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A Visual Representation of Online Interaction Patterns

Margarida Lucas
(University of Aveiro, Aveiro, Portugal
mlucas@ua.pt)

António Moreira
(University of Aveiro, Aveiro, Portugal
moreira@ua.pt)

Abstract: To understand learning processes we need to consider many different aspects that come into play within online learning environments, including mediating tools, learners' actions, their engagement in online discussions and how such discussions unfold over time. Content analysis of asynchronous discussions is usually applied to study knowledge construction, but little attention is paid on how interactions relate to each other over time and influence each other. Visual representations of online interactions can help us make sense of the temporal dimension of learning and its relation with other complex data. The present article proposes a new visualization tool, which is based on an interaction analysis coding scheme, to visually represent the multidimensional relationship between discussion content, participants' interaction and time.

Keywords: Online asynchronous interaction, Knowledge construction, Interaction analysis model, Visual representation.
Categories: L.2, L.3, M.5, M.7

1 Introduction

The growing adoption of communication technologies (CT) to mediate teaching and learning processes fostered the study of online interaction as an activity that can reveal students' behaviour during learning processes. In this context, interactions, usually in the form of written messages, result in artefacts that may help us understand and optimize learning and the environments in which it occurs.

Different authors stress the importance of CT in facilitating the creation of learning networks in which learning can happen as a result of the connections and interactions of their members [Anderson and Dron, 11; Wenger, 07] and many have attempted to analyse online interactions as a means to find evidence of learning processes, namely of knowledge construction [Zhu, 96; Gunawardena et al, 97; Pena-Shaff and Nicholls, 04; Weinberger and Fischer, 06].

Much of the research on knowledge construction focuses on the application of interaction analysis coding schemes to examine the content of online asynchronous message transcripts. However, and as the name suggests, such models focus on content analysis alone which does not account for a clear understanding of the dynamic nature of online interactions and of the discussion flow over a period of time.

It is widely accepted that learning does not happen suddenly nor does it result from accumulating information. Instead it involves the gradual introduction of new ideas and perspectives about contexts and the world, the development of different skills and new ways of making sense of information. As such, different authors consider time and temporality as a dimension of learning that should, therefore, be included in the study of learning processes [Roth, 06; Reimann, 07].

Visual representations of online interactions can be important tools for helping researchers make sense of the temporal dimension of learning and its relation with other complex data. Such representations can be more efficient than numerical or textual displayed information to view online interactions and analyse the flow of discussions over time. Besides retrieved information can also be important to "feed" the teacher or instructor, who can tailor online learning activities towards the individuals' needs or towards a specific group of students, but also students, who can analyse their individual interactions in relation to the group. In this respect, Hara, Bonk and Angeli [Hara et al., 00] recommend that participants in online discussions should have access to "graphical displays to indicate the potential links between messages, the depth of those links, and the directionality of communication patterns".

The present article builds on previous work [Lucas and Moreira, 11; Lucas et al., 14] to present a specific technique for analysing interactions that took place during a 30-day period. The technique described builds on the content analysis of asynchronous discussions carried out through the application of the Interaction Analysis Model [Gunawardena et al., 97], the participants in the discussions and the period of time over which the discussions took place. This technique led to the development of a visualization tool called Map of Relational Links (MRL is a registered trademark and is copyright protected) which is in a prototype phase and still needs fine tuning. Therefore, data presented is still preliminary, but enables us to detect patterns and establish relational links between interactions within a continuous temporal perspective.

After the introduction section, we present the case study that originated the current work in section 2, including the methodology used to analyse knowledge construction and the results achieved; section 3 begins with a short discussion of the reasons that prompted us to explore visualization techniques and moves on to describe different techniques/tools that were analysed to present our data; in section 4 we present an overview of our visualization technique and we conclude with section 5 by presenting some final considerations.

