Categorisation of Computer-Aide-Design Actions Through Visual Exemplification

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This paper summarises, in a preliminary announcement, some outcomes arising from the author’s research ‘A Developed Methodology for Recording, Evaluating and Presenting CAAD as a Vehicle for Designing’, in which a methodology for making visually explicit the design actions of architects has been designed, developed and tested. Specifically it describes the categorisation of computer-aided design actions through visual exemplification, whereby ‘Categories of Action’ of creative computer activity are constructed from, and defined by, grouped visual records of ‘Design Moves’ which exhibit similarity in character. The value of examining design actions as a means to stimulate and enhance creativity for other designers is explained, and the methodology developed and employed in order to construct a resource to do this is outlined. The main body of the paper focuses on descriptions of selected, constructed ‘Categories of Action’ which are outcomes from analysis of material collected as part of this research. Conclusions are drawn on their relevance to the designer and suggestions for further synthesis of the Categories of Action are offered.
Introduction

In this paper I refer to a Multimedia Matrix of architects’ design actions which was constructed as part of, and to further facilitate, analysis within the above-mentioned research. The matrix was formed using purpose-specific Hypermedia Analytical Tool which was designed by the author using Apple’s HyperCard, and drives QuickTime movies of demonstrated design actions, referred to here as clips. Each clip visually illustrates an individual design action, with accompanying audio dialogue (elicited from interviews). It is, therefore, only possible to fully convey the meanings of these actions through multimedia. Summaries of Categories of Action are given here in order to explain the outcomes of this research and the value this material may have to others. The terms ‘Design Episode’ and ‘Design Move’ are drawn from Akin (1986) and Goldschmidt (1992) respectively.

The Value of Examining Design Actions

The value of any design is most usually judged through the quality of the end product. This is because, to most observers or product users, the function and aesthetics of the finished product are of paramount importance. To those wishing to engage in designing, appreciation of the process by which the product is designed becomes equally important. However, even when examining or explaining such processes, the starting point is often the finished product. Two reasons that can be given for this are that the product gives focus to the explanation, and the quality of the process may be expressed through the quality of the product. That is not necessarily to say that the process is traced from the product in reverse, rather that the product is normally illustrated prior to the process being reflectively described.

When investigating and portraying the way in which others design, one must attempt to externalise that which is largely an internal process. We can approach this in a number of ways. From observation without participation we may, with experience, recognise the more visible actions, but leave large gaps in the overall approach. By interrogation, we can extract the designers’ own accounts of their activities, although this may be accidentally or deliberately inaccurate. When investigating design carried out largely through the computing medium we are presented with potential advantages. Firstly, there tend to be records which represent frozen sequences of completed phases of design. This could also be said of manual sketches and drawings although these records may not be as enlightening, are less dynamic and are less likely to be readily accessible. Secondly, the nature of the computing medium, can be seen to enforce—through additional interface or considered process—a more accurate
memory of activity in the mind of the designer in terms of what was actually done and the order in which it was carried out.

It follows, therefore, that the designers’ actions may be externalised by encouraging explained re-enactments of the designer’s creative activity, using design records as reference points. Resulting demonstrated designers’ actions can thus be captured as movements over time. Appropriate documentation of these re-enactments thus renders them available for analysis and presentation.

**A Developed Methodology for Examining and Analysing Design Approaches**

The author has developed a methodology for recording reflective demonstrations of computer-aided design activity. This has been achieved through interviewing the designer, and video-taping both the interview and the demonstrated computer-aided approach. The advantages of this method are that the designer is allowed to select and demonstrate design activities which he considers to be of importance—his own value system—whilst generating a visual and audible record which is available for analysis.

