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MODELLING CO-EVOLUTION IN DESIGN PRACTICE

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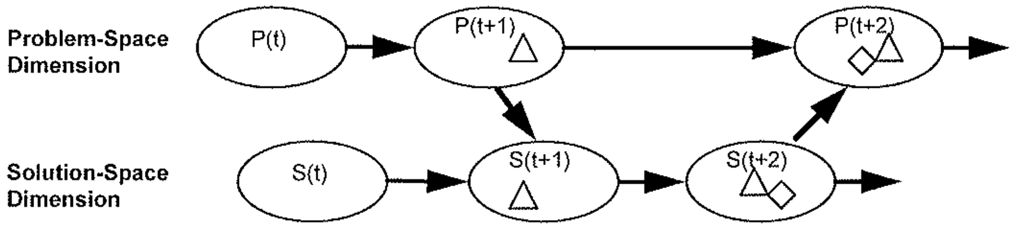
ABSTRACT
Co-evolution is considered as a key characteristic of designing. Several authors have described design thinking processes as the co-evolution of design problem and design solution. Its theoretical grounding is, however, still in an early stage. In this paper, we aim to bring the concept further by studying a real life design meeting of an architect and a client. We developed a model of how co-evolution in a multi-party setting might work, consisting of the problems as perceived by the architect and client, the solutions as perceived by the architect and client, and relations between those. A co-evolution episode starts with introducing an underdeveloped design-solution pairing from the perspective of the initiating actor and ends with summing up the discussion and/or agreeing on the decisions taken. The developed model was used to look in detail at the utterances in three co-evolution episodes and then refined by adding a intermediate space concerning the 'use' of the building that mediates between problem and solution spaces in interactions between designer and client.

Keywords: design model, design problem, communication, collaborative design, co-evolution

1 INTRODUCTION
Over the last ten years, several authors have described design thinking processes as the co-evolution of design problem and design solution (e.g. [1], [2]). In fact, this process of co-evolution has quickly become part of the 'conventional wisdom' about design - it is considered by some design researchers to be a vital and unique part of design thinking, and even to be one of the key characteristics that discerns design from other forms of human endeavor. Dorst and Cross [1], in particular, have been widely referenced in recent years as providing evidence for the co-evolution model, as depicted in figure 1.



P(t) initial problem space
P(t+1) partial structuring of problem space

S(t) initial solution space
S(t+1) partial structuring of solution space

S(t+2) developed structuring of solution space
P(t+2) developed structuring of problem space

Figure 1: Co-evolution model developed by Dorst and Cross [1].

Dorst & Cross base their introduction of the term 'co-evolution' on the observation that:
"...creative design is not a matter of first fixing the problem and then searching for a satisfactory solution concept. Creative design seems more to be a matter of developing and refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis and evaluation processes between the two notional design 'spaces' - problem space and solution space. In

creative design, the designer is seeking to generate a matching problem-solution pair. The model of creative design proposed by Maher et al is based on such a 'co-evolution' of the problem space and the solution space in the design process: the problem space and the solution space co-evolve together, with interchange of information between the two spaces." ([1], p. 434).

The key comment that has set the authors of the current paper to revisit the conceptualization of co-evolution, and to embark on an extensive (re-) modeling is that the model presented in the original Dorst and Cross [1] paper could be an oversimplification of design reality. That original paper was written as a reaction to the assumption that underlies some 'problem solving' models of design, namely that design problems are stable throughout a design project. One can see this 'the design problem is stable' assumption at work most clearly and explicitly in some of the phase-models of design processes that have been developed in the context of engineering design, where one is often first told to 'define the design problem' before moving into the conceptual stage. An extensive discussion on the problematic nature of this assumption can be found in Dorst [3]. The effort of Dorst and Cross [1] was focused on counterbalancing this assumption, and to make the point that design problems do change over time. This may have inadvertently limited the presented co-evolution model, limiting it to the level of complexity that is just enough to help the authors make their theoretical point, but possibly too simple to describe the complexities of co-evolution in real-life situations.

This is especially true if one extends the realism to considering the kind of multi-actor settings that are the basis of much design work, the kind of scene that shows the design-actors in their real life environment. In this paper we aim to redevelop the co-evolution model to encapsulate some of the complexities of the multi-actor setting, in an effort to get a descriptive framework that is closer to the real-life situation. We make use of an interesting data set figuring an architect and his client in two fully taped design review meetings [4]. The research questions that drive our current study include:

1. How do actors interact about problems and solutions in design meetings?
2. How can co-evolution in a multi-actor setting be modeled?

