Dialogue types for collaborative design: a front-end BIM application.

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DIALOGUE TYPES FOR COLLABORATIVE DESIGN

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Abstract: Collaborative design is an iterative process of selecting and evaluating solutions in the presence of several potentially conflicting requirements dictated by different professional expertise and preferences, a concept central to Building Information Modelling (BIM) implementation. In previous research, we showed that the core decision process can be better understood using argumentation-based models of practical reasoning. This allows the identification of the rationale and the relationships between conflicting issues, thus providing clarity and transparency for decisions achieved.

This paper aims to take one step further in modelling this process, and suggests a novel methodological approach that translates collaborative, conceptual and perceptual activities related to design processes undertaken by design and construction professionals to correspondent argumentative dialogue types such as information seeking, deliberation and negotiation. Computational models of dialogue identify protocols for collaboration establishing reasons and evidence of claims made and joint identification of goals and solutions. Therefore, the proposed argumentative dialogue permits the formalisation of collaboration analysis, design decision steps can be monitored and the dependency relationships between professionals involved and decisions taken can be traced. Future research would develop a computational model to be employed by intelligent software agents to assist professionals in analysing complex collaborative decisions.

Keywords: collaborative design, argumentation based models, argumentative dialogue types, protocols for collaboration, collaboration analysis.

1 INTRODUCTION

The core of Building Information Modelling implementation lies on effective and efficient collaboration while a shift of the design effort towards the early and conceptual design stages has the potential to lead to fewer problems during the later more complex design steps (Leon et al., 2015). The Architecture Engineering and Construction (AEC) industry is shifting its focus in relation to projects delivery, from the chain of activities to efficient collaboration and innovative ways of creating, sharing and collecting relevant information among AEC professionals (PAS 1192-2:2013). Therefore, collaboration and communication are becoming central for successful construction projects completion. However, collaborative design is a complex process composed by different phases that range from establishing a shared understanding of the design problem, through formulating objectives and solutions and selecting those that best suit constraints and preferences of different construction professionals involved.

This research is examining multidisciplinary team work during the early BIM and conceptual design stages and correlates design processes analysis with formal models of

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dialogue. Formal models of dialogue have been studied in Artificial Intelligence as methods to represent different entities collaborating in the accomplishment of a goal. Different types of dialogue exist according to the nature of the participants' goal. Derived from philosophical studies in Argumentation, dialogue protocols have been developed to model both the communication between participants, and the reasoning underpinning this interaction, including methods for challenging claims and discussing pros and cons for different choices (Walton & Krabbe, 1995, Reed, 1998).

We have shown in previous research that the collaborative reasoning applied for early BIM and conceptual design stages involves a process of argumentation where professionals with different expertise and domain knowledge establish agreements on the design solutions. Formal models of argumentation may contribute to understanding how requirements, expertise and information flow lead to a design. This is, however, insufficient to fully understand how a collaborative process happens during the design process as it does not represent the purpose of collaborative reasoning at different stages. We argue, in this research, that the dialogical context in which the argumentation takes place is a more suitable method to examine and model the communication between AEC professionals at early and concept stages of design.

In this research, we propose to investigate formal models of argumentation-based dialogue as an initial step to understand different dialogical contexts, where dialogical moves, such as a question, a declaration of agreement or disagreement with a particular claim, can be contextualised within the purpose of a particular design stage. The research rationale of this project is to understand, translate and model design team's actions into dialogue models, such as information seeking, deliberation and negotiation, for the purpose of formalising and monitoring design decision steps. This work is also based on the research developed by Leon (2015) and it extends previous research on the application of argumentation based reasoning for understanding multidisciplinary design processes and decisions (Leon and Toniolo, 2015).

2 Dialogue Types within Design Thinking

In this section, we propose two methodological perspectives on the representation of dialogue that underpin the thinking process of a team of professionals engaged in collaborative design. The first introduces some key concepts of collaborative design analysis in the context of BIM, and shows that better understanding of design actions among professionals is foundational to propose a more efficient and holistic design approach. The second approach, drawn from the use of dialogue models in Artificial Intelligence, shows that a formal model of dialogue of an argumentative form is a tool that may support the analysis of communication goals and issues, and may be employed as educational tool for improving reasoning and conceptual understanding. In the following section, we show how these two approaches may come together to analyse complex collaborative decisions among professionals within a front-end BIM context.