A method of analysis has been developed as part of the same research which aims to render these design activities available for characterisation and comparison in a way which is meaningful to the researcher, and subsequently to others. The relationships between terms used to represent objects within the analysis are explained in figure 2. The visual records are broken down into sets of actions *(Design Episodes)* that are given by the designer and the researcher to forward the design. These sets are then further disaggregated to expose their constituent activities *(Design Moves)*. Individual *Design Moves* are thus isolated (by the author) and their characteristics assessed. This has been achieved through digitally capturing *Design Episodes* and inserting them into a purpose-developed *Hypermedia Analytical Tool*, which was employed to construct a *Multimedia Matrix* of characterised *Design Moves*. From cross-referencing a number of interviews through this matrix, the isolated actions can be grouped according to observed similarities and then further analysed to form visually exemplified *Categories of Action*. The resulting material can thus form a resource of categorised design actions which are no longer pegged to the design product or individual designer. This resource may be employed to illustrate the wealth of opportunities open to the computer-aided designer, the real value of which is live, moving action.
The method of recording interviews with, and reflective demonstrations by, the designer was documented in (Kokosalakis and Moorhouse 1995a). Early development of the approach to interviewing was described in (Kokosalakis and Moorhouse 1995b). (Moorhouse 1996) explained the potential benefits of presenting visually exemplified design actions as learning material, the application and results of which were charted in (Kokosalakis, Brown and Moorhouse 1997). A more detailed description of the Hypermedia Analytical Tool can be found in (Moorhouse 1998).

A Review of Observed Creativity Through Descriptions of Selected Constructed Categories of Action

Outcomes, in the form of a Multimedia Matrix of characterised Design Moves and constructed Categories of Action formed through their comparison cannot, by their nature, be published in a paper. However, the categories can be expressed through descriptions of the design actions which formulate them to provide insight into the outcomes of this research. This has been attempted in the paragraphs below in the following way. Each selected category is discussed here by first introducing the captured design activity, and then illustrating the activity by example. Examples are referred to by an interview number given to each architect and a clip number within that interview. (When using the Multimedia Matrix, the movie clips are accessed through fields or dimensions organised by architect/interview and by Category of Action.) The significance of illustrating more than one Design Move to exemplify a Category of Action is that the category may be more fully defined, showing diversity in approach and also frequency of use by one or more designer. Finally, each description is concluded with the constructed definition of the category of design action.
Shape Manipulation

Three Architects demonstrated the useful manipulation of shapes when designing. Architect 3 [Clip 4] illustrated the manipulation of shape by transforming and adjusting the curve of a 2 dimensional line in section to form the contour of a 3 dimensional wave ceiling, which was extruded from the 2D design. In a similar way Architect 6 [Clip 18] multiplied and mirrored 3D elements during design to construct the sectional outline of a curved beam. Architect 1 [Clip 3& 4] explained the manipulation of shapes in terms of multiplying, mirroring, inverting and distorting drawn elements as a means to sketch. Advantages offered for this practice are that it is a flexible means to work without redrawing from scratch and that it provides opportunities to design in new (non-traditional) ways.

Shape manipulations can be seen to be operations applied to a 2D or 3D object, be it changing its form or orientation, in isolation or in multiplicity. Further, these actions can be performed in a fluent and dynamic way, rather than simply a series of independent and static actions possible from designing through a non-digital medium. Clearly such transformations are routinely applied in order to accelerate the drafting process, but in the cases selected to represent this category, it is shown to be useful for early sketching and designing.

Capitalising on Errors and Accidents

Instances of accidents or errors being beneficial to the design were explained by three Architects. Architect 1 [Clip 4] described forcing accidents to happen through shape manipulation (in this case rotating, flipping and distorting selected objects) as a means to increase the variety of approaches to design open to him. The accidents implied in this instance are a form of sketching or experimentation resulting from deliberately mis-positioning previously drawn elements. In contrast, Architect 3’s [Clip 8] reference to accidents concerns genuine mistakes in 3D modelling where elements are placed incorrectly (not deliberately) and spur further creative ideas. Further, Architect 3 considered that limitations in the software's ability to construct 3D form affect the way in which he designs. This was expressed as a positive attribute on the basis that awareness of such limitations allowed him to generate forms which differed from those perceived when creating them, thus potentially increasing creativity. Architect 7 exhibits controlled use of accidents throughout his demonstration. Particularly notable is the misreading of a sound file as a Greyscale image file and extruding it into 3D to assist with the conceptualisation of form [Clip 17]. Architect 7 has deliberately developed the use of accidents (misuse of software) as recognisable routines to assist with designing.