We start this paper with proposing a modeling of co-evolution in a multi-actor design situation. We then introduce the research method by which we studied interactions between architect and client in the DTRS architectural design meetings [4]. The model is subsequently confronted with the data and a revised multi-actor co-evolution model is proposed. The paper ends with a discussion and conclusions.

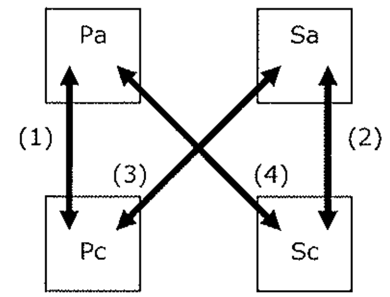
2 MODELLING CO-EVOLUTION IN MULTI-ACTOR SETTING

Co-evolution has hitherto been described as a single-person activity and subsequently only discussed at the intra-subjective level, which is the individual level, characterized by internal cognitive processes [5]. We extent that view to the inter-subjective level, that is the level among two or more individuals, and propose a descriptive model of how co-evolution might work in a multi-actor design situation, based on deduction from the Dorst and Cross model [1] and using the multi-actor setting of the Design-Manufacturing collaboration by Smulders and Dorst [6]. The preliminary multi-actor model we propose is depicted in Figure 2. We define co-evolution as a discussion concerning problem and/or solution in which the actors add insights to the problem-solution pairs.

The starting point for our model is that there are not only several actors involved within these design conversations, but also that these actors play different roles within the design situation. We see these roles as directly relevant to the process of co-evolution. In this paper we have limited the scope of modeling to the inter-subjective level of co-evolution.

The data that we analyzed concerns two meetings around a preliminary design concept of a crematorium. The actors of the meetings are the architect, the client, and a representative of a regulatory body. The building blocks of the model in Figure 2 are: the problem as viewed by the architect (Pa), the solution as viewed by the architect (Sa), the problem as viewed by the client (Pc), and the solution as viewed by the client (Sc). We assume that in a design project meeting, both the architect and the client have their own 'image' of the problems and solutions within the design situation. The architect 'owns' the 'factual' solution (i.e. knows more about the solution than the client) and the client 'owns' the 'factual' problem (i.e. knows more about the problems that are associated with the current situation).

Both the architect and the client have their own initial problem-solution (P-S) combination when the discussion starts. This gives us four possible lines of interaction, when co-evolution occurs, and 8 different vectors (alternating between actors, problems, solutions and problem-solution pairs). These lines of interaction are the relations, represented by arrows, in Figure 2. Co-evolution can also, however, take place in the cognitions of just one person – architect or client.



legend:
P= problem S= solution
a= architect c= client

relations:
(1) Pa -> Pc, Pc -> Pa
(2) Sa -> Sc, Sc -> Sa
(3) Pc -> Sa, Sa -> Pc factual axis
(4) Pa -> Sc, Sc -> Pa

Figure 2. Preliminary model of co-evolution in a multi-actor design situation.

So the possible moves within a co-evolutionary conversation are:

1. Relation 1: The comparison of the images that the architect and client have of the problem area at hand. For instance, the architect has to understand the problems that the client has encountered with the current building.
2. Relation 2: An information exchange around the images that architect and client have about the solution. The clearest example of this is when the architect presents a possible solution to the client by showing a new drawing and talking about the new design solution. The client then has to construct an image in their head of what the solution entails. This is a vital process because failure to build up an image of the design in the client's mind will let the design process run out of control.
3. Relation 3: The client uses their knowledge of the problem area to question the solution proposed by the architect. This is a possible locus for co-evolution: here both problem and solution can start to evolve in the conversation. The proposed solution might put a different slant on the initial problem statement, causing it to be developed or even reframed.
4. Relation 4: The opposite to relation 3 can also happen. The client comes up with possible solutions that actually upset the initial view the architect had of the problem, causing it to be redeveloped or reframed. This might easily happen because of a misunderstanding in the briefing process or when the architect introduces a problem that the client tries to solve.

A design conversation is aimed at the construction of an agreed problem-solution pairing, through an exchange of information and value judgments about possible problem-solution pairings. The goal is to work towards a correspondence of the matching Pc-Sa and Pa-Sc pairs, through a shared understanding or even the complete resolution of the issues. If this goal is achieved then the P-S pair disappears, and becomes Pca-Sac (i.e. Pa=Pc and Sa=Sc) as there is consensus over the factual problem and the quality of the factual solution. The test as to whether this has been achieved comes when the architect is able to defend Pca within their own office, and when the client is able to defend Sac to other stakeholders in the process (for example the funeral services companies).