2 Analysing knowledge construction in a postgraduate course

The analysis of knowledge construction dealt with in the present article pertains to a study that was conducted in the context of a first year course subject – Multimedia and Cognitive Architectures (MCA) – which was part of the Masters Degree on Multimedia in Education (MMEdu) offered to students under a b-learning regime at the University of Aveiro. The course combined two face-to-face (f2f) sessions (one at the beginning and another one at the end of the course) and distance work for the span of four weeks. The course started in February and ended in March.

In this course, students, mainly in-service teachers, were expected to: (a) deepen their knowledge about cognitive systems and learning theories related to the process of knowledge construction; (b) explore the potential of social networking tools to augment interaction and (c) conceive a plan for the collaborative development of interaction and implement it as an in-class activity. Along with the aforementioned objectives, the course aimed at developing competences related to students' professional activities, such as (a) the integration of CT into teaching practices, with strong emphasis placed on social software; (b) the development of collaborative work; and (c) the development of research, management and information organisation skills.

By the time MCA started students were already comfortable in the use of social software since these had been introduced and adopted right from the beginning of the postgraduate course. At that time, students were encouraged to participate in two blogs ("mundomac" and "bestofpdi") created as a discussion platform for the course, and to save and share any information they deemed pertinent resorting to a social bookmarking site. They were also challenged to write their progress and final reports collaboratively using a wiki and to adopt Netvibes or Pageflakes as an aggregation platform to help them follow and manage all course activities. In sum, students were encouraged to create their own learning environment, in which they could organise activities or information and were allowed to add third party services pertinent to their interests (subject and non-subject related) throughout the whole course, a strategy difficult to implement with Blackboard, the institutional platform.

Students were not required a minimum or maximum number of contributions in the discussions launched in the two blogs used in the course, but participation represented 15% of the course assessment. Topics discussed in the blog "mundomac" were launched by the course teachers and followed no previous schedule, i.e., after the initial post, which framed some of the issues being explored during the course, topics for further discussions emerged from the interaction that was taking place. The topics explored in the blog "bestofpdi" were launched by students, who were free to choose what they wanted to share and discuss as long as it related to the issues being dealt with in the course, in their projects or in their professional activity. Topics dealt in this blog were unveiled by each group at the beginning of their moderation day; they ranged from e-twinning to violence in schools or game based learning and discussion usually included the role played or that can be played by CT in such areas. The management schedule of the blog was negotiated among teachers and students in "mundomac" and it comprised 10 days (one day per group).

2.1 Methodology

The discussion transcripts of 28 posts were selected for this study, which resulted in 758 messages, from which 752 were analyzed. In order to examine the level of social knowledge construction, we used the Interaction Analysis Model (IAM) [Gunawardena et al., 97] which proposes five different levels or phases of activity starting from lower mental functions to higher mental functions as depicted in Figure 1.

For each phase, authors established different types of activity:

- PhI includes (a) a statement of observation or opinion; (b) a statement of agreement from one or more participants; (c) corroborating examples provided b one or more participants; (d) asking and answering questions to clarify details of statements; (e) definition, description, or identification of a problem.
- PhII admits (a) identifying and stating areas of disagreement; (b) asking and answering questions to clarify the source and extent of disagreement; (c)

restating the participant's position and possibly advancing arguments or considerations in its support by references to the participant's experience, literature, formal data collected, or proposal of relevant metaphor or analogy to illustrate point of view.

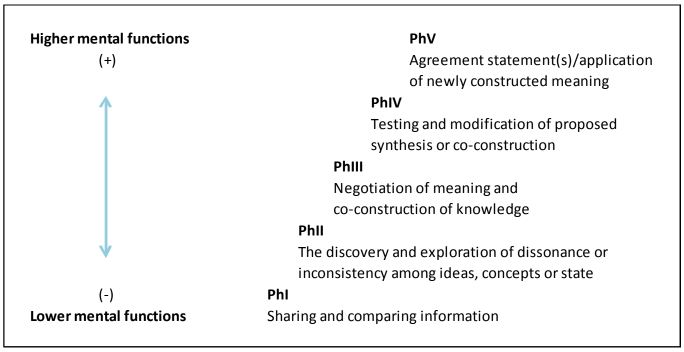

Figure 1: Phases of knowledge construction proposed by the IAM.

