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AUTOMATING DIGITAL CAPTURE OF ENGINEERING KNOWLEDGE

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ABSTRACT

Today's CAD systems are excellent tools for recording the end result of a design process, particularly at the detail design stage. However, they are poor at capturing the rationale and underlying intent within the design itself. As a consequence of this, when changes are required at a later stage in the product's life cycle, the consequences of these are unclear because the affects of and reasons for previous decisions may not be readily understood since the dependencies within a design are not explicitly represented. Of course an engineer could manually log these dependencies during the design but this would inevitably reduce design productivity, interrupt the engineer's cognitive creative design process and lengthen design lead times. Also there would be no consistency in the quality or structure of the capturing process or the captured information since this would greatly depend on the individual engineers involved in the process. If CAD systems could automatically capture the reasoning underlying the development of a design then - even years after the original design had been created - engineers could understand the consequences of potential upgrades and modifications. However, the state of the art in knowledge capture at this time appears to rest with the digital enterprise industries. Implementations of automated profile generation in Amazon, Google and Myspace show advanced methods in automated capture and analysis of user activities, where there are no cognitive or time costs for the user. This paper briefly surveys the state of the art in automated knowledge capture (both commercial and academic) and details an example of an experimental system for the automated capture of design knowledge. Particular emphasis is placed on the use of XML to provide a structured format for the design logs generated. An initial analysis of the results of two experiments collecting a total of over 700 design sessions is shown.

KEYWORDS

Knowledge Capture, Computer Aided Design (CAD), Knowledge Management

1. INTRODUCTION

An engineering drawing (or 3D CAD model) only defines one instantiation of a solution to a design process. Although many industries (eg aerospace and defence) have established systems for documenting the analysis done to verify the functionality of a given component, much of the knowledge developed during a design process is lost. In other words, although the solution to a problem is recorded, the process by which this solution was derived and the constraints discovered during the process go largely un-archived. Essentially there are two issues: (1) documenting the mapping between the design parameters and the performance parameters as predicted by the analysis and evaluation techniques and (2) documenting the relationship between the design parameters and the performance parameters as observed for the artefact in test/use. The two mappings will be different, and it will typically take a long time to achieve the second. The work reported here is focussed on the first of these problems, which occurs for many reasons, including:

- the design process is frequently distributed over long periods;
- there is a reluctance to document mistakes and failures inherent in the discovery of constraints;
- the method of documentation required is unclear;
- the additional time required to create documentation detracts from the process of producing the design.

This is unfortunate, as a concise and accessible a summary of a component's design process would aid engineers who, sometimes years later, have to revisit product designs to upgrade or modify them. For many years these problems have appeared intractable but the last decade has seen the migration of all aspects of the design process from paper onto networked computers. Consequently the opportunity now exists for previously unimaginable amounts of data related to product development to be archived, accessed and manipulated. However the challenge is to provide a structured record of a design process that allows the details to be effectively abstracted, searched and browsed.

Motivated by these needs the authors are undertaking research into the automated capture and re-use of design, design activity and design process data. *The goal is to automatically capture more of the process by which a particular design was reached and the lessons learned by the designer during this process*. However a practical difficulty faced by all efforts to study and record the design process is that "real" engineering design activities are spread both temporally and physically with testing frequently occurring in the field which is remote from desk bound observers of the design process.

To allow progress towards the goal of automated design rationale capture, the authors looked for a non-trivial design environment that had the following properties:

- all stages of the design process are supported from conceptualization to functional detailing;
- an intuitive graphical interface allowing non-expert users to participate in the experiment enabling a large number of participants to take part;
- a short design cycle that incorporates integrated in-line testing;
- a feasible, competitive and engaging design goal;
- measurable design success;
- innate design criteria; and
- accessible data logging.

The CBBC BAMZOOKi™ application was identified as providing a self-contained 'design-build-test' environment; the structure, operation and interface of which make it an ideal platform for this research. The BAMZOOKi application allows users to construct virtual creatures (zooks) from building block elements and modify the properties of these elements to change either the form or motion of the zook. The environment also includes a test section where the performance of the zook can be measured against a set of standard tasks.

If real-time design and process data could be captured while people use the BAMZOOKi application to design or modify zooks to achieve a target performance in these tests then it should be possible to post-process these captured data to extend the capability of current design practice either through the automatic extraction of higher level information about the design itself, by mapping the process or by providing an accurate description of the problem solving approaches used. The version of the BAMZOOKi software distributed by the BBC does not support any continuous user logging; however, discussion with the software's developers (Gameware_Development_Ltd 2006) suggested that this would be possible if a detailed specification was provided. Such a specification was developed and is reported in this paper.

The rest of this paper is structured as follows: Section 2 briefly outlines the literature and academic context of the work. Section 3 describes the BAMZOOKi program. Section 4 outlines the proposed experimental methodology. The experimental procedure is defined in Section 5, and a discussion and some initial results from two trials of novice users are given in Section 6 and conclusions are drawn in Section 7.