2.1 Design Processes

Collaborative design is highly influenced by critical behaviours, i.e. social relationships' factors and clear communication paths, rather than operational and technical problems or human error (Badke-Schaub and Frankenberger, 2002). The creation of favourable dynamics during a collaborative project is hindered by these critical behaviours and especially by issues of communication, negotiation, reflection, and social processes. Collaborative design processes are also hindered by poor incorporation of some important

design concerns (like later life-cycle issues and sustainability design decisions), (Klein et al., 2003). Likewise, obstacles that often appear during the collaborative design processes are issues of education and different design and engineering backgrounds of the professionals, thus, communication problems, technological challenges arising with the application of BIM within different professionals and issues of compatibility, team building and working, workflow, cost and responsibility allocation (Randy, 2011).

Methodologies that analyse design processes based on themes and actions (i.e. collaborative, cognitive, physical actions) have been extensively researched by Gero and McNeill (1998), Suwa, Purcell et al. (1998) and Salman, Laing et al. (2014). Similar research has been applied for investigating designers' collaboration and interactions with computational design mediums (Gu, Kim et al. 2011). These methodological approaches intend to provide an analysis and understanding not only of the design processes but, most importantly, of the different types of interactions and activities that occur during design processes.

As a result, this research is applying a design process methodological analysis at a macroscopic level applicable at conceptual design stages, thus, defining designers' cognitive actions in a systematic manner during the design stages and at providing further insight in the designers' design processes, as defined by Gero and McNeill (1998) and Suwa, Purcell et al. (1998). The specific methodology is defined as design protocol analysis and it includes the recording of a design activity and its segmentation in verbal protocols according to subjects' intentions and the contents of their thoughts or actions. Design protocols can be segmented either according to subjects' verbal events like pauses, phrases and intonations (Ericsson, Simon 1993) or according to subject's intention and to the theme of the content (Suwa, Tversky 1997). For this research the latter approach has been considered most suitable because it is capable of encapsulating the essence of collaborative design interactions (Suwa, Purcell et al. 1998); thus, the division of the segments was based on "the statements made to build a representation of scientists' mental operations" (Dunbar 1995).

Once the thematic segmentation of a design process is completed, the segments are categorised according to an actions' coding scheme corresponding to physical, perceptual, functional and conceptual actions (Suwa, Purcell et al. 1998). The segments' division is case depended and the categories in which they can be divided is determined by the research scope (Gero, Mc Neill 1998). As a result, the current research follows protocols suitable for analysing synchronous collaboration among multiple participants (Gu, Kim et al. 2011), protocols on cognitive actions during design processes (Suwa, Purcell et al. 1998) and protocols on function-behaviour-structure model (Gero, Mc Neill 1998).

2.2 Formal Representation of Dialogue

In Artificial Intelligence, dialogue has several interpretations and uses. In this research, we consider dialogue in the form introduced by the seminal work of Walton and Krabbe (1995). Dialogue as a complex form of communication that has a goal (such as making a decision on what to do, or gathering some information) and is a sequence of questions and replies that can be modelled using a protocol. Such protocols have been employed by software agents as methods for effective communication (Reed, 1998). An agent is an autonomous entity that have the capability of observing the world and deciding how to act upon these observations. A protocol is a set of rules that specifies what utterances can be exchanged during the dialogue. Walton and Krabbe (1995) define a characterisation of dialogue types according to the goal of the dialogue. Participants aiming at increasing their knowledge on a topic would engage in an information-seeking dialogue, for example while

in a deliberation dialogue the intention is to decide what to do. In order to model complex interactions, these dialogue types include a component of argumentation, hence referred to as argumentation-based dialogue, permitting agents to state pros and cons for claims made and justify actions to be adopted. Formal games based on dialogue protocols have been proposed to formalise different argumentation-based dialogue types (McBurney and Parsons, 2002). Ravenscroft (2007) highlights the educational potential of systems employing formal dialogue game structures to facilitate collaborative argumentation for improving conceptual understanding and development.

Recent research on argument mining, the automatic extraction of argumentation structures from text, suggests that understanding dialogical context facilitates the identification of arguments (Budzynska et al, 2014). We suggest that such dialogical context in early BIM design phases may be identified by establishing the relation between the types of dialogue proposed by Walton and Krabbe (1998) with the analysis of communication at different levels proposed by Leon (2015). On the basis of this latter analysis, Leon and Toniolo (2015) showed that professionals involved in early BIM design stages undergo a process of argumentation in order to make decisions concerning the design project. Our work in this research attempts to establish the premises for an enriched and potentially automatic analysis of communication amongst professional during early stages of design. This may represent the basis for mixed-initiative argumentation-based dialogue between professionals and agents acting as mediators to improve detection of conflicting ideas and information at different phases of design.