- PhIII refers to (a) the negotiation or clarification of terms; (b) the negotiation of the relative weight to be assigned to types of argument; (c) the identification of areas of agreement or overlap among conflicting concepts; (d) a proposal and negotiation of new statements embodying compromise, co-construction; (e) a proposal of integrating or accommodating metaphors or analogies.
- PhIV includes (a) testing proposed synthesis against "received fact" as shared by the participants or their culture; (b) testing against cognitive schema; (c) testing against personal experience; (d) testing against formal data collected; (e) testing against contradictory testimony in literature.
- PhV relates to (a) the summarization of agreement(s); (b) applications of new knowledge; (c) metacognitive statements by participants illustrating their understanding that their knowledge or way of thinking (cognitive schema) have changed as a result of the conference interaction.

We determined the whole message as our unit of analysis and adopted the coding steps suggested by different authors [Chi, 97; Marra, 04], applying the highest phase evidenced in each message as a coding result.

Teachers' messages were coded and treated as any other message, as their role in the course was that of co-learners, sometimes monitoring the discussion, but almost never modelling the actions that could stimulate knowledge construction. Instead, they shared, asked and collaborated in a way that their presence became diluted in the course of events.

Three independent coders codified the messages. Two were familiar with the model and had already used it in the course of their work, whereas the other had never used it. An initial meeting took place for this coder to work with examples of the different phases of knowledge construction and to discuss details regarding the model and its application. The transcripts were then coded by each of the coders and a sample was selected for calculating interrater reliability. The percent agreement was 0.78.

2.2 Results

As we mentioned before, results presented in this section relate only to data retrieved from the two course blogs – “mundomac” and “bestofpdi”. Figure 2 shows the number of messages coded in each phase and the total number of messages codified regarding “mundomac”.

PhI					PhII			PhIII					PhIV					PhV			Total
a	b	c	d	e	a	b	c	a	b	c	d	e	a	b	c	d	e	a	b	c	
12	8	14	16	2	6	15	10	8	5	4	30	7	11	5	9	2	3	10	2	12	
52					31			54					30					24			191

Figure 2: Number of messages coded in each phase and the total number of messages codified from the “mundomac” blog.

Figure 3 shows the number of messages coded in each phase and the total number of messages codified regarding “bestofpdi”.

PhI					PhII			PhIII					PhIV					PhV			Total
a	b	c	d	e	a	b	c	a	b	c	d	e	a	b	c	d	e	a	b	c	
8	2	1	6	0	6	8	4	2	0	2	7	2	1	0	3	2	0	9	1	1	[illegible]
11	4	4	25	0	3	4	0	0	0	0	1	0	0	1	5	0	0	1	0	12	[illegible]
6	2	2	14	0	3	0	0	2	2	0	3	0	2	0	2	2	0	3	0	4	[illegible]
7	0	2	10	0	1	9	2	3	0	1	4	0	1	2	2	5	0	3	1	5	[illegible]
10	0	1	5	0	5	3	0	0	0	0	0	0	1	0	9	0	1	3	0	11	[illegible]
15	3	4	6	0	3	1	3	3	0	1	8	0	0	0	5	1	0	0	1	2	[illegible]
23	0	0	6	1	2	8	0	1	0	0	0	0	2	0	4	5	3	3	0	9	[illegible]
10	1	3	12	0	4	0	0	0	0	0	4	3	0	0	3	7	0	3	4	4	[illegible]
15	2	1	18	0	2	1	3	5	1	1	3	0	0	2	4	2	0	5	0	1	[illegible]
4	0	2	11	0	2	2	1	0	1	0	2	0	0	0	1	0	0	0	0	3	[illegible]
109	14	20	113	1	31	30	13	16	4	5	32	5	7	5	38	19	4	30	7	52	[illegible]
257					80			62					78					89			551

Figure 3: Number of messages coded in each phase and the total number of messages codified from the “bestofpdi” blog.