2. LITERATURE REVIEW

The engineering design process has been extensively studied by academic researchers who, based largely on manual observation, have proposed various models in attempts to characterize and structure the activity. Typical of these is the model, similar to that depicted in Figure 1, proposed by Wächtler (Pahl and Beitz 1988) that explicitly models the learning process that develops a design:

"The 'learning system: designer' takes a problem from, and returns a solution to, the environment. Discursive and intuitive actions produce solutions (ideas) that are held in the short-term store of the

learning system. A comparison of the proposed solution with the environmental demands (requirements) may throw up discrepancies calling for new decisions and hence lead to new actions. Once the discrepancies are reduced to a minimum, the optimum solution is to hand. A cycle in this process of optimisations is called a learning element. The learning system must not be considered in isolation from the environment. In other words, the environment not merely imposes the requirements and receives the solutions, but frequently plays a crucial part in finding the latter."

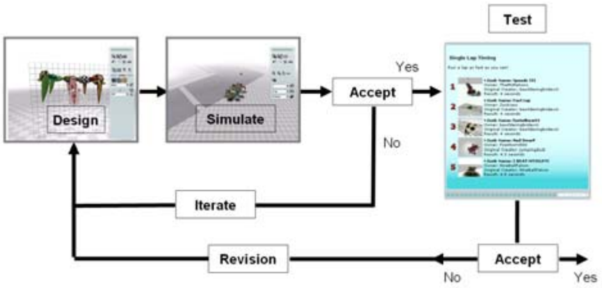


Figure 1 - BAMZOOKi Design Process

However many academic models are defined in terms of high-level concepts remote from the details of the design process. Consequently researchers have reported work that seeks to automatically record the details of what designers actually do.

Campbell et al. (2005) describe a method of recording design activity on a PC, capturing information such as file names, file creation/destruction times, web pages viewed, screen shots, text input, CAD model construction, meta data of files opened etc. In addition, interface information is observed called Profile Elements (PEs). Monitoring "Information Use PEs" is good for capturing and recording the order of execution of tasks whereas "Interface Action PEs" (user behaviour) enable information "push" such as providing links to relevant documents as a user undertakes a task.

Stumpf et al. (2005) describe a system which monitors user behaviour in a similar approach to Campbell et al. (2005), whereby interactions with Microsoft Windows are monitored. The actions are tracked, and a prediction is made as to what task is being carried out; hence, in which folder to place any documents produced. In this case the object is not to collect knowledge but merely to assist knowledge workers in organising task related information. The concept of costs to the user is identified, where the costs can by physical, mental, time and/or cognitive. There is an initial cost for the user to set up the system and identify the tasks that they work on. The authors also raise the issue of the user's perceived loss of control when predictions are made and suggest that predictions are only used if there is high confidence in the results.

Mueller and Lockerd (2001) and Chen and Anderson (2001) studied users' behaviour while using a web browser. The latter showed that for 50% of users in their test there was a 0.8 correlation between eye gaze and cursor location. So in many cases it is possible to predict a user's focus of attention based on the location of the cursor on a screen.

Varga et al. (2004) provide a survey of hand motion processing (HMP) technologies with a view to adapting hand motions as an input for 3D conceptualisation. Their analysis is to identify technologies that will provide real-time information extraction and conversion. They compare contact vs. non-contact methods. Contact methods include gloves and stylus and non-contact are based on 2 cameras or camera and shadow analysis.

If it is possible to unobtrusively monitor a designer's behaviour and progress, and hence derive the context of the user's work, then there is also a possibility to provide context aware information either on a push or pull basis. Investigations of the advantages of push and pull information systems for a mobile information unit have been carried out by Cheverst et al. (2001). In this case context was derived from the physical location of a mobile information display unit via GPS.

Jin and Ishino (2006) use the combination of user activity logging and data mining to automatically generate design activity knowledge.

Similarly, work at Heriot-Watt University has demonstrated the use of immersive virtual environments to derive design process knowledge from logs of user activity. Much of this work has been based on cable harness design case studies (Ritchie et al. 1999; Ritchie et al. 2006; Ritchie et al. 2006; Robinson et al. 2006; Robinson et al. 2006; Robinson et al. 2007) and has provided an ideal design task classification and experimental approach which can be extended into the downstream acquisition of knowledge, rationale and design process capture during product design and planning.

The current state of the art in automated knowledge capture at this time appears to rest with the digital enterprise industries. Implementations of automated profile generation in Amazon (www.amazon.com), Google (www.google.com) and Myspace (www.Myspace.com") show advanced methods in automated capture and analysis of user activities, where there is no cognitive or time costs for the user. For example Myspace provides additional knowledge tools in the form of peer-to-peer networking. While in the area of Artificial Intelligence research into connectionism and the nature of virtual communities is being carried out by (Memmi 2006).