3 RESEARCH METHOD

The empirical study concentrates on the two architectural meetings (A1 and A2) that are part of the DTRS7 data [4]. In these meetings a preliminary design concept of a crematorium is discussed between the architect, the client, and a representative of a regulatory body. According to the organizers of the DTRS7 the "Design meetings were filmed with four camera angles to capture, as far as was possible, all activity at the meeting. Digital cameras, recording to hard disk and placed discreetly around the meeting room, captured activity from a number of perspectives. A wide angle camera gave an overall view of the environment in which the meeting took place. Other cameras were zoomed either to capture material under discussion or on the participants taking part in discussion. It was not possible to remotely control cameras so all cameras remained with a fixed view for the duration of the meeting. Meetings lasted between one and three hours. A number of pilot studies were conducted to determine the optimal setup of cameras and in general the amount of information that has been captured was good" [4]. The data captured by the digital cameras were transcribed in detail and formatted with line numbers with notations of every passing minute. This allows quick reference to the exact location of particular pieces of data [4].

The goal of our empirical study is firstly to get insight in how actors interact about problems and solutions in real-life design meetings, and secondly to evaluate the effectiveness of our descriptive multi-actor co-evolution model by using the insight on the interactions. After a general analysis of the videotapes and transcriptions of the meetings, we divided the meetings into several episodes, with each episode a discussion about a specific issue. We then carried out a qualitative analysis of these episodes, focusing on the discussions that took place. The unit of analysis were the utterances of the actors in the project meetings. The data were independently coded by two researchers from differing backgrounds (industrial design and architecture) to ensure reliability.

We started with identifying the episodes in the meetings where co-evolution was seen to take place, namely when the architect and/or the client added a new insight to the discussion. Then, three particular co-evolution episodes were selected for more detailed analysis. The three co-evolution episodes we selected for further analysis are A1 (327-548) which concerned the size of the sanctuary, A1 (549-974) which concerned the audio-visual room and A1 (1130-1207) which concerned the stepping-stones. The criteria for selecting these episodes were: the clarity of the episode, real client involvement in the solution, and real engagement of the architect with the problem. All utterances in the selected co-evolution episode were coded as problem, solution, or 'other' and we tried to extract interaction patterns in the co-evolution episodes. In this way, we tried to get insight in the interactions about problems and solutions and to see whether our preliminary model matches the design situation in practice. To get more insight in the phenomenon of co-evolution, some more analyses of the meetings were performed. To determine the relative proportion of co-evolution in the meetings, for each co-evolution episode, the beginning transcription line and end transcription line were noted. The numbers of lines of all co-evolution episodes were then compared to the total number of lines for each meeting. Subsequently, we analyzed the opening and closing utterances of co-evolution episodes. We identified how co-evolution episodes start – with a problem, a solution, or otherwise – and the means by which the issues in the episodes were resolved – through an emergent solution, or through other means such as patterns of social interaction.

The data-analysis was done with the model in mind, but was open to the possible occurrence of events that fall outside the model. These observations were dealt with separately and gave rise to revise the model.

4 CONFRONTING MULTI-ACTOR CO-EVOLUTION MODEL WITH PRACTICE

In the data we identified 13 co-evolution episodes, each concerning a specific issue (see Table 1). In the following subsections, we first discuss the analysis of the design meetings and second, discuss the preliminary multi-actor co-evolution model.

Meeting	Start	End	Total	Start utterance (paraphrased)	End utterance (paraphrased)
A1	85	198	113	(A) Introducing present state of the design in relation to previous meeting.	(A) Summing up conclusions regarding the waiting room.
	198	326	128	(A) Introducing subject of previous meeting: porte cochere.	(A) Summing up conclusions regarding the porte cochere.
	327	548	221	(A) Introducing entrance to chapel by describing use-process.	(C) Ending with an 'OK' regarding an analogous situation that is representing the solution that was just discussed.
	549	974	425	(A) Summing up the subjects that have been discussed in the meeting so	(A) Concluding that a (new) brief is necessary for the audio-visual room.

