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Towards computational dialogue types for BIM collaborative design: an initial study.

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Towards computational dialogue types for BIM collaborative design: An initial Study

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Abstract. Collaborative design is an iterative process of selecting and evaluating solutions under potentially conflicting requirements, a concept central to Building Information Modelling (BIM) implementation. Previous research has shown that design can be better understood via computational argumentation-based dialogue. We suggest that in BIM context different types of dialogue should be considered and we propose an approach that translates collaborative, conceptual and perceptual activities undertaken by design and construction professionals to dialogue types.

1 Introduction

Increased multidisciplinary effort during the early design stages of the Architecture, Engineering and Construction (AEC) industry is a prerequisite for effective overall design and construction stages, especially due to the Building Information Modelling (BIM) mandate in 2016 [10, 19]. The core of Building Information Modelling (BIM) 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 [11]. The Architecture Engineering and Construction (AEC) industry is shifting its focus in relation to projects delivery to efficient collaboration and innovative ways of creating, sharing and collecting relevant information [13]. 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 dialogue. The domain of early design phases makes it a natural environment for introduction of argumentation-based reasoning in order to model different hard and soft constraints, misaligned goals, information and different methods to proceed with the design. This has been shown in many design applications, from engineering (eg, [2]) to software development (eg, [5]) to name a few, with both positive and negative usability feedback [16]. In previous research, we analysed collaborative reasoning applied for early BIM showing that conceptual design stages involve a process of argumentation where professionals with different expertise establish agreements on design solutions [9].

Formal models of argumentation may contribute to understanding how requirements, expertise and information flow lead to a design. However, to fully understand how collaborative design proceeds in BIM the purpose of collaborative reasoning should be represented at different stages. We argue, in this research, that the dialogical context in which the argumentation takes place is a suitable method to model the communication between AEC professionals at early and concept stages of design. In previous research, Black et al [3], proposed a new type of computational model of dialogue derived from real team design context. In the long term, our objective is to build upon their work and formalise the dialogue that takes place between AEC professionals in early design stages. We believe that dialogue in this context can be understood as a combination of existing dialogue models (such as information seeking, deliberation and negotiation) with continuous shifts and interleaving between these models. Based on real examples extracted from Leon [10], we discuss an initial methodology that may provide some support to this claim.

2 Dialogue Types within Design Thinking

In this paper, we aim to draw a comparison between model design team's actions as prescribed by the AEC research methodology for analysis of team work and computational dialogue model goals. Here, we show how these two approaches may come together to analyse complex collaborative decisions among professionals within a BIM context.

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 [1]. Collaborative design processes are also hindered by poor incorporation of some important design concerns (like later life-cycle issues and sustainability design decisions) [8]. Methodologies that analyse design processes based on themes and actions (i.e. collaborative, cognitive, physical actions) have been extensively researched by Gero and McNeill [6], Suwa, et al. [17] and Salman et al. [15]. These methodological approaches intend to provide an analysis and understanding of the design processes and, most importantly, of the different types of interactions 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 providing further insight in the designers' design processes, as defined by Gero and McNeill [6] and Suwa et al. [17]. 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. 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 [17]. The segments' division is case dependent and the categories in which they can be divided is determined by the research scope [6].

Formal Representation of Dialogue. Formal dialogue has several interpretations and uses. In this research, we consider dialogue in the form introduced by the seminal work of Walton and Krabbe [18], where a characterisation of dialogue types is made according to the goal of the dialogue. Formal games based on dialogue protocols have been proposed to formalise different argumentation-based dialogue types [12]. Ravenscroft [14] highlights the educational potential of systems employing formal dialogue games to facilitate collaborative argumentation for improving conceptual understanding and development.

Furthermore, recent research on argument mining, the automatic extraction of argumentation structures from text, suggests that understanding dialogical context facilitates the identification of arguments [4]. We suggest that such dialogical context in early BIM design phases may be identified by establishing the relation between the types of dialogue

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

proposed by Walton and Krabbe [18] with the analysis of communication at different levels proposed by Leon [10].

3 Analysis

During this research, we analyse segments from two different studies focusing on concept and early BIM multidisciplinary collaboration, where two multidisciplinary design teams are monitored while working on a design brief. The first step for gathering information about the kind of dialogue existing in early stage construction design is to collect, extract and transcribe data from the study with AEC professionals. This data extraction and transcription phase is focused on the identification of stages of collaborative design that involve debate over options as well as creation of new solutions. The studies raw data are collected according to protocol analysis as described in [10]; the studies are video recorded, transcribed and divided into smaller units (segments). The specific segments are chosen due to their thematic complexity.

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 are categorised and coded according to three levels, those focused on physical perceptual and conceptual actions are adapted from Suwa et al. [17] while the collaboration level is adapted from Gu et al. [7] and Gero and NcNeill [6].

Dialogue types. Among the different types of dialogue proposed by Walton and Krabbe [18], we have identified three most relevant dialogues for early BIM multidisciplinary collaboration: (i) Deliberation Dialogue: how to act in collaboration; (ii) Negotiation Dialogue: how to allocate scarce resources; (iii) Information-Seeking Dialogue: improve limited knowledge. These dialogue types represent different dialogical contexts characterised by an initial arising situation and a subsequent goal to be achieved through the discussion. Here we simply focus on this dialogical context and we draw potential links with the scheme presented in Table 1.

Analysis. We propose two examples where we suggest a connection between the dialogue context and the actions' coding scheme. The focus of the analysis is on the two levels concerning verbal actions: perception & concept and collaboration.

In the first segment, a building surveyor (BS), a quantity surveyor (QS) and an architect (A1) are discussing some specific aspects of a building, focusing on storage space.

Table 2. First Segment

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

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. Furthermore, 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 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. The combination of annotations indicates an information-seeking dialogue.

In Table 3, 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. BS 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. BS creates the necessary premises to enter the negotiation phase, by highlighting that costs should not be considered as an issue. QS 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, QS and BS propose solutions that best suit their individual design ideas and expertise, leading to a compromise that satisfies the resource constraints. BS 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 Table 2. 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 participants enter a phase of deliberation dialogue.

Table 3. Second Segment

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

As each segment in the study of Leon [10] is annotated with the actions presented in Table 1, actions' coding provides a dialogical context for the dialogue at different design stage. In future, this will enable a more granular account of the speech acts involved.

4 Discussion

This research is focusing on a methodological approach that translates collaborative, conceptual and perceptual activities related to design processes undertaken by BIM professionals to correspondent argumentative dialogue types such as information seeking, deliberation and negotiation. The proposed argumentative dialogue may better inform the formalisation of collaboration analysis for built environment applications while design decisions can be monitored and traced. The work presented here is only a starting point for investigation of the domain and potential of the approach. While thematic action coding for clips is currently manually performed, we will investigate methods to automatically identify factors that would allow us to annotate each dialogue clip on the basis of a combination of keywords and speech acts. Much future work is, however, needed to provide a framework to systematically analyse dialogue in early BIM stages.

We believe that although design has been thoroughly studied in existing research, the richness of the design process underpinning early building and construction design stages has potential for further future research. This may inform current computational models of dialogue with focus on dialogue shifts and practical reasoning [18]. Experiments such as that presented in [10] provide a rich source of data that may have potential for application and advancement of current research for example in argument mining [4]. Our work also attempts to establish the premises for an enriched 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.

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