Accidents and errors can thus be seen to be useful in three different ways: (i) By deliberate use of transformations applied to shapes in order to experiment with their shape and orientation. (ii) By recognising limitations in software capabilities and forcing accidents through these limitations and unintentionally misplacing objects. (iii) By deliberately misreading digital data to conceptualise. The differences outlined can be expressed as representing different levels of taking the opportunity to capitalise on errors and accidents in order to prompt, or even present, new design solutions.

Increasing Options

Five interviewees intimated that the computer can be used to increase options, so extending design choices. Architect 2 [Clip 8] recounted that old models were retained for comparison with current ones as the design develops. Quick sketch models were constructed to generate options for particular elements. Architect 1 [Clip 6] described printing (parts of) computer sketches to circulate between designers for feedback. Architect 5, [Clips 2 and 6] charted the use of CAAD as a facilitator for optioneering, whereby the speed and ease of drawing, representation, editing and reproduction allows several options to be generated in a short time period. Similarly, Architect 6 described producing five options for a sketch scheme where, without CAAD use, only one would have been developed. In contrast, Architect 7 [Clip 6] demonstrated creating 3D forms by extrusion. Multiple options are generated by re-running the operation using different extrusion cell sizes to create different, and not pre-conceived, forms.

Options are thus felt to be increased by the ability to reproduce images, by the creation of fast sketch models, by accelerating the design process and by repeating operations whilst varying conditions. The potential benefit of the designer being able to increase options is that design decisions can be made from a more informed standpoint, be they conceptual or detailed, and in cases where feedback is required from others, a greater range of alternatives can be presented.
Mixing Media

The computing environment need not be an isolated medium and can be integrated with manual sketching and modelling methods. Architect 2 [Clips 1 and 2] output hard copies of CAAD images through a printer, worked on them manually and scanned the resulting images back to the computer as part of his sketch design process. Architect 7 [Clip 5] also used a scanner, in this case for importing colour images for conceptual development, and additionally imported sound (music) for the same reason. Architect 3 [Clip 3] employed physical and 3D CAAD modelling in tandem as a developmental design process, each offering different restrictions and benefits due to their nature. The CAAD model allowed greater detail and trueness to representation (as well as easy editing and updating), whereas the physical model gave a more tangible 3D impression. Architect 5 described the combination of manual designing and CAAD, stating that projects often moved from ‘drawing board’ to computer and then elements of the design were taken back to the drawing board for others to work on.

The uses of computing to assist design need not, therefore, be an isolated activity. It is used by certain interviewees as an activity (if a central one) which is integrated with other media. In this way the use of computers can be seen to enrich and enhance the variety of media through which designing can take place.

Using Different Input Devices

The majority of interviewees use a standard keyboard and mouse as a means of inputting data to the computer. Architect 2 [Clips 2 & 15], in addition, uses a flat-bed scanner and a pressure-sensitive digitising tablet. The digitiser is touched with a pen and is used for sketching freely as well as to control the computing environment. This returns to the architect much of the freedom of manual sketching lost by the restriction of a keyboard and mouse. Further, new opportunities are presented by the pressure-sensitivity, such as varying line weight and colour depth by varying the pressure of the pen stroke. Another way of inputting data, especially images, is by using a scanner. Such activity is exemplified by Architect 2, who scans a printed CAAD-generated perspective which has been touched-up by hand, and Architect 7 [Clips 7, 8, 19] who scans different images in search for ‘cultural’ relationships when developing a conceptual scheme. These images are then manipulated through image editing software to assist with conceptualisation (see ‘Mixing Media” above.)