				far, moving on to the audio-visual room.	
	1130	1207	77	(C) Introducing a concern regarding a design feature: the pond.	(A) Discussing how to finalize the design on that point.
	1305	1435	130	(A) Introducing the issue of materials in the final design.	(C) Ending with an analogous situation in order to make sure the solution is shared enough.
	1758	1882	124	(C) Introducing a new feature by client: signage and getting lost.	(A) Ends when the problem seems resolved.
	1883	1999	116	(C) Referring back to a subject from previous meeting: the ancient hedge.	(C) Ends by summing up conclusions.
	2000	2154	154	(C) Introducing a subject that still needs to be discussed: book of remembrance.	(A) Ends by briefly mentioning that it is OK as discussed.
			1488	**Total lines of co-evolution identified in Meeting A1**	
A2	119	279	160	(A) Starts with 'OK' regarding the last subject and fluently goes over to the next subject, guided by the drawings.	(A) Ends when the situation is clear and the issue resolved.
	354	408	54	(C) Mentioning a concern regarding the staff room.	(C) An 'OK', indicating that the concern is resolved.
	409	551	142	(C) Starts after a pause with discussing the office space.	(C) Nodding OK regarding the solution offered.
	1802	1957	155	(A) Introducing an option to the present design.	(C) Summing up and agreeing on next step focusing on options.
			511	**Total lines of co-evolution identified in Meeting A2**	

Table 1. Analysis scheme of design meetings: co-evolution episodes.

(Legend: A: Architect, C: Client)

4.1 Interactions about problems and solutions in the design meetings

With our analysis, we found episodes in which some of the interactions resulted in a changed insight, which is, according to our co-evolution definition, labeled as co-evolution. These new insights of the client and or architect made it possible to reframe their position in the discussion. Thirteen co-evolution episodes have been identified in the data and summarized in Table 1. An example of a conversation that indicates co-evolution is where the architect addresses the size of the waiting room. He mentions that although the design is according to the specifications it is "kind of small to my eye in relation to the size of the project" (A1, 93-94). This remark is directly related to the solution. However, he doesn't seem to have a design problem that could justify increasing the size of the waiting room as a new solution. During the discussion they seem to seek for this justification in terms of identifying the problem it could solve. At the end they agreed on extending the waiting room with a couple of meters because it would allow for enough seating for separate groups of people (e.g. successive funerals) as well as for people passing through to the porch area or to the loos. Over this co-evolution episode, the problem as viewed by the architect (Pa) and the solution as viewed by the client (Sc) both were subject to change resulting in a new problem-solution pair.

In another example they discuss the possibility of having a double funeral with two coffins that need to fit side by side in the sanctuary. In the discussion they don't really know whether the present design will be sufficient and what the size of a trolley (that carries the coffin) is. Although the client mentions that "we'll have a measure up on that" (A1, 370) the architect sees already some possibilities and begins to sketch while mentioning: "well there's a couple of things that I can do, I can make the whole thing bigger for a start to help you make this work I can also splay the opening a bit wider as well" (A1, 376-378). This brings the discussion first on to visibility lines inside and later on possible Corbusier-like windows that provide the outside visibility on the pond. Towards the end the architect summarizes the discussion which in fact forms the start of an additional co-evolutionary interaction. The client (Anna) mentions another form of use of the room under discussion which in its turn triggers the architect (Adam) to improve the design by proposing some extra build in seating (Extract 1).

Extract 1, Co-evolution interaction (A1, 519-536).

519	Adam	good so in principle you really like the idea of its spirituality being
520		amplified to make it very calm
521	Anna	Yes
522	Adam	And spiritual
523	Anna	Yes
524	Adam	Relaxing
525	Anna	Yes
526	Adam	Meditative sort of place
527	Anna	Yes not even necessary for funerals but for sort of
528		Memorial services or something that people could come later or some
529		area to come and visit to spend some time people sometimes like
530		coming back in the chapel and you know when we've got no services
531		on for sort of private reflection or something so there's nothing saying
532		that they couldn't do that but that would allow them to have an area as
533		well that they could also just sit in quietly and sort of that would be
534		quite nice
535	Adam	and should it therefore include perhaps some built in seating a built in
536		bench for a couple of people or /something like that\

This episode clearly shows that the client implicitly challenges the existing problem-solution pairing that is subsequently explicated by the architect by adding a new feature to the design, i.e. a new insight to the existing problem-solution pair. In the co-evolution episodes, all actors are equal; formal roles becoming less important. Outside the co-evolution episodes, we see many factual statements (informative, explanatory).

