Programmatic form-finding and the visual analysis of creative works (architecture, sound, sculpture, painting, music or dance) can be combined to develop “alchemical” processes for the computational exploration of form. This paper reports two project-based form exploration experiments using such a process. The first experiment develops a process for capturing, manipulating and generating form based on a piece of dance choreography. The second experiment explores the decompression of space and architectural elements encoded within the Duchamp painting “Nude descending a staircase”. A discussion for incorporating programmatic strategies and for developing an innovative approach to conceptual form processing based on the language of geometry is presented.
COMPUTER APPLICATIONS IN CONCEPTUAL DESIGN

Computer-aided design (CAD) primarily responds to the needs of practice in the production and documentation of buildings. The potential of complementing CAD through conceptual applications is immense. This paper focuses on the use of digital tools as a means of formal analysis going beyond CAD to more central (perhaps more traditional) concerns relating to understanding and comprehending the genesis of form. The computer is a powerful platform for exploring compositional logic, visual representation, morphological analysis and generation.

The use of low-level programming is one route to a more thorough understanding and exploitation of developments in form generation. The programmatic form-finding approach is finding increasing acceptance within innovative design curricula.\(^1\)\(^2\) For instance, Streich presents a discussion in favour of including programming knowledge in the design education of an architect.\(^3\) Burry et al present cogent arguments on aiding spatial and temporal understanding using computer programming.\(^4\) The use of programming for teaching structured problem-solving in design has a long tradition.\(^5\)\(^6\)\(^7\)\(^8\) Here, concepts of recursion, iteration, parametrics, transforms and descriptive geometry are introduced through programming exercises. Weizenbaum makes the observation that

One programs not because one understands, but in order to come to understand. Programming is an act of design. To write a program is to legislate the laws for a world one first has to create in imagination.\(^9\)

While programming is a test of understanding in a problem-solving domain, the relationships between programming and design are not always symmetrical. The translation of design problems to problems in programming constructs, while useful forms of abstraction, present non-trivial and difficult transitions for the novitiate. A more
inclusive induction to the precepts of computation within the discipline of design under the broad theme of "computer applications" is necessary.

For example, Maeda develops a pedagogy based on "design by numbers" and the understanding of visual design using computational processes and media. The use of software programs to explore constructed worlds and their relation to craft and abstraction is developed in McCullough. Here, the central role of engaging in digital design through geometry modelling, rendering and animation of spatial artefacts is replaced by a more thematic (hybrid, alchemical) approach to using digital tools (software, programming constructs, spreadsheets, video capture, image processing to list a few). This process of extending the world of computation by engaging with digital and physical artefacts and seeking to inform one with the other forms the focus of this paper.

Form finding experiments that engage in exploring the broader relationships between media, process and hybrid understandings of the digital analysis and means of expression are being developed in the computer applications course in Deakin University. The experiments comprises the analysis and study of a distinct piece of creative work (architecture, sound, sculpture, painting, music or dance) using digital media and computational exploration and generation of form based on the analysis. Two form-finding experiments from this course are described to illustrate alchemical form processing: translating visual and spatial expression from one medium to another using digital means.

PIROUETTES OF MOTION
The goal of this experiment is to develop and explore form generation techniques based on tracing the motion of the human body through space. Motion tracking technology remains expensive and requires markers, body suits, or other devices attached to the subject. This experiment is predicated on developing an inexpensive solution to the problem of recording, capturing and manipulating the traces left in the wake of body motion through space in an intuitive form suitable for form finding studies enables the recovery of the traces of motion as points moving in space.

Eadweard Muybridge captured the first photographic recordings of humans and animals in motion in his famous publication "Animal Locomotion" in 1887. In his studies of motion, Muybridge recorded each time-step with several camera views. This process enabled him to capture motion using still photographs taken over time. Italian and Russian Futurists such as Russolo, Boccioni, Larionov and Goncharova attempted
to represent movement through an approach known as “dynamism”, almost a century earlier.

To recover detailed three dimensional information for form finding, a combination of video motion capture, a physical three dimensional grid, keypoints and simple generative programming is used. The goal is to reanimate the motion cycles under programmatic control to generate points, lines and surfaces that encapsulate the process of tracing motion in space.

Fig. 1. Setting up a physical grid with three cameras to capture motion.

First, the physical grid was set up in a photography laboratory comprising gridpoints spaced at 200mm centres in three axis, front, side and above (Fig.1). Setting up the camera’s in the grid space proved to be one of the most challenging parts of the process. A light fixture was removed from adjustable lighting ceiling and a tripod setup over the hole. The camera filming from the top angle was mounted on the tripod, the buttons pressed and the ceiling raised to its maximum height, allowing the largest area of grid space in the view finder.

To simplify the process of motion capture, twelve key points of interest were marked with fluorescent tape on the subject. As the subject moved through the space, three separate camera's capture independent views of the points at an instant in time. Each view captures a single vector, marking the position of a point in relation to the gridded background. In this manner, the points are mapped in three dimensional space. The video footage is then processed into digital form. Using a video editing software the data is then further broken down frame by frame into still image sequences. Each image sequence comprised 780 stills. For simplifying the data set, thirteen frames from the 780 image sequence are extracted (the intermediate positions are generated by interpolation). The final dataset comprises thirty-nine still images in space (13 images from each of the three video sequences). These thirty-nine images are then processed to retrieve (x, y, z, t) values of each of the key points (marked with fluorescent tape), where (x, y, z) indicates the position of the point at time t. From this information, two sequences are available for formal exploration. First, the collection of
thirteen values for each point indicates the motion traced by the point through space. A simple script generates b-splines using these points as knot values. Second, the collection of twelve values for each time instant captures the abstract trace of a form.