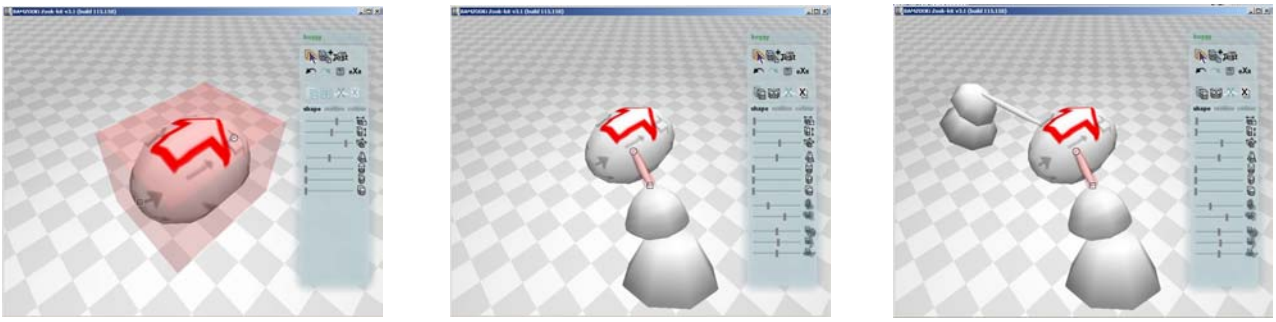
3. BAMZOOKI

BAMZOOKi was developed for a BBC TV children's programme and the toolkit is available free for download and standalone use. Zooks are virtual creatures that users create to perform with specific mechanical behaviours. Users can then send their zooks into battle with other players' creations, and watch to see who wins. Winning depends on players developing a complex understanding of how to create a zook and what behaviours to design into it to perform. Competitions on the website include sprinting and hurdles.

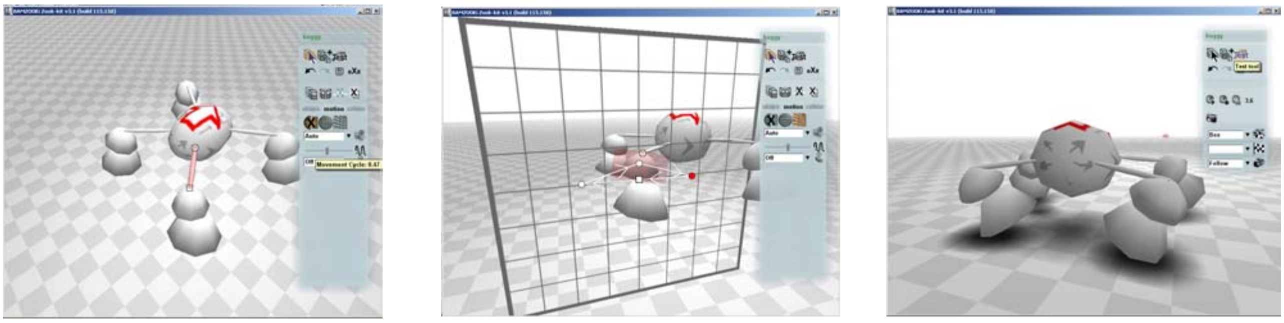
The BAMZOOKi Zook-kit is an intuitive 3D design environment. The interface allows interaction with 3D models based on “blobs”. Initially the model is a single blob representing the Zook’s body as in Figure 2(a). The user can change a number of variables such as: length; width; “squareness”; and “pointiness” to customise the shape of the blobs, either moving the sliders on the menu or dragging key nodes on the model itself. The user can then add blobs, or pre-defined limbs constructed of blobs, to the body as in Figure 2(b). Mirroring tools allow the rapid population of limbs (see Figure 2(c)). In addition to shape variables, blobs have movement variables that can be accessed through the motion tab on the edit menu (Figure 2 (d)) and on screen (Figure 2(e)). At any point during the design cycle, the user can test the Zook by running a simulation animation of the Zook using the test tools (Figure 2(f)).

Despite its ease of use, BAMZOOKi offers an impressively rich, yet constrained design environment ideal for design task analysis. As one of its developers said:

"BAMZOOKi's bespoke integrated artificial life technology suite combines physics, artificial intelligence and 3D graphics for anyone who can point and click a mouse. Anyone can play and compete with BAMZOOKi's entertaining and educative system to learn the art of physics, movement, and mechanics with ease through CBBC’s engaging online and TV mass media channels. It's simple, fun to use and freely available through CBBC online, yet it's one of the most powerful forms of cyber-plasticine available anywhere." (Saunter 2005)



(a) The body **(b) Adding a leg** **(c) Mirroring a leg**



(d) Adjusting the leg phase **(e) Adjusting the leg gait** **(f) Testing**

Figure 2 - Creating a Zook

4. THE EXPERIMENT

4.1. AIMS

The objective of logging the evaluation sessions is to investigate the processes by which people "discover" what aspects of their design, i.e. the zooks, can best be changed to meet a ***specific*** performance goal. There are many options open to the designer to improve the Zook's performance: weight reduction; leg lengthening; change of gait etc. Each designer will "discover" which of these parameters has the most effect. The research challenge is to extract this "knowledge" created during the design process from the log files.