When looking at the two blogs as a whole, the total number of messages coded per phase resulted in the percentages represented by Figure 4. Although results show that the highest percentage of interactions occurred in PhI, which is in line with most studies applying the IAM conducted so far [Gunawardena et al., 97; Paulus, 07; Schellens and Valcke, 05; Sing and Chee, 09; Wang et al., 09; Hou et al., 09], results differ from these in the highest levels of knowledge construction, as occurrences in the other phases are very balanced.

Number of messages					Percentage				
PhI	PhII	PhIII	PhIV	PhV	PhI	PhII	PhIII	PhIV	PhV
309	111	116	103	113	41%	16%	15%	13%	15%

Figure 4: Distribution of knowledge construction activities in the two blogs.

We find similar percentages from phases II to V, which suggest increments in knowledge construction that may indicate that students were building on each other's ideas. Also, triangulation with other data (questionnaire, focus groups and interviews) suggests that students perceived the 'hands-on' experience developed in MCA as a valuable one, that allowed them to develop their skills, develop new ways of learning and build new knowledge, not only socially as a community by means of sharing and collaborating, but also internally by means of personal meaning negotiation and adjustment of new ideas.

In discussing results, we suggested that results may be related to the nature of the learning environment and the instructional design applied which transferred responsibility for the learning process to students and combined it with autonomous learning, context situated problem based learning and intra and inter-group collaborative work. We also pointed the nature of the communication tool itself which may influence the type of learning that it supports [Anderson and Dron, 11; Lucas et al., 14]

3 Exploring visualization techniques

After analysing our data we felt somehow disappointed with the lack of capability to demonstrate the social and interaction dynamics that went beyond the categorization proposed for the knowledge construction stages. Although we consider that the IAM presents clear and validated stages for the construction of knowledge, we sense it did not truly reflect the meaning of students' knowledge construction, for it did not capture interactions that went beyond the explicit ones, such as 'unspoken' interactions between participants and their environment, nor the chronological and systemic evolution of such interactions. Furthermore, it did not provide an accurate picture of the discussion flow nor the progress and development of students' knowledge.

As a result, we started by exploring other methods that could help us visualize the process of knowledge construction as a whole, a kind of visual conversation of individual and group interactions over time. The first method explored was Social Network Analysis (SNA), which we abandoned after a first attempt using a sample of our data. We then sought software that could triangulate multidimensional complex data: the participants involved in discussions, the quality of interactions (based on the IAM) and the temporality of the discussion. We explored CourseVis [Mazza and Dimitrova, 07], which we also abandoned because it works with Web log data generated by course management systems (CMS), something not possible in our case since our data was retrieved from two blogs and the Seascape and Volcano software

[Lam and Donath, 05]. With the exception of CourseVis, we briefly detail the exploration of these techniques in the following sub-sections.

3.1 Social Network Analysis (SNA)

After exploring different Social Network Analysis (SNA) software such as Gephi, GraphViz and NodeXL, we opted for NodeXL for various reasons, one of them related to the fact that it works as a MS Excel application to enable the representation of generic graph data and the visual exploration of networks. As our data was already in a MS Excel database, we felt appropriate and less time consuming to explore this software. Also, we found a substantial body of authors that applied NodeXL in their research [Bonsignore et al., 09; Hansen et al., 10].

NodeXL is a free open source software designed especially to facilitate learning the concepts and methods of social network analysis with visualization as a key component. It imports Excel spreadsheets and opens them as a workbook with a variety of worksheets containing the elements of a graph structure, such as edges and nodes and it applies common graph metrics, such as centrality, clustering coefficient and diameter.