The additional use of alternative input devices may be seen as a means to overcome limitations constructed by standard hardware arrangements (namely the restriction of manual sketching ability) whilst providing powerful tools for collage and image manipulation. This category can be seen to be closely linked with Mixing Media.

Focusing on of the Appropriate Grain of Detail for Design Action

Two architects exhibited a command of the computing medium through manifesting an awareness of the grain of detail necessary for the task in hand. Architect 5 [clip 13] demonstrated a micro approach, working in close-up within the main project CAAD file on only the elements which were deemed to require a high level of detailed modelling or visual description. In [clip 22], experience of working to a required level of resolution and detail is outlined, together with a need to avoid being too ‘captivated’ by the computing environment. This experience was applied to communicate ideas in a simple way. It was then shown how files were manipulated to display required project information to assist generation of design ideas. Architect 2 [clip 5], during design through conceptual sketching, set the image size to a chosen minimum resolution (pixel dimension) after having decided the requirement for printed output. This was done in order to retain a minimum file size and to maximise the speed of filters applied to the sketch to keep the design process fluent.

Whilst the computer offers the potential to model every element of the design 3-dimensionally, or draw and render in fine detail, it can be important to retain freedom from the need to do this while designing and not be forced to make design decisions too early. Awareness of the necessary grain of detail permits the freedom of creativity to remain without forcing hard edged designs to emerge too early.

Working Creatively with Input Digital Data

This category of action is, in effect, a sub-category of ‘using different input devices’, dealing specifically with the use of digital information. Architect 5 [Clip 3] illustrated the use of a digital survey drawing, created using electronic survey equipment and provided on disk by the survey engineer. This information was then used as the basis for modifying an existing building and accurately producing a design for its extension. Architect 6 [clip 21]
also used digital mapping and, in addition, used images taken from a digital camera [Clip 17] to form a collage with a rendered perspective taken from a 3D model.

Digitally input data can be seen to increase accuracy and save time, prior to and during the design process. From the point of view of creativity, the dynamism of lines in digital surveys facilitates rapid modification in, for example, design modifications to existing buildings.

The Value of Manageability of Visual Information

Six architects expressed the value of manageability of visual information. Most computer applications make available a number of ways of controlling the information visible on the monitor. Generally, when designing, the designer deals with a large and increasing body of visual data. It can be seen to be important to readily access (only the) required data if fluency in creative thought is to be maintained. Architect 1, [Clip 5] demonstrates one of the most common and effective methods through the use of layers. Elements are assigned to a number of layers which can be turned on or off depending upon whether the data is required to be visible or altered. Architect 5 [Clips 4] shows how different design proposals are drawn using diverse pen colours for clarity and distinction, to permit design selection between alternatives to be made. Architect 5 also uses reference files, data files which are called up and displayed within the current project [Clips 10, 11, 14, 15]. This allows the combination of various files within the project window. In addition to reference files, data may be assigned to any of 63 levels (layers) with the potential for alternative line weights, styles and colours for each. These levels are controlled from a dialogue box showing a matrix of rows and columns allowing, for example, each row to represent a storey [Clips 14, 15]. Levels and reference files are thus employed to provide a matrix to allow extended control of what data is displayed. This is held by him to be vital when dealing with vast amounts of data [Clip 13]. Architects 3, 4 & 5 all work to some extent with several projections (2D and 3D views) on screen at once whilst Architect 6, who also uses layers [Clips 8, 10], alternates between 2D and 3D windows [Clip 13]. This gives control of the creative environment in a manner suited to the particular architect’s creative approach or idea generation needs.

Manageability of visual information is a key attribute in the use of computers to facilitate the development of projects. From the use of layers and reference files to organise and control the visibility of data, it is possible to access a large amount of information which, if displayed simultaneously, would lead to confusion and illegibility. The effects of changes made to 2D and 3D representations can be monitored by viewing the project through different projections, either shown together on a divided screen or by simple commands which generate alternative views.