4.2. METHODOLOGY

Each participant in the experiment was given a default Zook (known as the "Baseline Zook") with a performance goal they are required to meet, e.g. perform the sprint test at 40cm/s. The participants then proceeded to modify the design of the zook to meet this specification.

Figure 3 shows an outline of the expected data flow in this data capture and re-use scenario. The first phase of the process involves capturing a detailed record of the design activity (logfile) and the design output produced (zook model geometry and performance data). The second phase involves interrogating this complete data set to extract specific data that is relevant to certain research questions and objectives. These extracted (focused) data sets are then reformatted for importing into different downstream applications so that detailed analysis can take place.

The objective of the logging capability is to unobtrusively capture a complete record of each BAMZOOKi design session without interrupting their cognitive design through process. To be effective during downstream analysis the recorded files must include sufficient detail that enables the session activity and evolution of the design to be accurately reconstructed solely from the information contained within the files. It must also be possible to identify all of the files that were created during a single session, e.g. to separate the model geometry file and the corresponding data, say based on time, from the different files.

The log data will be stored in XML (Extensible Markup Language) which is a W3C-recommended general-purpose markup language currently used in the BAMZOOKi application (http://En.Wikipedia.Org/Wiki/Xml, 2007). The primary purpose of XML is to facilitate the sharing of data across different information systems and XML languages are easy to design and to process. The XML data can be post-processed to conform to a lexicon to become an efficient information model.

