Individual Research Paper

ENGN2225 Systems Engineering Design

Attributes Cascade for the Inclusion of Quadriplegic Children in Board Games

Christopher Zhang
u5351895@anu.edu.au
Tutorial Group W12A

Abstract

System design specification links customer requirements to a system's interface; helping transition from an advanced design to a validated engineering solution. One method of doing so is through an attributes cascade, in which key system attributes are broken down into secondary and tertiary tiers of attributes and then linked to the related subsystems of the solution. A case study was first analysed, then application and analysis of an attributes cascade was conducted on the groups project topic of including quadriplegic children in board games - with a focus on the effectiveness of voice recognition technology. This yielded relevant information on which subsystems must be included in the final design solution, and what further improvements must be made in order to fully meet customer requirements. Conclusions can be drawn that gameplay is possible with the use of voice recognition technology, however is enhanced when used in conjunction with a hands free tracking system.

Background of System Design Specification [System Attributes]

System design specification is a key aspect of the systems engineering process. It is a process that when followed correctly will link customer requirements to the system interface. This in turn is beneficial if a change were to be applied to a system and the flow on effects are to be fully understood (Browne 2014). The beginning of defining system attributes marks the transition from advanced development to a validated engineering design (*Figure 1*). It is in this stage that Kossiakoff et al. (2011), believe that the requirement of 'what the system is to do' is converted into 'how the required functions are to be implemented'.

One method of system design specification is construction and analysis of an attributes cascade. An attributes cascade lists design requirements determined earlier in the systems engineering process (in requirements engineering) as primary system 'attributes'. These primary attributes are then subsequently broken down into secondary, tertiary, (etc.) attributes. The significance of this cascade is that the final tier of attributes are linked to the design's subsystems and thus determinations can be made into which subsystems have the most substantial effects on key system attributes.

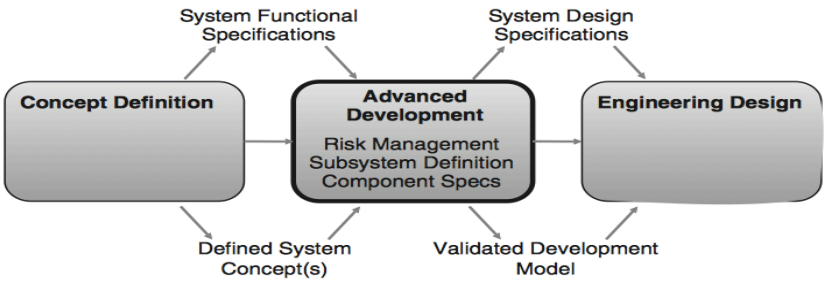

Figure 1 – Advanced Development Phase of Engineering Design Process (Kossiakoff et al. 2011)

The implication of defining clear system attributes can be seen in a case study concerning the improvement of schooling systems (*Attributes of Excellent School Systems* 2011). It was established in this study that schools that utilised system design specification techniques were able to draw connections between their ideal schooling model and the school's subsystems. Subsequently, they were able to identify desired improvements in specific subsystems (such as improvements to teaching equipment or teacher proficiency) and implement attainable and relevant solutions accordingly. The result of this was improvement in student performance, benefitting all stakeholders. Understandably, not every school surveyed had the same ideal model due to factors such as; history, culture, politics or wealth. However, this particular journal emphasizes that through system design specification and ensuing analysis, 'any school could improve from any starting point' (*Attributes of Excellent School Systems* 2011)

Project Background

The focus in our project is to modify an existing board game so that a quadriplegic child can participate without the assistance of a carer. From previous application of course content it has been concluded that it is of utmost importance that an existing game is modified rather than just creating a new game. This is so that the child feels full inclusion rather than feeling as if they are the reason for everyone having to play a new game. In order to accomplish this customer requirement, the technology of voice recognition, available regularly on both mac and pc (as duly noted in proceeding group research tasks), is under heavy consideration. Despite the current game focus solely being 'Guess Who', a comparatively simple game to understand and programme, the use of computers in conjunction with voice recognition technology would also open up the possibility of creating a generic game interface and adapting more games (i.e. creating a generic grid, which could be used for chess, guess who and battleship). The suitability of this suggestion is largely dependant on how this voice recognition solution will relate to the requirements of the customer.

