever logical aspects they want visualized. On click, a regular expression searches the annotations and raw text, and on matching, the relevant emoticon and label are displayed inline as shown in Figure 3. When users hover their cursor over the emoticon, explanations are displayed. Each subcategory of logical terms is assigned a different colour and emoticon. Hyperlinks to audio and video explanations in both Japanese and English are provided.



Inductive reasoning Conclusion Professor X is an efficient and effective teacher. Premise Informal fallacy All his students enjoy his classes according to the feedback given on the student feedback questionnaires. Premise Informal fallacy Every student who attended the course in full received a grade A which is testimony of his expertise in teaching. Premise Informal fallacy The professor not only holds a doctorate in physics but is also a polyglot and a polymath. Premise Informal fallacy His course is always popular with students. Premise Informal fallacy Every course offered in the previous two years has seen enrolments meeting or exceeding the minimum number of students. Premise To ensure he has enough energy, he always brings a cup of coffee to the classroom. This is yet more evidence of his dedication to his students. Premise Informal fallacy Finally, the Facebook page of Professor X has received thousands of "Likes", a clear indication of votes of confidence in his teaching.

Figure 3: Screenshot of extract of output of the Argument analyzer

The Argument Analyzer is used extensively throughout the *Logic and language* course. In the first half of the course students primarily use the tool to view pre-loaded texts while in the latter half, students also use the submission system for annotated texts to complete their coursework and final assignment.

4. Preliminary evaluation

This tool transforms a plain black-and-white text into an interactive multi-coloured text with embedded multimedia explanations. Computer science majors taking an elective course, *Logic and Language,* were able to interact with annotated texts, clicking on toggle buttons to hide and show particular logic features and use the on-hover function to reveal further details. Users are, therefore, able to scaffold their own learning by deciding which features to reveal and which explanations to read, listen to or watch. Teachers can use this tool for discovery-based, inductive or deductive learning activities.

The accuracy of the Argument Analyzer is contingent on the accuracy of both the regular expressions and the annotations in the texts. All the regular expressions are simple, each matching only one specific annotation tag. There were no occurrences of false positive or false negative results and so the accuracy rate for the regular expressions is 100%. The accuracy of the annotated texts is more difficult to determine. The meaning of any text is negotiated between the writer and the reader, who may not share the same background knowledge nor make the same assumptions. The context (i.e. shared cultural environment) and cotext (i.e. words occurring before and after annotations) may also affect the meaning. The ambiguity that is pervasive in all natural languages adds a further dimension of complexity. The pedagogic purpose of the annotations also needs to be taken into account. The aim is to enable students to practice the application of the logical concepts taught. Most initial annotations were completed by students. which were double-checked and amended where necessary by the author.

The efficiacy of the Argument Analyzer has not yet been empirically tested, but the results of focus group usability tests undertaken during the software development phase were positive. In addition, on the standard student feedback questionnaires administered by the institution at the end of course, the usefulness of the visualizer was mentioned by a number of students.

This is the first beta release of the Argument Analyzer and no doubt there are numerous areas in which further improvements can be made in terms of software design, accuracy of annotated texts, quality and quantity of explanatory materials and the associated learning efficiacy. Given that no comparable tool exists, the Argument Analyzer is leading the way towards providing interactive online learning materials that harness language visualization and multimodality to help students learn logic.

Future cohorts of students now have access to a large bank of practice materials that they can use anywhere, anytime.

5. Future work

More textual and multimedia explanations will be added by the next cohort of users. In terms of effect on learning, a small-scale empirical or experimental study could be used to evaluate its efficacy. Where feasible, rule-based parsing of raw rather than annotated text will be used to reduce reliance on manual annotations.

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