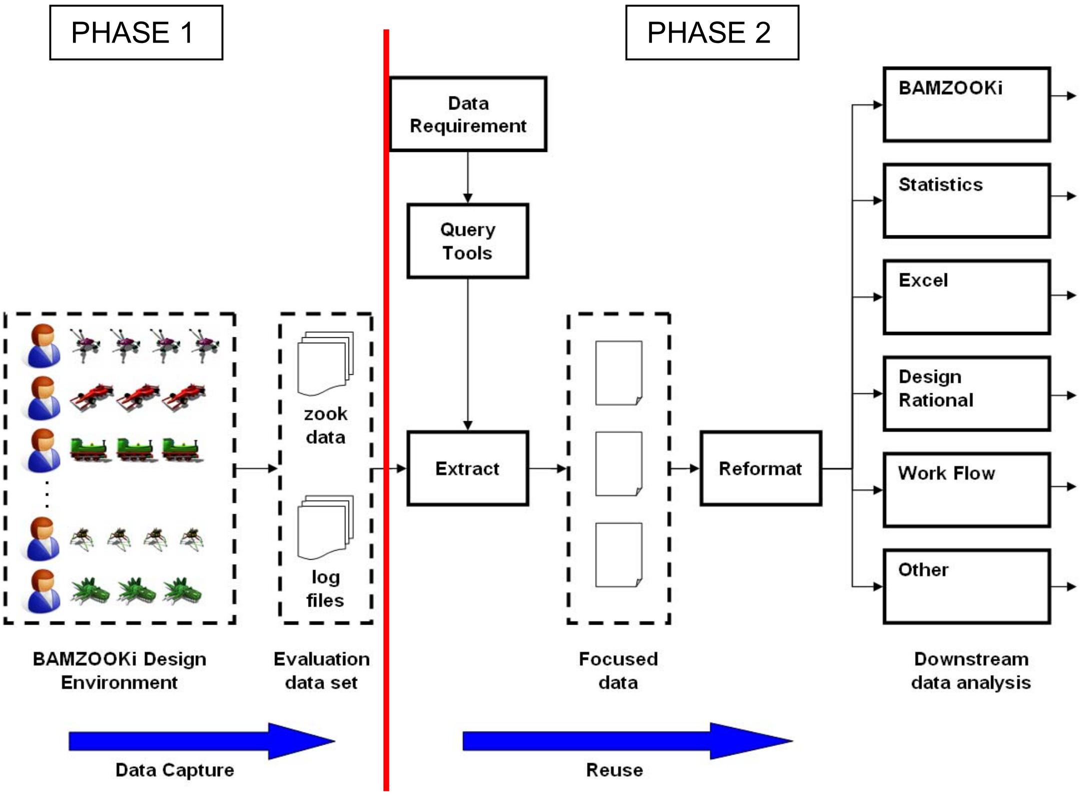


Figure 3 - Overview of Data Flow

```
<logfile >
    <header >
        <session_id text = "20070310_120934_11" >
        </session_id>
        <session_start hour = "12" minutes = "09" seconds = "34" seconds_milli = "921" >
        </session_start>
        <session_control filename = "Apprentice.xml" >
        </session_control>
        <baseline_zook filename = "Test Zook" >
        </baseline_zook>
        <copy_to_log_header copy_att = "an attribute" >
            <copy_element value = "test" >
            </copy_element>
        </copy_to_log_header>
    </header>
    <body >
        <event desc = "Zook" >
            <time hour = "12" minutes = "09" seconds = "37" seconds_milli = "296" >
            </time>
            <select_interaction >
                <detail body_part = "1" type = "body_part" >
                </detail>
            </select_interaction>
        </event>
    <event desc = "Zook-Physical" >
            <time hour = "12" minutes = "09" seconds = "53" seconds_milli = "312" >
            </time>
            <ui_interaction >
                <parameter_change Flatten_Side = "1" body_part = "1" >
                </parameter_change>
            </ui_interaction>
        </event>
                        :
                        :
        <event desc = "UI Only" >
            <time hour = "12" minutes = "10" seconds = "34" seconds_milli = "468" >
            </time>
            <ui_interaction >
                <mode name = "test" >
                </mode>
            </ui_interaction>
        </event>
        <event desc = "UI Only" >
            <time hour = "12" minutes = "11" seconds = "02" seconds_milli = "140" >
            </time>
            <ui_interaction >
                <mode name = "edit" >
                </mode>
            </ui_interaction>
                        :
                        :
    </body>
    <footer >
        <time hour = "12" minutes = "24" seconds = "58" seconds_milli = "859" >
        </time>
        <parameter filename = "20070310_120934_11_007_parameter.genome" >
        </parameter>
        <passport filename = "20070310_120934_11_007_passport.txt" >
        </passport>
        <model filename = "20070310_120934_11_007_model.zook" >
        </model>
        <hologram filename = "20070310_120934_11_007_hologram.vrml" >
        </hologram>
    </footer>
</logfile>
```

Figure 4 - Exemplar of Design log file

One useful lexicon may be the Decision Support Problem Technique (DSPT) developed by Kulkarni et al. (2002), which, “provides a framework to represent typical decisions or tasks in a product realisation system.” A draft sample of an XML log file that is generated by a BAMZOOKi session is shown in Figure 4.

One of the advantages of using XML is that is both machine and human readable. Hence in Figure 4 Section A it is apparent that the code shows the opening dialog of the xml file, where details of the session are logged, including: the start time (12:09:34:921); the controlling session file (Apprentice.xml); and the baseline zook used (Test Zook). In section B, the log shows that the user has selected body_part 1 and changed it by modifying the Flatten_side parameter. Section C shows the user has spent some time testing the zook (12:10:34:468 to 12:11:02:140) and finally the session ends at 12:24:58:859 and details of the associated files that are stored are seen in section D.

5. PROCEDURE

As explained in the methodology section, each participant starts a design with a "Baseline" zook and a "goal" for its performance. The next section details these.

5.1. BASELINE ZOOK

The BAMZOOKi session starts with a baseline zook (revision 0). The overall design of the zook used may change but in the first instance described in this paper will be an eight legged 'spider', see Table 1.

Table 1 - Baseline Zook Properties

Physical (approx. values):		Performance:	
Height:	10 cm	Sprint:	40 cm/s
Width:	30 cm	Block Push:	25 cm
Length:	30 cm	Hurdles:	5 cm/s
Weight:	1 kg		
Components:	22		

The baseline zook has a 'below-average' performance in the three test tasks (sprint, hurdles, block push) and its design includes specifically incorporating 'poor' elements that can be identified and modified to improve this performance.

Several variations of the baseline zook may be used to provide different levels or complexities of starting 'problem'. Example zook problems and possible solutions are detailed in Table 2.

5.2. GOAL

The goal of the participants is to make modifications to the zook that will lead to it achieving a higher 'Gold' level of performance. This 'Gold' performance must be set at a realistic level (average) that can be achieved by a typical user within the timescale of a test session. This is unlikely to be a best in class performance and further improvements may be expected from a longer session or with more experienced users. Three levels of users were anticipated, beginners, intermediate users and experts, and so three sets of goals were developed, apprentice, master and wizard respectively. The performance parameters for these levels are shown in Table 3.

Table 2 - Possible Zook Problems and Solutions

Problem	Potential Solution
Sprint:	
The zook walks rather than runs.	Increase the gate cycle speed.
The zook takes small steps.	Increase the stride length.
Legs are too close to increase stride length.	Increase body length and increase leg spacing.
Legs are too short to have a big stride length.	Increase leg length.
Zook appears to 'limp' or is 'jerky'.	Adjust phase of legs within the gait cycle
Block Push:	
Zook is too small to push the blocks.	Make the zook bigger.
Zook legs contact the blocks rather than the body / head.	Make head larger or change angle of front legs, (etc).
The head makes contact but zook skids on the blocks.	The front of the zook has a point contact, make the jaws larger and wider to produce a more stable contact.
Hurdles:	
Zook gets stuck on the larger hurdles.	Increase the zook's ground clearance.
Zook cannot get onto the larger hurdles.	Change gait cycle to increase step height.
The zook is unstable and sometimes falls over.	Increase width of the zook.