Scale Hopping

Three architects in particular demonstrated the application of scale hopping to facilitate creative actions. The benefits of being able to examine micro (detail) and macro (general) elements of a design by changing the resolution, or visual scale, of the same drawing were opined by Architect 2 [Clip 9]. Architect 1 [Clip 5] used zooming in and out on parts of a drawing as a means to fluently work at different levels of detail on the same design. All interviewees demonstrated and explained the advantages of this feature and, in particular, Architect 6 [Clip 9] used a close up of part of a 3D element, combined with switching off of layers, to investigate part of his design and modify or progress where appropriate.

What the computer offers here is the ability to combine any, or all, of the information produced throughout the design and to examine it as a whole or in detail. This permits fluency in visualisation from complete 3D representations of the design to small-scale detailed elements within the same workspace, allowing a previously impossible fusion of different levels of design.

The Computer as a Device to Assist Conceptual Design.

Whilst all architects interviewed used the computer from an early stage when designing, two in particular exemplified using the computer as a device to assist conceptualisation. Architect 6 [Clip 20] demonstrated the development of a concept from sketching 3 curved lines—said to represent the sea— through to producing the cascading form of a building. This concept was reinforced by using similar curves to develop bow-shaped structural elements. Architect 7 [Clip 1] attempted to use computers to reflect the ways people perceive the world around them. Experimentation between metaphors and images [Clips 4 & 8] was carried out through the computing medium. Different images (a site plan and images considered culturally relevant to the project) were
scanned and morphed together [Clip 6 and 20] and the action was repeated a number of times in order to search for relationships which would forward the conceptual design [Clip 7]. The resulting image was then extruded to create a 3 dimensional form [Clip 10 and 22], beginning the move from concept to actual design.

The first case illustrates a rather traditional approach to conceptualisation, where the computer is used to develop an initial idea through sketching and shape manipulation. In contrast, the second example exploits the potential of the computer to add something unexpected to the process in a way which would not be possible through any other medium.

Conclusions

Ten examples of Categories of Action of Design Moves have been briefly described. These descriptions represent part of the second, and arguably the most useful, dimension, or field, of the Multimedia Matrix (the first dimension being the ordering or design actions by architect or interview). Each category can be examined from within this matrix and a range of visual examples of Design Moves specific to the chosen category can be viewed. The potential benefits to other designers of using this matrix, or any resulting learning resource, are that ‘live’ visual examples of Computer-Aided Design Actions can be explored in the context of similar examples from different designers. This may be inspiring to the un-initiated, would-be computer-aided designer as a means to understand the variety of approaches used by others. Further, more experienced designers may use the material to expand their range of creative options. Aside from the visual nature of this material, a novelty in this approach to exemplifying design activity is that the exposed design actions are not pegged to the design product which they were used to create. This has the advantage of generalising the action, allowing users to see an example or explanation of the action and interpret the context in whatever manner they find useful in developing their own design approach.

I have explained how video-taped reflective demonstrations of design activity can be analysed and disaggregated into Design Moves, and how these moves may be characterised and grouped to describe Categories of Action. This data can be further synthesised (beyond the two dimensions of Architects and Categories of Action) to form an extruded, or three dimensional matrix. Whilst a full description of this is beyond the scope of this paper, it warrants mention as further direction. The merit of such additional synthesis is to better understand the nature of the exemplified activity, and so better present the actions to others. One way this may be done is by examining relationships between Categories of Action in terms of their interdependency or (mutual) exclusivity. Another way is to assess the way in which the computing medium has enhanced creativity. This can be done by considering a Category of Action as (i) a direct creative action—for example misreading a sound file as an image, and extruding the resulting image to generate 3D form—whereby the computer extends beyond a mirror in the metaphorical design conversation and becomes a partner or converser, or (ii) an indirect creative action—for example, the manageability of visual information—whereby the computer facilitates creative action.

As previously mentioned, the depth and relevance of this material can only be truly appreciated through viewing the recorded actions from within the Multimedia Matrix, and those requiring further information should contact the author.

Credits

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References