Examples of conversations that were not labeled as co-evolution are when explanations of the problem or solution were given, so not adding any changes to the existing problem-solution pairs. For instance, this occurs where the client mentions that one needs to push away curtains at a certain location for walking through (A1, 1006-1010). This remark results in the following clarifying interaction among the actors. (Extract 2).

Extract 2, Clarifying interaction (A1, 1011-1015).

1011	Adam	you don't necessarily have to go that way
1012	Anna	No ...
1013	Adam	there are three possible routes they either come through here one or
1014		they go through here two or they can go through there three
1015	Anna	OK that's alright lovely

This episode clearly illustrates such explanatory conversation.

Given the kind of data used – design meetings between designer and client – we only looked at co-evolution taking place when the designer or client contribute to the problem or solution, i.e. the inter-subjective level. As we stated earlier, however, co-evolution can also take place in the cognition of one actor, the intra-subjective level, which was modeled by Dorst and Cross [1]. .

In A1, 64% (1488 out of 2342) of transcription lines can be identified as 'co-evolution lines'. For A2, this figure is 24% (511 out of 2124). The amount of co-evolution in design meetings may thus depend on the stage in which the project is (besides many other things it depends on). The second meeting comes some months after the first one and concentrates more on elaborating the design. A possible hypothesis could be that early phases of designing conversations among different actors tend to have more co-evolution episodes than later phases. There is no evidence to suggest that the co-evolution episodes are longer than the non-co-evolution episodes in the data, and the length of co-evolution episodes seems not to depend on the phase of the design process.

The start of co-evolution episodes was analyzed for the 2 meetings. Table 1 shows that, at the beginning of A1, the architect raised issues that had still to be resolved as well as presenting (partial) solutions to issues that had come up earlier in the project. Later in A1 the client introduced the new subjects of discussion. In A2 both architect and client introduced new subjects. It seems that the architect had prepared a list of questions about issues that still need to be discussed in order to get resolved. The client was also given room to bring in issues they are concerned with. In that sense it was an open dialogue with input from both parties.

The issues are finally resolved within a co-evolution episode as follows. Table 1 shows that episodes seem to end when some sort of shared satisfactory situation is reached. Satisfactory situations are: the problem is 'solved' satisfactorily, a consensus about a vision is reached, or there is agreement on a further course of action. Where further design activities are needed there seems to be agreement about more abstract issues, sometimes concretized by naming an analogous situation (Le Corbusier like windows (A1, 493), built in seating like at the city centre church (A1, 535-542), etc.). Where a resolution occurs the whole subject seems to disappear from the discussion (for example, signage (A1, 1758-1882)).

Analyzing the co-evolution episodes we were able to identify some co-evolutionary interaction patterns among the actors. The patterns we identified are: the application of use scenarios and use plans, introducing precedents, use of drawings, and role-switching behavior. In the next paragraphs we will discuss and illustrate each of these interaction patterns.

Use scenarios are especially helpful to the client, who would never be able to create a design brief that contains all the information required. Sometimes it seems as if the client is reporting a film that shows the behavior and the thoughts of the users both of the current building and future users of the new building. Such a narrative is a very effective way of making explicit the implicit knowledge structures of the client that help the architect to better understand future use of the building; for instance, as the client mentions the funeral process of babies and young children (A1, 416) that need a special area that can somehow be 'curtained off' (A1 456).

What is also interesting to note is that the architect applies a form of use to externalize his knowledge. By giving descriptions of certain activities in and around the building, the architect aims to explain to the client the reasoning behind the design. These descriptions of behavior are by no means as rich as the use scenarios given by the client. They are more like what Roozenburg and Eekels [7] and Houkes et al. [8] call 'use plans'. The use plans of the architect and the use scenarios of the client need to coincide in order to prevent problematic use situations surfacing in the future. The architect enriches his use plans by taking over elements of the scenarios of the client, although his concluding remarks are still always made in the terms of his own 'thought world'. The application of use plans and use scenarios seems to be the most important co-evolution strategy among these actors.

Another pattern of social interaction aims addresses implicit knowledge structures by referring to precedents as commonly available knowledge (for example the Ronchamp chapel of Le Corbusier (A1, 493)) and using drawings, e.g. where the architect shows some conceptual diagrams on an additional drawing that illustrates where his design is coming from (A1, 660). These reference points sometimes help elicit implicit knowledge while in other situations serve to convey to other actors the meaning or origin of a complex solution without ever being able to explicitly describe that solution.