Table 3 - 'Gold' Performance Parameters

Apprentice Level			
Physical (approx. values):		**Performance:**	
Height:	no limit	Sprint:	75 cm/s
Width:	no limit	Block Push:	30 cm
Length:	no limit		
Weight:	2 kg		
Components:	25		
Master Level			
Physical (approx. values):		**Performance:**	
Height:	no limit	Sprint:	75 cm/s
Width:	no limit	Block Push:	30 cm
Length:	no limit	Hurdles:	30 cm/s
Weight:	2 kg		
Components:	25		
Wizard Level			
Physical (approx. values):		**Performance:**	
Height:	15 cm	Sprint:	100 cm/s
Width:	40 cm	Block Push:	50 cm
Length:	35 cm	Hurdles:	75 cm/s
Weight:	2 kg		
Components:	25		

5.3. THE BAMZOOKI DESIGN SESSION

Each design session has three distinct phases: start, design and exit.

5.3.1 START

The participant starts the BAMZOOKi session through a 'start' dialog box with a baseline zook automatically loaded. Each session has a unique log file; this is created and the 'header' data completed at the start of the session.

5.3.2 DESIGN

The participant looks at the 'My Goal' performance targets for the zook. 'My Goal' is a new 'pop-up' dialogue box that is activated from the 'general zook menu'. 'My Goal' lists the target 'Sprint', 'Block Push' and 'Hurdle' goals for the session. Then the sequence of action is typically as follows.

1. The participant tests the baseline zook to see what its current performance is.
2. The participant modifies some aspect of the zook model geometry.
3. The participant tests the zook to see what effect this has had on performance.
4. The participant continues to modify and test the zook until the 'Gold' zook performance target is reached. (Design Cycles).

All of this activity is recorded in the log file as it happens with a time stamp of when it happened.

5.3.3 EXIT

The participant exits the session. This causes the log file footer data to be added to the log file and the log file to be terminated.

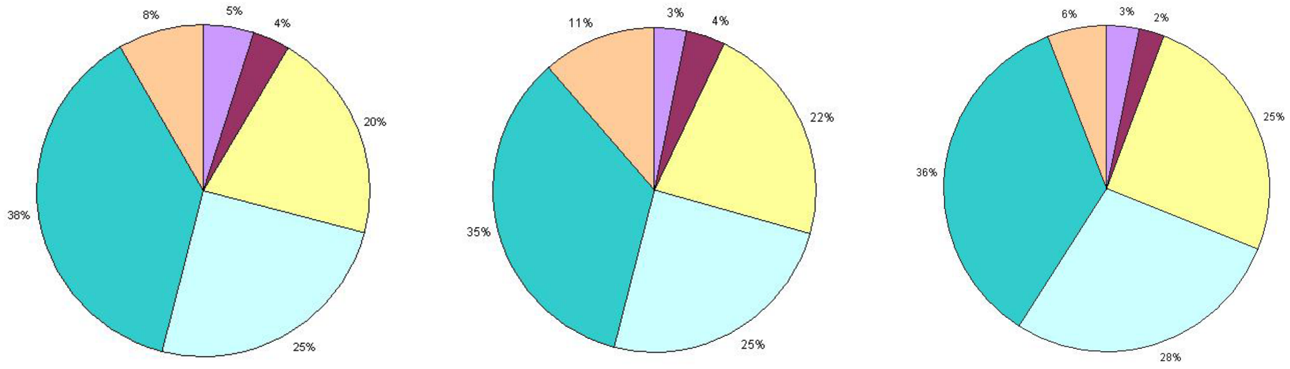
7. RESULTS

The software modification required to generate XML logs of user activity with the BAMZOOKi software have been implemented by Gameware. Initial experiments to gather data from novice users took place 10-11 March 2007 during the National Science and Engineering Week (NSEW) exhibition at Satrosphere, Aberdeen's Science Centre and 2-15 April 2007 at the Edinburgh International Science Festival (EISF) at the Wonderama venue. A total of 315 sessions were logged at the NSEW event and a further 475 sessions logged during EISF. The majority of sessions were Apprentice Level at both venues.

Design Activity Categories founded on the work by Robinson et al. (2006) have been built into the structure of the logged XML data, and appear in the log files when the associated events described in Table 4 occur. They define the users activities based on the interaction with the design environment. The aim is to identify events which directly progress the design goal, (eg. creating or changing a body part) as opposed to events which are required by the user interface, such as selecting a body part or menu item.