3 METHODOLOGY

During this research, we analyse two segments from two different studies focusing on concept and early BIM multidisciplinary collaboration, where two design teams are monitored while working on a design brief by implementing BIM (Leon, 2015). The specific segments are chosen due to their thematic complexity and they are categorised and coded according to three levels, including physical level, perception and concept level and collaboration level, as per Gero and McNeill (1998) and Suwa, Purcell et al. (1998). In the analysis, we provide an annotation of the different levels of interaction between participants. We propose how actions' coding may correspond to a type of dialogue of those presented by Walton and Krabbe (1995). We show that the actions' coding provides a dialogical context for the dialogue, suggesting its overall goal. This permits us to link this coding to a dialogue type that will eventually permit us to study a more granular account of the speech acts involved.

3.1 Actions' Coding scheme

The purpose of the actions' coding levels is to provide answers regarding the participants' interactions among them and with the physical and digital media, the participants' cognitive, conceptual and perceptual actions and the general evolution of the design processes. These three main levels applied for coding the studies' segments are presented in Table 1 and include: the collaboration level focused on cognitive synchronisation, ideas clash and workflow drivers; the concept and perception level focused on setting goals, making decisions, brainstorming and re-examining new and existing features; and the physical actions level for drawing and sketching both with physical and digital means, and also for inspecting design elements. The segments focused on physical perceptual and

conceptual actions are adapted from Suwa, Purcell et al. (1998) while the collaboration level is adapted from Gu, Kim et al. (2011) and Gero and NcNeill (1998).

Table 1: Generic coding scheme

Levels	Categories	
Collaboration	Cognitive synchronization	Argumentation and negotiation
	Workflow driver	Decision making
Perception & Concept	Perceptual Activities	Focusing on new or existing features
	Set up Goals	Goals on new and existing functions
	Co-Evolution	Brainstorming
Physical Actions	Sketching/ Drawing	Drawing, importing images, inspecting elements

3.2 Dialogue types

Among the different types of dialogue proposed by Walton and Krabbe (1995), we have identified three most relevant dialogues for early BIM multidisciplinary collaboration.

- Deliberation Dialogue: A team engages in dialogue to decide how to act in collaboration. The participants aim to find an agreement on the course of actions to adopt according to their preferences, expertise or commitments.
- Negotiation Dialogue: A team with limited resources may disagree on how to allocate these resources, the dialogue aims to resolve these conflicts.
- Information-Seeking Dialogue: Participants may have limited knowledge of a topic and engage in dialogue to improve their knowledge.

These dialogue types represent different dialogical contexts characterised by an initial arising situation and a subsequent goal to be achieved through the discussion. A protocol may, then, specify how participants would interact in the specific dialogue context. In this research, however, we simply focus on the identification of the dialogical context and we draw potential links with the scheme presented in Section 3.1.

3.3 Analysis

In this section, we propose three examples where we suggest a connection between the dialogue context and the actions' coding scheme presented in Section 3.1. The focus of the analysis is on the two levels concerning verbal actions: the perception and concept level and the collaboration level.

BS: What kind of storage do we need? What is going to be stored?
A1: Models
BS: Are these models small or large?
A1: I suppose sometimes they might be large models
BS: Storage space would need to be reasonably sizable.
A1: It depends how much you value the workshop, if the strategy of the client is to value the model making, workshops and storage should be big
BS: Yes, especially if it is for archive. How long do we have to keep documents for?
QS: Five years
BS: Hence we need a sizeable paper storage as well as space for models.
A1: And also, I suppose, this kind of facilities needs things like boards, or drawing tables

Relevant Clip Annotations:
Collaboration – Cognitive Synchronization: Shared Understanding and Representation
Collaboration – Workflow Driver: Decisions on New Features
Concept and Perception – Perceptual Activities: Problem finding
Concept and Perception – Co-Evolution: System Brainstorming

Figure 1: First segment

In the first segment, different professionals, including a building surveyor (BS), a quantity surveyor (QS) and an architect (A1) are discussing some specific aspects of a building, focusing on storage space. We notice that in this extract professionals are engaged in the conversation to find further information from other professionals about the requirements of the storage space. This represents an instance of information seeking dialogue arising from a situation in which a participant has some knowledge that the other participants lack but require in order to achieve a design that is compliant with the client requirements. The dialogue is driven by the questions raised by the building surveyor, while the other professionals complement each other's knowledge. Furthermore, we notice that participants enrich the knowledge exchange by providing justifications for the information proposed (e.g., client values model making), forming an argumentation-based information seeking dialogue. The annotations for this segment, as shown in Figure 1, indicate an establishment of shared understanding, and decision on new features at the collaboration level, while at the concept and perception level a phase of problem finding and system brainstorming is identified. We can conclude that the combination of these annotations may then be considered as indicator of an information-seeking dialogue.