The final pattern of interaction that we have identified is the role-switching behavior of the actors which happens when actors forget their own 'formal' role either as client or as designer. An example is where the client takes the architectural role when she suggests swapping two rooms in order to hide the technicians for the visitors and to provide a better view for them on the service (A1, 572). Similarly, when the client introduces the solution of one-way mirrored glass for that technicians room to prevent visitors to look inside and see the operators tapping on keyboards (A1, 585). This idea is later incorporated in the more integrated solution of the architect (A1, 724), but again later questioned by the client because of reflections that the visitors might see of themselves in the mirrors (A1, 833). At these points, the actors act in a very trustful situation where there are no distinct roles for a certain period of time. Towards the resolution of the subject the actors again resume their roles, e.g. the architect asks the client to write a new brief (A1, 971). This strategy would appear to be related to their aim of better understanding the design solution, on the one hand, and the design problem, on the other.

From the analysis above it becomes clear that co-evolution in a multi-actor setting is not limited to one specific pattern of social interaction. The patterns that we identified aim to arrive at a more satisfactory problem-solution pairing by externalizing implicit knowledge structures that either reside within the mental system related to the architectural solution space or to the client's problem space.

4.2 Reflecting on the co-evolution model

Concerning the building blocks of the model, we see the client Anna and the representative of the regulatory body Charles both as clients. In general, it was unclear whether the utterances of the actors should be coded as PROBLEMS or as SOLUTIONS. It was often not clear whether the actors talked about the problem or about a possible solution per se. This holds for the architect as well as the client. For example in Extract 3 the architect says:

Extract 3, Referring to the problem or the solution.

376	Adam	well *[begins to sketch]* there's a couple of things I can do I can make the
377		whole thing bigger for a start to help you make this work I can also splay
378		the opening a little bit wider as well so you've got an even better view in
379		if that helps and that would certainly enable you to get a wider catafalque
380		inside there that might be suitable for two people the architectural
381		idea here is to have like a cylinder which will be top lit at the top
382		perhaps a glass pyramid something like that so you can get top light

The text not underlined might be considered to be related to the solution, whereas the underlined text seems to refer to an (underlying) problem. On the other hand, addressing problem and solution space in coherence with each other supports the actors in arriving agreement on a certain problem-solution pairing. They discuss and apply images of the use of the current building and the future operation of the new building. Use seems to lie between problem and solution and facilitates the process of arriving at satisfactory problem-solution pairings. For the architect, use was more closely linked to the solution, whereas for the client (Anna especially), use was very close to the problem. Extracts 4 and 5 show examples of this.

Extract 4, Use for the architect is related to the solution.

323	Adam	OK *[begins to point]* so having got this far everyone is now under cover
324		at this point erm + the way it's designed at the moment the roof edge is
325		actually on this line here + so that's the bit that covers you OK so that is a
326		length of about nine nine metres or so OK + from this point you go
327		through a lobby into the chapel [continues]

Extract 5, Use for the client is related to the problem.

351	Anna	I don't know I think I would say it might just I mean at the moment they
352		can just they can just go in side by side but it's difficult to squeeze in to
353		put the coffins on at the moment even because you've also you've got the
354		two catafalques in side by side and you need to have four routes for
355		people to go either you need the one in the middle for both people to go
356		and the ones at the end for them to drop the coffins off erm but even two
357		catafalques isn't always enough we've had three or we've had car
358		accidents you know we've had three coffins and we've not been able to
359		accommodate all the you know I mean if we can do two that's the

These observations raise the question of whether it is possible at any time in a design project to make a strong separation between 'problem' and 'solution', even if theoretically one might be able to distinguish them. The only exception to this is when there is a clear problem without a solution or a clear solution without a problem. For example extra features, like the stepping-stones in A1 (1153-

1155), are often introduced by an architect, with his own goals, ambitions, and feeling for architectural quality; strictly speaking they are outside the specifications [9].

Turning now to the relationships detailed in our model (Figure 2), we were able to distinguish each type of relationship in the data, but it was difficult to indicate the separate building blocks of the model. We were also not able to count the number of alternations between problem and solution, as was proposed in the method, or to quantify the number of relationships of a certain type in order to discuss how prevalent they were in the data. An example from the data of each type of relation is given below.

Relationship 1: The client knowing the 'problem' and the architect aiming at understanding the problem. Architect: "...my question for you is how wide would it need to be for two coffins..." (A1, 368). But the client knowing the problem doesn't know how to convey that message to the architect stating: "we'll have a measure up on that" (A1, 370).