Table 4 - Definition of Categories

XML Tag	Event	Event Possibilities	Category (Legend)
UI Only	Selection of main panel tab	Select shape, motion and colour tabs	**Design Support UI**
	Selection of mode	Possible modes: add, edit and test	
	Selection of test buttons	Start timer, stop timer, reset timer, photograph, cool, blockpush, sprint, hurdles, high jump	**Design Verification**
	Achievements from trials		
Zook-Cosmetic	Setting colour	Change RGB colour parameters	**Design Goal - Cosmetic**
	Setting texture and brightness	Change bitmap and brightness value	
Zook-Dynamic	Setting motion parameters	Movement type, movement control, movement cycle, part targeting	**Design Goal - Dynamic**
	Moving Kinetic (IK) point	Dragging	
	Adding/Deleting IK Point (n/a)	Main panel, keyboard shortcut	
Zook-Physical	Changing body part parameter with panel sliders Changing body part parameter by dragging it around	Change of width, height, length, pointiness, flatten_end_ flatten_side, squareness, base_up-down, base_left-right, twist, tip_up-down, tip_left-right	**Design Goal - Physical**
	Mirror body part		
	Adding body part (n/a)		
	Deleting/Cutting body part (n/a)	Keyboard shortcut or main panel	
Zook	Selecting body part		**Design Support ZOOK**
	Selecting IK point		
	Copy body part		
	Undo/Redo	Main panel selection	



(a) Apprentice Level **(b) Master Level** **(c) Wizard Level**

Figure 5 - Category Analysis of Novice Data

Charts showing the average percentage of time users are show in Figure 5. Combining the values for Design Goal Cosmetic, Dynamic and Physical, these results show that users are spending 29% to 30% of their time achieving the design goal. This value is similar to the figure of 27% published by Robinson et al. (2006) in their study on cable harness design. It is also notable that 60-65% of the time is spent in Design Support tasks, that is selecting menu items, body parts or IK (kinematic) points, reflecting that the user interface, although intuitive, still requires a large amount of time to operate. This figure is similar to the 65% time spent navigating and conducting system operations in the Robinson et al. (2006) cable harness design study.

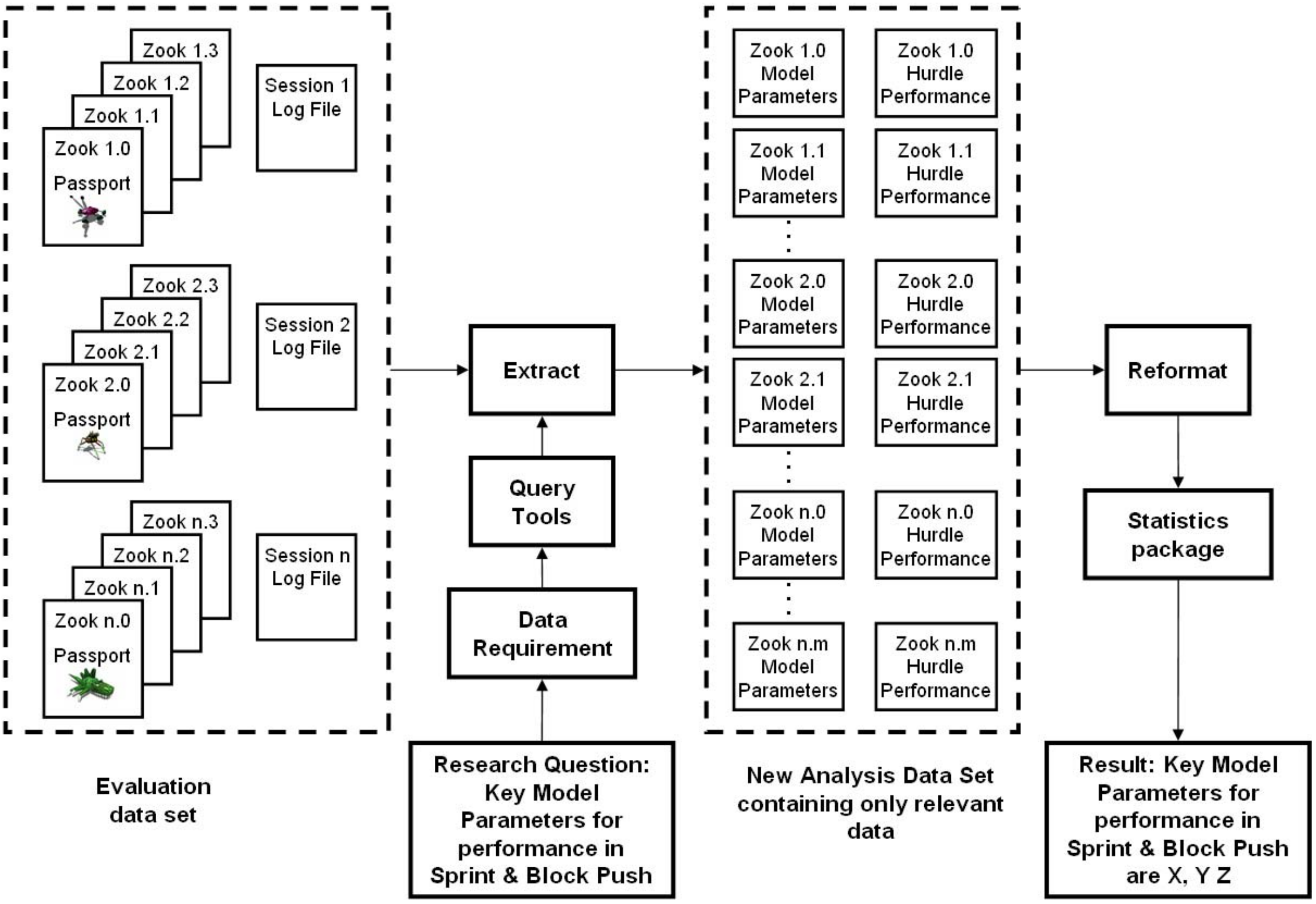
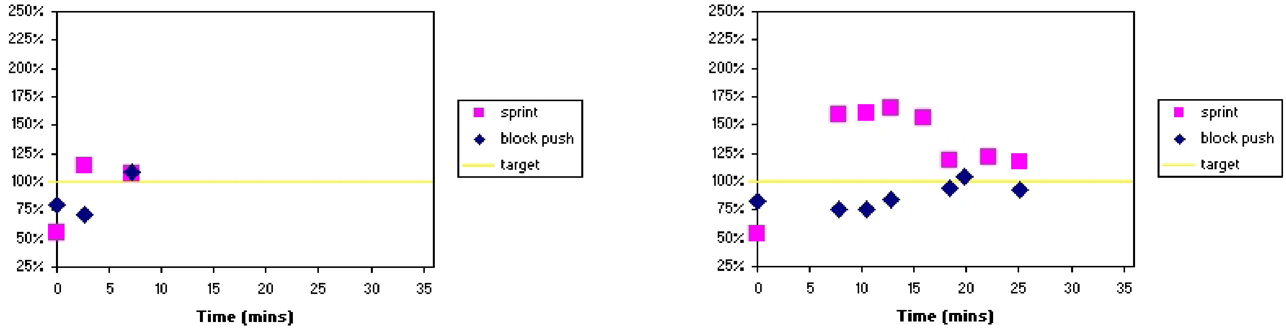