Our first attempt to explore NodeXL was made using data from one of the "mundomac" blog posts, corresponding to 98 interactions. Figure 5 illustrates one of the graphs that resulted from our analysis. Despite providing interesting information on interactions, participant's relevance and relationship intensity, the result did not match our initial expectations. Connections and relationships were built based on quantitative data alone, which left the quality of interactions out of the visualization.

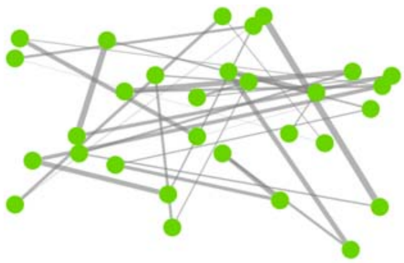

Figure 5: Visualization of students' interaction using NodeXL.

The intensity of relationships is based on the number of times one interacted with one another regardless the quality of the interaction established. Also, the visualization provided does not consider interactions established over a period of time, which prevents us from understanding knowledge construction as a dynamic and continuous process. For these reasons, the exploration of NodeXL was abandoned.

3.2 Seascape and Volcano

Seascape and Volcano [Lam and Donath, 05] use periodic animation loops to represent key social interaction features in online discussions. The tool pays special attention to timeless motion in representing data about behavior and actions, creating visualizations that intuitively depict different levels and types of activity. Seascape (Figure 6) displays squares, each one representing a thread in a newsgroup. When in motion, they work as waves propagating and looping from left to right.

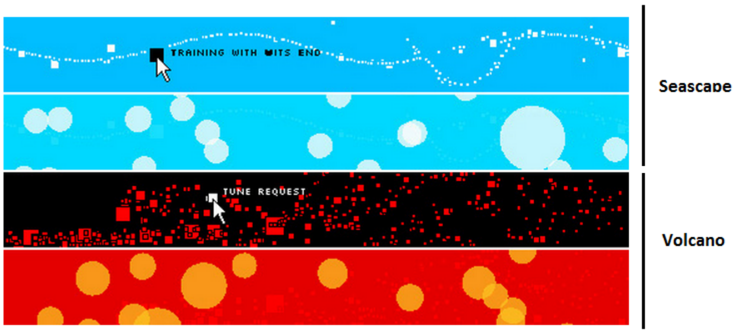

Figure 6: Visualizing interactions using Seascape and Volcano.

Volcano (Figure 6) displays square particles bouncing up and down. The variation of speed, direction, amplitude and frequency in every square particle provides a quick impression of the participants' activity.

In their study, authors refer that most users found the interface easy to use as they could navigate well between the participants and the thread views. Despite this and despite providing the user with notions of social structure and quantitative characteristics of particpants, we consider that the representation enabled by Seascpae and Volcano disregards the discussion flow and does not display it in a way in which pattern interaction is easily identified.

4 Map of Relational Links (MRL)

Assuming the construction of knowledge as a process that extends over time and results from the interactions of the participants who take part in discussions and joint problem solving, we sought to build a visual map that could triangulate 3 different aspects:

- participants and their interactions;
- the relation among participants/interactions within a temporal perspective;
- the phases of knowledge construction proposed by the IAM.

We started by creating a table in which participants in the discussions were identified and the days and hours for each of their interactions were discriminated (cf. Figure 7). The intersection of these data was then completed with the coding assigned to each of the interactions, which was identified by a colour. Relations were established based on the reading of the discussions, the continuity given to the topics covered and the identification of traces that were left throughout the discussions by the participants.

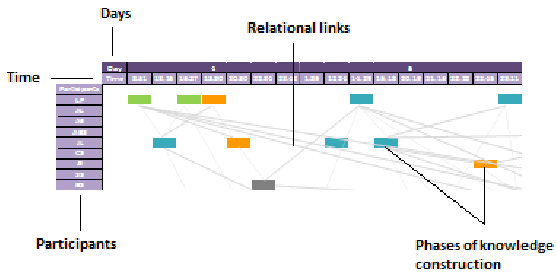

Figure 7: Example of the visual map depicting participants, days and hours of interactions and their quality according to the phases proposed by the IAM.