Relationship 2: The architect knowing the solution and the client aiming at understanding the solution. For example the architect says: "so if you'd like me to increase the size of that space I certainly can do" (A1, 389). However, the client needs additional information to evaluate the solution and asks the architect: "how many people would you get on the seats?" (A1, 391). Other examples are when the architect proposes to: "... chalk out a three point one diameter circle on the ground somewhere" (A1, 438), and when the client proposed: "I think if we could put a bridge or something that looks like a bridge" (A1, 1148), which the architect follows with "you can have that as a bridge if you wanted not necessarily stepping stones" (A1, 1149).

Relationship 3: The client knowing the problem and the architect knowing the solution. The client tries to match the use of the building with the solution of the architect. For instance, after having investigated the solution the client wonders: "I'm just trying to think if people are at the end of those seating they also need to be able to see the coffin..." (A1, 397). To which the architect responds: "I didn't see it as being a doored off space I mean rather like an antechapel in a cathedral or whatever I just saw it as a space that you could walk in to..." (A1, 411). And then it's clear to the client: "yes that's fine" (A1, 414). When the architect does not want to change the design, he tries to change the client's understanding of the problem, as like the discussion about the stepping-stones as extra architectural feature (A1, 1153), for example. During the discussion, the architect mentions a number of times that there are more routes to the entrance by which he aims to resolve the concerns of the client. In the end, the client decides to keep the idea and proposes a meeting with future users (A1, 1204).

Relationship 4: The architect focusing on the problem and the client focusing on the solution. Within the two meetings, there are several occasions when it is possible to see a slight reversal of roles happen. During an episode where the architect and client discuss the light reflecting off the pond into the circular antechapel the architect mentions: "I saw the pond initially as being quite still but there's no reason why it couldn't have a fountain in it or something ..." (A1, 511). Elsewhere, during the discussion of the audio-visual room, the architect mentions a possible problem: "that's a difficult one because if they can see out then people would be able to see in" (A1, 583). The client then introduces the solution of using one-way mirrored glass (A1, 585).

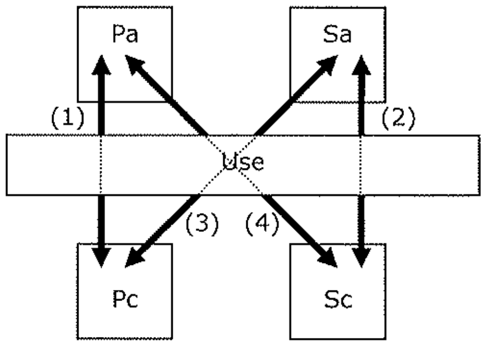
In most of the co-evolution episodes we have seen more than one of these relationships addressed during the design dialogue, most of them facilitated by 'use'. The mechanism by which the client and architect co-evolve is by adding to the future & present use of the building. Use, here, mediates between problem and solution spaces, explicating their coherence to each other.

5 MULTI-ACTOR CO-EVOLUTION MODEL

Based on the confrontation of our multi-actor co-evolution model with practice, we propose some revisions. We start this section by reflecting on the coding and analysis process.

In general, there was a very close match between the two coders. About the coding of the design episodes, we can remark that sometimes there was disagreement about the start of a new subject; the start is often just an introduction, reiterating what was known before. Coder 2 did not always include the summary at the end of the discussion in the coding. For the coding of the two episodes, there was no agreement about whether an utterance concerned the problem or the solution. Coder 1 labeled many utterances as SOLUTION where Coder 2 labeled them as PROBLEM. What we found was that, when discussing these differences, the concept of 'use' became extremely important.

From our analysis, we have found that it is difficult to distinguish the concepts of 'problem' and 'solution' as clear-cut statements and that 'use', mediating in between problem and solution spaces, seems to be what is discussed. Through discussing possible future use in the new building and the present use within the existing building, both parties learn from each other. There are for instance use cues about the smoking habit of people (A1, 163) that requires outside seating. Or about people that feel 'frightened' to sit too close to the mourning family, which requires segregated forms of seating in the waiting room (A1, 149-162). There is sometimes a transition within the same episode from the behavior in the present situation to possible behavior in the future building in order to discuss and improve the problem-solution pairs, e.g. when they discuss the size of the port cochere in the second episode (A1, 198-326). Reference is also made to the use in other crematoria, like the routing in the case of Amersham with only one building and the two buildings on the site under development (A1, 1799-1804). The final form of use that we identified is related to the more general behavior of people in circumstances of a funeral. Examples of these are when they discuss the funeral of young children (A1, 416-421 & 446-459), or the funerals where the visitors are not exactly on speaking terms (A1, 143-150).
We therefore propose a multi-actor co-evolution model that includes a conversation about 'use' in its different forms, mediating problem and solution spaces in interactions between the architect and client. The revised model is depicted in Figure 3.