Figure 6 - Example of Data Extraction Process



Participant A **Participant B**

Figure 7 - Sprint and Block Push Test Results

The nature of the data collection technique through a public engagement event where the participant's enjoyment is important, and there is little control over the environment, means spurious data has been collected. This situation represents the most extreme uncontrolled environment an automated system will be exposed to. Our initial aim is to identify the most efficient and effective design process for zooks, with conflicting requirements of high sprint test and high block push test. In this case it is firstly most important to identify successful designs. Figure 6 illustrates the process to extract all the "sprint" and "block push" performance data (cm/s) and the model data for all of the zooks that had a "sprint" and "block push" test result (including its design cycle number).

Initial data showing how the "sprint" and "block push" test results changed through the duration of the design session of two participants can be seen in Figure 7. These graphs provide a useful visualisation of the design process, and shows that participants A and B adopted a similar approach by initially improving the sprint performance. Participant A achieved success in attaining the required target level for both sprint and block push performance in less then 10 minutes, however, participant B's progress over 25 minutes shows clearly that there is these are conflicting requirements as the sprint performance does drop as the block push performance improves. Future work will be further analysis to identify the key model parameters for both sprint and block push performance now that the successful designs have been identified.

7. CONCLUSIONS

The design log files generated by these activities will form a unique data set that will be freely available to design researchers. Post processing of the captured data files will involve using 'query tools' to allow a researcher to define parameters that identify specific data to be extracted from all the files that make up the evaluation data set. In other words tools will be developed that allow a "trial and error" design process to be mined for information about effective performance enhancement strategies.

This data extraction will produce focused data sets only containing the data of interest to the researcher at that time. Extraction procedures to identify successful designs have been described in Section 6. However, any part of the data set could be extracted depending on the current goals of the research. This focused data set is then reformatted so that it is compatible with the importing requirements of whichever package will be subsequently used to undertake the analysis of this extracted data.

5. ACKNOWLEDGMENTS

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Gameware Development is a pioneer of cross media artificial life technology, creating exciting games and interactive communications for TV, PC, console, wireless and hand-held games devices. Based in Cambridge in the United Kingdom, Gameware Development comprises of Creature Labs, the A-Life division fuelling Gameware's development projects, and SceneMachines the mobile technology division evolving and inventing cutting edge intellectual properties to entertain users on the move. www.gamewaredevelopment.com.

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