Application to Modifying Board Games for Quadriplegic Children

Five key system attributes will be focused on in the construction and analysis of an attributes cascade in this research paper. They are; user friendly and compatible, promotion of equal treatment, flexibility in gameplay, portability and convenience, and safe for the user. These attributes are taken from our design requirements from the 'requirements engineering' stage of our project and can be seen in a TPM (technical performance measure) table in Appendix 1.

As aforementioned, the step of system design specification links the attributes of the system to its subsystems. Therefore, it is important to recognize which subsystems will be involved when playing a computer or laptop game. A simple subsystem integration taken from the 'subsystem integration' stage, depicting the subsystems and links between them, can be seen in Appendix 2. With reference to this appendix, the major subsystems to be related in this cascade are the; computer display, board game coding, microphone, webcam/other system, computer, and user. Ideally, the user subsystem should not be linked to any of the attributes, as this would insinuate that an input from the user is required. Issues would therefore arise, as the user in this case has very few input capabilities.

Primary Attribute	Secondary Attribute	Tertiary Attribute	Related Subsystems
A1.0 User friendly and compatible	A1.1 Suitable for kids aged 5 - 17	A1.1.1 Low in difficulty	Display/Coding
		A1.1.2 High in enjoyment	Display/Coding
	A1.2 Can be played by children without use of limbs	A1.2.1 Effective voice recognition technology	Microphone/Coding
		(OR) A1.2.2 Use of mechanical system or other system	Webcam/Other
A2.0 Promotes equal treatment	A2.1 Can be adapted to an existing game	A2.1.1 Electronically adaptable game interface	Display/Coding
		A2.1.2 Game rules remain unchanged	Display/Coding
	A2.2 Does not require assistance of carer or parent	A2.2.1 Independent set-up	Computer/User
		A2.2.2 Independent gameplay	Display/Computer/Coding
A3.0 Flexibility in gameplay	A3.1 Multiple games adapted to game interface	A3.1.1 Simple generic game interface	Coding
		A3.1.2 Method to switch between games	Computer/Coding

	A3.2 Multiple players allowed	A3.2.1 Ability to distinguish different voices	Microphone/Coding
		A3.2.2 Sufficiently sized display screen	Display/Computer
A4.0 Safe for user	A4.1 No swallowable parts		Computer
	A4.2 No exposure to electrical hazards		Computer
A5.0 Portable and convenient	A5.1 Accessible in different environments	A5.1.1 Adaptable to different devices	Coding/Computer
		A5.1.2 Adaptable to different locations	Coding/Computer
	A5.2 Easy to set-up	A5.2.1 Low in difficulty	Computer/User
		A5.2.2 Time effective	Computer/User

Figure 2 – Attributes cascade for the inclusion of quadraplegic children in board games

The break down of secondary and tertiary attributes is most effectively done through the application of the 'five how's technique' – an adaptation of the 'five whys technique', where to progress from a primary to a secondary attribute one must ask 'how' the attribute will be achieved (Serrat 2009). For the cascade of attributes; A1.0 user friendly – A1.1 suitable for kids – A1.1.1 low in difficulty, to derive the secondary attribute (A1.1) from (A1.0), one must ask 'user friendly, how?' which results in A1.1 – suitable for kids. A similar process is followed in derivation of A1.1.1. A4.1 and A4.2 were not extended into tertiary attributes, as these would be particularly vague and would not assist in further defining the system (e.g. A4.2.1 – no manufacturer defects).

Discussion

From the attributes cascade it can seen that the game set up is still very user dependant (A5.2 & A2.1.1). All other aspects can be controlled through game coding, the computer, its display, and the technology of choice. However, further investigation will need to be conducted into a system or technology that can induce a computer start up and game start up without a manual input. There will be a compromise with introducing the aforementioned, and that will be that the final design may become less adaptable to different devices and in different locations. It is noteworthy that in the pairwise analysis conducted on our customer requirements in the 'requirements engineering' stage (Appendix 3), the requirement of inclusion outweighed the requirement of adaptability and thus this compromise is desirable.