Fig. 2. The motion of the subject is recorded in video against the physical background with key points marked for capture with fluorescent tape.

Fig. 3. Stills from the process of generating and animating the points in space. Capturing the traces of the moving points by applying surfaces (below).
CASE STUDY 2: DESCENDING A STAIR

Duchamp's 1912 painting "Nude Descending the Staircase, no. 2" (Fig. 4) is a combination of two major forms of art, Futurism (their style of depicting movement in space) and analytic Cubism (spatial composition of fractured parts). In this famous work of art, the subject is depicted moving down a staircase. The goal of this experiment was to develop an understanding of the composition through an exploration of the spatial depth and projection using digital means. The compressed space in the composition, the interplay between the static structure of the stair, the representation of human motion encoded in the painting are explored.

The process of analysis involved using regulating lines in two dimensional space to interprete the possible relations between the motion of the descending nude, the space beween and the staircase. A three dimensional spatial frame to decompress the painting is developed by generating and extending the geometric analysis. Fig. 5 illustrates the major lines of movement that can be discerned in the painting and their projection onto a three-dimensional frame. The superposition of the movement of the body and its relationships to the stair are captured in the two major diagonal curves. The next step considered the construction of the stair based on the major features in the painting and the abstract lines of movement.
Figure 5. Regulating lines based on the Golden Section (top right) superimposed on Duchamp’s 1912 painting (top left).\(^{13}\) A hypothetical projection of the lines of movement of the stair and the body onto three dimensional space (upper right).

Using the frame, a series of formal explorations develop the major elements of the body, stair, handrail and direction of motion. These formal explorations are superimposed in a hypothetical model of the space within the painting (Fig. 6). Finally, the implicit space and its contents are used to re-animate the trace sequence in a digital animation whose final still is the frame corresponding to Duchamp’s landmark 1912 experiment in conceptual art.
Fig. 6. Construction of a stair and handrail based on the features of the painting and their projection onto space. The generation of the figure as a collection of lines. The combination of the three within the projective space of the painting.

DISCUSSION
The “alchemical” experimentation reported in the paper frame a wider debate on the close relationship between experimental techniques, media and visual form processing. The ability to blur the boundaries between an object and its trace in space (what Cache terms “Objectile”, or Goodman’s “Exemplification”) led us to a better understanding of how forms in motion can be captured, generated and manipulated through programmatic means using off-the-shelf technology. 14,15

Further, the process provides a better understanding of the power of tried ideas, such as Muybridge’s original use of chronophotography as a means of spatial and temporal understanding. The investigation of Duchamp’s Nude opens a seam of material rich in higher-order compositional techniques such as montage, collage and assemblage remain problems for further experimentation. The simplification of the datasets in both experiments remain issues from a technical and aesthetic standpoint, due to the need for some manual processing of the data stream. Use of more sophisticated real-time algorithms and translation techniques (For example, from live choreography to form) remain topics open for research.
The approach taken here is one in which the barriers to facilitating experimentation in design are removed by a hybrid combination of elements taken loosely from the domains of descriptive geometry, computer programming and forms of visual expression. Admittedly, the emphasis on rational and repeatable processes in the use of algorithms and data structures skews the debate towards computable aspects of visual reasoning and mimics well-known processes of formal experimentation, known from the early days of Modernism. This bears explanation. The goal of digital alchemy, as understood here, is to attempt to comprehend how ideas of space, form and time can be investigated in an environment of open inquiry driven by curiosity of how disparate forms of expression can be brought together within digital media. As Herbert Simon put it,

> The natural sciences are concerned with how things are. Design on the other hand is concerned with how things ought to be ...\(^{16}\)

Despite the reductive emphasis, a number of critical issues are discernible in this debate. First, the wide spread adaptation of CAD in both schools (and practice) underscores the implicit understanding that computers support a narrow and well-defined band of needs associated with architectural production, namely, the communication and documentation processes. The two experiments reported here attempt to push these neat definitions by construing digital media in the broader spectrum of formal experimentation involving visual production. The compression of an essentially spatial expression, choreography, into points and lines underscores the relationship between the language of dance and its transformation into a formal language shared within the plastic arts, the frame of mathematical description. The search for spatial elements within the conceptual art of Duchamp’s Nude forces one to confront not only the nature of abstract expression but also its underlying frame, plastic composition. The computer remains a supple instrument that aids and abets formal exploration, rather than a mechanical prescriptive tool for translation of idea to form.

Mathematics and descriptive geometry forms a significant proportion of architectural exploration. With increased specialisation of discipline streams this proportion has declined in contemporary curricula despite their historical relevance and their contemporary significance. The alchemical process of transcribing evocative visual media using computers enables one to reintroduce the central and mediating role of the language of geometry in form-finding processes.
ACKNOWLEDGEMENTS

The author would like to acknowledge Jo Bandy and Alistair Lucas for the case studies, which formed part of an advanced computer applications course conducted in the School of Architecture and Building, Deakin University.