BS: From building regulations, the minimum occupancy factor is 6, so each office space must be a minimum of 6 square meters
A2: But we should go for the best quality of the space, so if we are designing an office for research and design we should aim for bigger desks and room for devices
BS: Yes, a building that is used to function, people need space to be creative. From a cost point of view we should design what we want
QS: But a flexible budget is unrealistic, we should make it functional. We have to define priorities in terms of what we want and what we can really can afford.
BS: otherwise we get a disparity between the budget and where ideally we want to be.
QS: At this stage, you made an assumption of a four storey building, let's not make that assumption just yet because the higher we go the more expensive it is going to be. We need to design for a big number of people, now, it might have an influence on what type of structure we are going to use.
BS: It is going to be an issue anyway because of the slope of the site
QS: If you are going for steel you are going to struggle to get it to the site
BS: I was initially thinking that it would be concrete, if you post tension it, you get slimmer floor elements, with open plan spaces we can use thinner column sections.
QS: More expensive frame but you save in terms of height and materials
BS: Yes, and you get more usable space as well.

Relevant Clip Annotations:
Collaboration – Cognitive Synchronization: Shared Understanding and Representation
Collaboration – Cognitive Synchronization: Negotiation
Collaboration – Workflow Driver: Decisions on Existing Features
Concept and Perception – Set-up Goals: Goals for Objectives and Functions
Concept and Perception – Perceptual Activities: Focus on Features and Relations

Figure 2: Second segment

In Figure 2, we report a second segment, where the discussion brings the professionals to the analysis of costs in relation to construction issues. In this segment, we see two different types of dialogue negotiation and deliberation. The need to decide what to do, such as the dimensions of office space, is interleaved with the need to find a trade-off between costs, numbers of storeys and design material. The building surveyor and a second architect (A2) initiate a phase of deliberation by considering the open problem of designing office space, where the participants share options driven by room requirements and regulations. The building surveyor then create the necessary premises to enter the negotiation phase, by highlighting that costs should not be considered as an issue. The quantity surveyor, advocating for a trade-off between budget and design choices, acts as the opponent proposing reasons as to why the building should be lower in height. In turn, the quantity and building surveyors propose solutions that best suit their individual design ideas and expertise, leading to a compromise that satisfies the resource constraints. We may also see that the building surveyor establishes the premises for starting a new phase of deliberation, by asserting that the access to the site is difficult, hence, a further decision on what is to be done about the slope needs to be taken in later stages.

The actions' coding indicates that there is a phase of shared understanding, similar to that in Figure 1. This is clearly an identifier of argumentation that underpins all three types of dialogue presented in this research. Negotiation differs from deliberation and can be recognised by the initial situation: the former arises from an open problem (e.g., that of setting up goals) while the latter focuses on a decision on existing features on the basis of scarce resources. We suggest that the actions' coding should be used to differentiate between dialogue as follows. At the collaboration level the actions' coding includes a phase of negotiation, in combination with a decision on existing features as a workflow driver. As suggested by the use of the similar terminology, the combination of these actions indicate a phase of negotiation dialogue. The actions at the concept and perception level, such as setting up goals, are indicators that the participants are entering a phase of deliberation dialogue.

4 Conclusions

This research is focusing on a novel methodological approach that translates collaborative, conceptual and perceptual activities related to design processes undertaken by design and construction professionals to correspondent argumentative dialogue types such as information seeking, deliberation and negotiation. This is achieved by examining two different segments taking place during concept design stages within a BIM context, analysing them according to design actions' coding scheme and then identifying the different dialogical contexts. The proposed argumentative dialogue permits the formalisation of collaboration analysis for built environment applications while design decisions can be monitored and traced. As a result, dependency relationships between different professionals involved in a built environment project and decisions taken can be traced.

The impact of this research is focused on developing a deep understanding of how collaborations work within a dialogical context to clearly identify the stages of design, thus leading to more tailored interventions for overcoming communication issues and potential disputes. This research will further develop into a computational model applicable by intelligent software agents to support multidisciplinary design teams of the AEC industry in analysing complex collaborative decisions for informed decision making and therefore disputes prevention. Furthermore, future research will analyse emerging collaborative patterns and examine linking dialogues development with building models.

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