A viable option to diminish the need for a set up input is to use a technology that harnesses both facial movements and voice recognition technology. The *SmartNav* head mouse is an example of a hands free tracking system that works on head movements to move a cursor. Voice directives such as 'left click' or 'right click' can then be used to operate commands. Mackay (2004) finds that it is 'an especially versatile solution' while Dernoncourt (2012) says that 'its precision is as good as a computer mouse'. Although cost is not a restriction, *SmartNav* is also the cheapest head tracking system on the market as per Dernoncourt (2012). This technology would still require the assistance of a friend or carer to initially open the laptop or turn on the computer, but after that the user would be completely independent in accessing and participating in games.

Recall that a strong group consideration was introducing flexibility in which games the client could choose to play. One of the issues with adapting a visually complex board game would have been the coding required (well out of our reach). However, the client may, with the assistance of *SmartNav*, already be able to find these games online. This would lead to a greater variety of accessible board games and subsequently, to satisfy the primary attribute of flexible gameplay (A3.0), a generic game grid and the subsequent programming will no longer need to be created.

Another noteworthy conclusion drawn from the attributes cascade is just how important the subsystems of the computer and the board game coding are to each of the key customer requirements. Although it may have already been a foregone conclusion to include these subsystems in the final design, this result further emphasizes the importance of the incorporation of relevant coding in conjunction with an accessible and appropriate gaming device to whichever design solution may be chosen.

Conclusion and Further Work

This paper has related the customer requirements of a quadriplegic child wanting to participate in board games, to the subsystems involved in participating in these games through a computer with voice recognition technology. Conclusions drawn from the analysis of the attributes cascade are that, although voice recognition is suitable for gameplay, it alone will not make the game setup process appropriate. An additional system or technology, such as the *SmartNav* head mouse can be used in order to diminish the input required for game setup and add valuable gaming flexibility.

The next step in the engineering process is verification and evaluation where numerous tests will be used to validate system performance with respect to customer requirements. This will ensure that the newly introduced technology is still suitable for the client's particular needs.

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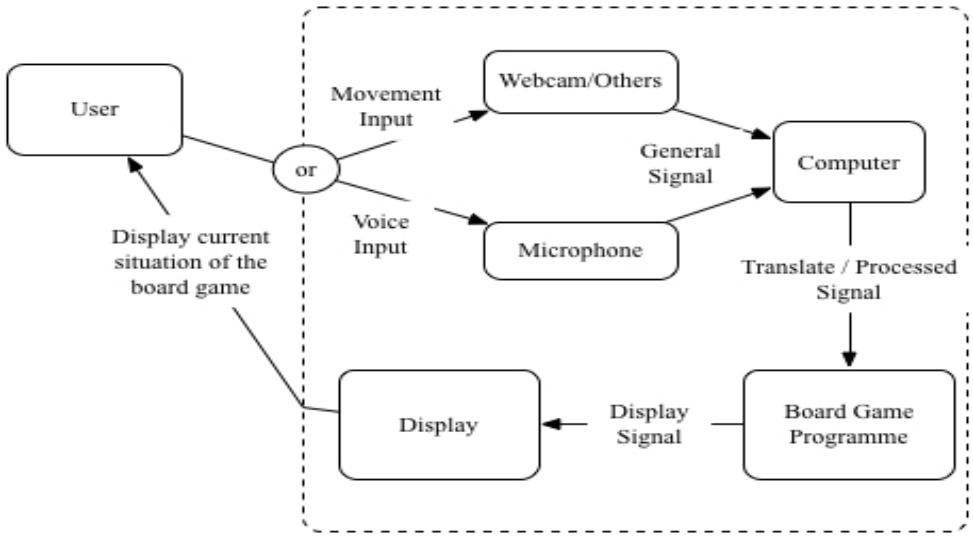
Appendix 1

Design Requirements	Engineering Characteristics	Metric (TPM)
Provide an effective participation	+ time spent in recreational activities	s (Time)
Conduce equal treatment	+ times invited to participate	% (Percentage)
Flexible usage	+ Chance of usage	% (Percentage)
User-Friendly	- Effort required to use the product	N (Force)
Portable / Convenient	- Size	m^2 (Area)
	- Setting time	s (Time)
Safe for the user	- Chance of accident	% (Percentage)
	- Gravity of occasional accident	1/10 (Scale)

Appendix 1 – TPM table, key attributes derived from design requirements (*Andreatta et al.* 2014c)