legend:
P= problem S= solution
a= architect c= client

relations:
(1) Pa -> Pc, Pc -> Pa
(2) Sa -> Sc, Sc -> Sa
(3) Pc -> Sa, Sa -> Pc factual axis
(4) Pa -> Sc, Sc -> Pa

Figure 3. Proposed co-evolution model in a multi-actor design situation.

'Use' corresponds with the concept of 'use plan' developed by Houkes et al. [8]. It also corresponds with the concept of behavior as defined by Gero & Kannengiesser [10] who position behavior between function (corresponding with problem, the domain of the client) and structure (corresponding with solution, the domain of the architect). One could say that the 'battlefield' of architectural designing is about behavior. Architect and client talk, in their dialogue, about the use of the existing and new building, and get insight through this: the client designs the future use of the building (to anticipate problems) by presenting rich use-scenarios, while the architect needs to build up an understanding of that desired use because many details simply cannot be captured in a brief.

6 DISCUSSION AND CONCLUSIONS

In this paper, we have tried to further develop the notion of co-evolution in design. We started from the intra-subjective co-evolution model developed by [1] and developed a preliminary inter-subjective co-evolution model that would represent a multi-actor design situation. This model was confronted with a real-world conversation between an architect and his client in the latter stages of the design project (DTRS meetings A1 and A2, [4]), and adjusted to better suit the analysis of interactions about problems and solutions.
The real-world setting gave us a much richer picture of co-evolution. Taking the discussion between the actors as the subject of study helped us to describe co-evolution in a multi-actor design situation. This is a step forward from earlier studies solely focusing on individual designers and in lab situations. Based on the analysis, we found that our preliminary model should be enriched with the concept of 'use' as a bridging concept in discussions between architect and client. Further research should indicate whether our revised multi-actor co-evolution model could even be more refined, by confronting it with practice again to find more anomalies.

The co-evolution model as proposed here is developed based on the specific DTRS data set of the architectural meetings, which limits the generalization of the model. These meetings concern a specific type of architectural project, with infrequent mention of resources like time and money (money was only mentioned at three points: A1, 1418, A1, 1467 and A1, 2033), the stage of the project with the design almost finished, and most conceptual issues decided, the type of architect, who is open for dialogue and stakeholder participation: he asks questions and offers the client space to put forward her ideas and solutions. The clients have an equal position to the architect, which makes it safe for them to make suggestions. Finally the kind of data collected, with only two meetings of a larger design process recorded. The fact that these were just two meetings within the context of a single project, and individuals that clearly have a personal style in their approach to this project, do limit the scope of our conclusions; however, many episodes and utterances have been studied.

For future research we propose to test the model with the same data and data from different design projects in different fields, dealing with different phases of the design process. Also more fine-grained coding scheme, based on a solid theoretical framework, might refine the model. Apart from adding the existing intra-subjective level to the model, possible theoretical directions could be team learning theory, the synchronization of different thought worlds [11], [12], [13], the individual 'objects worlds' described by [14], or the notion of team mental models [15], [16], [17] that contain implicit and explicit knowledge structures [18] or even the exchange of 'deep smarts' that actors have been building up over the years [19]. The study of co-evolution in other fields, like in organization design (e.g. [20]), might also offer useful insights. The aim of these future studies would be to find more detailed patterns in design conversations on the basis of which we could start to discern different kinds of co-evolution (perhaps at different levels – detailed and at more general levels, for example – or more normative – better or worse – types of co-evolution and the criteria to distinguish them), perhaps working towards a typology. This could help to stimulate and improve co-evolution processes in design education and in professional design practice.

What we have shown in this paper is that while co-evolution was more or less introduced to contrast with 'normal' problem solving theory in an effort to adapt it more to design, it clearly is one of the collaborative thought patterns, and patterns of discussion within the design arena – and possibly a very important one. We hope, with this paper, to have opened up the notion of co-evolution in multi-actor settings for further research. Now it is time to refine the concept and to further inform, define and scope it.

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