Computer Aided Design: Past, Present, Future,
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Computer Aided Design: Past, Present, Future

Jonathon Allen & Paul Kouppas

INTRODUCTION

Computer aided design (CAD) has evolved at a tremendous pace, from simple two-dimensional (2D) draughting, to more complex three-dimensional (3D) modelling, to the use of animation and the linking with artificial intelligence. Since the first integrated circuit was developed in 1958, computational processing speed and memory capacity have grown exponentially, doubling every two years or so – a phenomenon known as Moore's Law after Gordon Moore the co-founder of Intel who first identified and predicted this trend. The proliferation of ever more powerful and cheaper computers has provided a fertile environment for CAD's growth but, moreover, the great leaps forward have been when CAD has migrated from one discipline to another. This chapter is about this important migration. The way in which CAD has evolved by jumping between disciplines is indicative of the evolution of the design professions themselves. The resultant cross-pollination of ideas, practices and tools has led to new hybrid design disciplines. Computers are now increasingly mediating design processes and have changed much of design practice itself.

CAD AT THE CORE OF DESIGN PRACTICE AND DESIGN EDUCATION

The ever-evolving and multi-modal nature of the design process means that design students and professionals will necessarily need to be conversant in a wide range of CAD programs, and further, will often be simultaneously learning whilst using software. Knowing which process or software to use, and when, is perhaps the key to addressing today's design challenges and meeting ever-shorter timescales. The new design virtuoso's instrument is the computer and the designer's virtuosity is in drawing together a range of computer tools to compose their designs or perform their role in delivering a good response to a brief. The designer at times will perform solos, but will typically be working alongside (whether literally or, increasingly, virtually) other specialists as part of a team working on the different aspects of a complex design project. These projects can often involve many people in different parts of the world. The integration and management of these projects pose their own challenges, such as the consideration of file formats and compression to allow for the acceptance and delivery of files, and a suite of computer tools more readily assists this process.

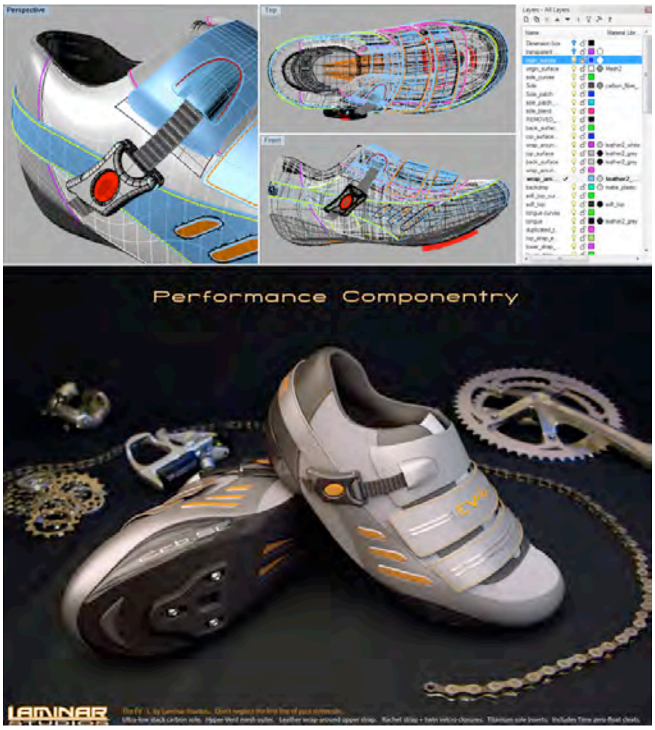


Figure 1. EV-L, 2009. Conceptual sneaker design by Shayne Reynolds, completed in his 3rd year of studies of Industrial Design in a module that introduces students to the fundamentals of NURBS surface modelling for conceptual product design

Navigating these challenges can be both exciting and daunting, but if approached in the right way CAD can help unleash and augment the designer's creative capacity.

That creative capacity, of course, must already exist in the designer. CAD can assist in realizing visions and facilitating a greater understanding of concepts, but still requires ideas to be worked out via more traditional means such as drawing, argument, critique and research. As with any instrument, CAD requires talent and diligence to master.