Appendix 2



Appendix 2 – Subsystem Integration of Voice Recognition Gameplay System (*Andreatta et al.* 2014b)

Appendix 3

	Inclusion	Simplicity	Adaptability	Safety	Comfortable	Discreetness	Weight	Cost	Score	Rank
Inclusion		1	1	1	1	1	1	1	7	1
Simplicity	0		0	1	1	0	1	1	4	3
Adaptability	0	1		1	1	1	1	1	6	2
Safety	0	0	0		1	1	1	1	4	4
Comfort	0	0	0	0		1	1	1	3	5
Discreetness	0	1	0	0	0		1	1	3	6
Weight	0	0	0	0	0	0		1	1	7
Cost	0	0	0	0	0	0	0		0	8

Appendix 3 – Pairwise analysis showing that inclusion is ranked above adaptability (*Andreatta et al. 2014a*)

Peer Review 1

Demonstration that the task requirements have been met:

All task requirements have been met. The Title is very relevant. The Abstract is thorough and to the point. The background lacks the use of case studies about how System Attributes have been used in previous situations.

***Take a whole-of-system approach when discussing the design*:**

You have clearly used the Systems Engineering Design Process properly. The mapping of the customer requirements to the System Attribute table shows the logical progression of the Design Process. It would have been good to outlines the exact limitations of the clients and the extent to which they are able to perform. Also consider mentioning why you chose a specific game - ' Guess Who?', was this a customer requirement?

***Detailed understanding of the systems engineering theory*:**

You have understood the systems engineering design theory well. The use of diagrams and thorough explanations of the different phases makes the research paper very easy to follow.

***Demonstration of systems theory to improve design outcomes or operational performance*:**

The use of the System Attribute table was excellent. Great job on referencing your findings from Requirements Engineering. It however requires a short explanation to highlight the important bits of the table, and the thought process behind it.

***Quality and relevance of bibliography*:**

Harvard referencing was done properly. However, the bibliography lacks references from Case studies and the physical limitations of the client.

Peer Review 2 (Quite long, cut down to include most important aspects)

Demonstration that the task requirements have been met

This seems to be missing. The background section does not necessarily show an example of how system attributes has been applied. Including a real-life example would help the reader to understand how the theory actually works. All of the figures seem relevant. Including diagrams from past topics has allowed the reader to refer to them if more information was required. **Is Figure 1 self-made?** It seems to be missing its source.

Take a whole-of-system approach when discussing the design

When discussing the design, you broke the section into three parts: project background, application and discussion. There was a natural flow in your argument which was really good. I also liked that you linked systems attributes to the previous topics by explicitly pointing out, for example, that your key attributes were taken from requirements engineering.

In your Project Background section, it may be worth just noting that this is what you have derived so far from previous topics. Currently it may confuse the reader as it looks like you're jumping straight to the cascade part by introducing the key attributes.

The application section did not explain how your secondary/tertiary attributes were derived. Maybe a simple sentence stating that you took the "how?" approach and showing an example (user friendly- suitable for kids - low in difficulty) would help. Also a brief explanation for leaving the tertiary attributes for "A4.0 Safe for user" would help. In the Discussion section, I wasn't able to immediately depict where the game set up was in the table. Reference it? (e.g. As seen in A5.2 Easy to set-up)

Besides that, I think your discussion reflects on your results from the cascade table and provides evidence that you have done your research on possible alternatives to best meet the most important requirement- that the game be user-independent. You have also further explained the positive and negative effect of introducing the Smartnav on the overall performance of the design (e.g. its impact on flexability), which further proves that you have taken a whole-of-system approach.

Detailed understanding of the systems engineering theory

There is a natural flow in your theory background section. Again, I think it's important for you to include an example of where systems cascade was applied to show how the primary-secondary-tertiary attributes are achieved and how this process can help relate back to the subsystems.

Demonstration of systems theory to improve design outcomes or operational performance

As discussed in Aspect 2, you have demonstrated that you understand the link between the cascade results and the design outcomes. This is particularly shown in the first paragraph of your discussion section.

Quality and relevance of bibliography

References are not in alphabetical order. The figures in Appendix are missing reference. I think you need to reference your past work too. I think it's important that you show a notable example of how the theory was applied and include the reference for it. Overall high quality references