Data illustrated pertain to interactions among a group of students during the first and second day of the course. Figure 8 illustrates 22 days of discussion that correspond to 98 interactions that took place in one of the posts from “mundomac” (the same data displayed in Figure 5). At first glance, it is hard to make sense of the amount of information, but upon closer and detailed scruting (which we are unable to reproduce here) it is possible to envisage aspects relevant to the process of knowledge construction that the IAM alone cannot provide and that other techniques referred cannot easily display. Apart from the advantage of helping us speed our understanding of the information triangulated, we can look at it as whole, i.e. at a group level and at an individual level. The visualization provided helps us understand collaborative learning processes, as well as the participants’ performance and behaviour in relation to the group.

The use of colours to identify phases of knowledge construction facilitates the recognition of the emergence of patterns that may help us identify, at least, three different aspects: (a) actions of social interaction, conflict, negotiation, agreement; etc.; (b) the person(s) who prompted those actions, replied to them by agreeing or disagreeing or abandoned them; (c) the time actions occurred, how long they endured or evolved to other actions. The choice to visualize data on an individual level allows us to understand the participant’s cognitive schema during learning processes.

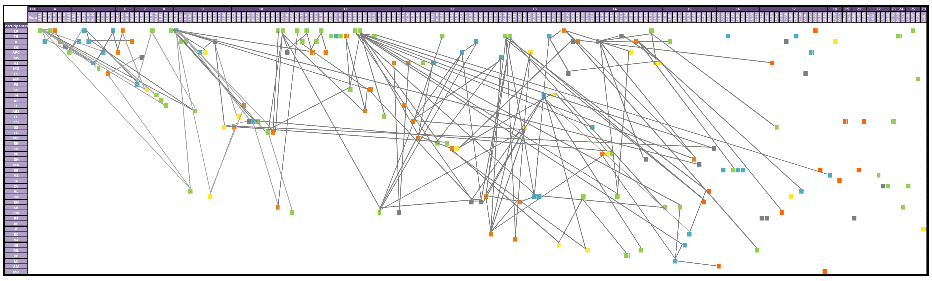

Figure 8: Visual map of online interactions.

In order to have a complete holistic view of the interactions that took place in the two course blogs, we would have to add all the data from “mundomac” and from the “bestofpdi”, which we found hard to accomplish in a satisfactory manner given the great amount of data and lack of an adequate software that could integrate the variables mentioned earlier. Therefore, we proposed the development of a visualization tool that is currently being fine tuned at our University.

The MRL visualization tool works in conjunction with a qualitative analysis web-based software to build visual maps of the coded data. Maps built are interactive and, such as in the Seascape and Volcano tool, they enable a timeless motion mode that allows us to have a comprehensive understanding of the discussions flow and of interactions as a whole. Hovering over any colour will display the coded message and clicking any relational link will highlight its path, where it began, expanded and ended.

5 Conclusions

Methodologies for the study of online asynchronous discussions usually rely on the application of content analysis models to examine learning processes, one of which relates to the construction of knowledge. Although still validate and appropriate, content analysis *per se* disregards the temporal dimension of interactions and should, therefore be complemented by other methods that can help researchers better understand such processes and facilitate additional in-depth analysis.

Considering the process of knowledge construction as a continuous one that happens over time and taking into consideration that it is mediated through interaction (in online learning environments usually in the form of written messages), we need to study interaction over time to understand how knowledge construction happens and its relation with other complex data.

Visual representations of online interactions may add insights to the study of learning processes. In this respect, we presented MRL, a visualization tool generates dynamic visual maps to represent the multidimensional relationship between discussion content, participants’ interaction and time.

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