From starting a design degree to commencing a professional career in design will take between three and five years. In that time you will be exposed to a plethora of software applications, from general word-processing, web-searching and communication tools, to more specialist 2D draughting packages for the generation of engineering and plan drawings; 3D modelling software for creating accurate representations of products, buildings, packaging or animation characters; animation applications for the generation of fly-throughs or short movies; digital imaging software for vector and pixel based image generation and manipulation; multi-media applications and web authoring tools for interactivity; as well as analytical software to help verify and evaluate design ideas.

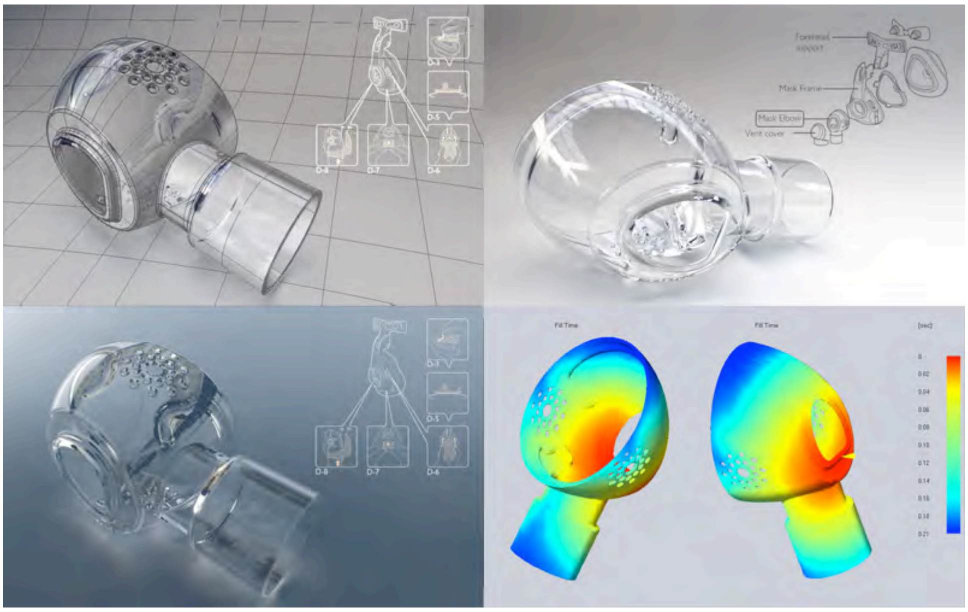


Figure 2. Nasal Mask Elbow Component, 2008. NURBS surface model, HDRI (High Dynamic Range Rendering) with caustics and design verification. Paul Kouppas

You may spend three or four years honing your skills with these packages, before perhaps entering the profession you've trained for. An important realisation is that the field of CAD will also evolve dramatically in this time, with upgrades and new features – indeed by the time you graduate, the software you began using may look nothing like it did when you started learning it. The software may not even be available, or new players may enter the market, such is the pace of change and competition in the CAD software market.

This may seem rather formidable, and indeed there is a lot to learn, but understanding how CAD has evolved and how it is being applied to help realise designers' ideas can be quite inspiring. Investing the time to hone design skills – both manual and digital – is vital to your success as a designer. Having an appreciation and understanding of how computers are, or potentially could be, used in the design process, along with some generalizable technical skills in their application is now increasingly important. It matters less what particular software you use. What's more important to employers is your knowledge of CAD, the adaptability of your skills and your ability to learn quickly. Indeed, many companies use their own in-house proprietary software (e.g. Pixar) and so the only way of learning the package is to work there. What is important is garnering the fundamental processes that are the foundation of most proprietary software. So if your dream job is to work at Pixar (whose isn't?), then you need to equip yourself with the principles of traditional animation such as 'squash and stretch', 'timing and motion', and so on. Even if your ambition is not to work for an animation studio, a knowledge of animation and the ability to 'stage' an idea, can facilitate both a better presentation of your designs and can help you incorporate personality, expression or the mood in your design ideas. Increasingly designers are combining inspiration, skills and techniques whilst adopting tools from outside their primary discipline.

When faced with learning a CAD package, the terminology can be somewhat daunting and alien – from *ACIS SAT* to *splines* and *NURBS*, the terminology used in CAD sounds like something more akin to science fiction – and certainly the field of CAD is guilty of acronym abuse. So what does it all mean, and what do you really need to know to get your head around the subject? In order to answer this, and anticipate what your future as a design practitioner will be like, it is worth not only looking at current practice, but also how we have got to here. In turn, we can better anticipate how CAD is likely to evolve in the near future.

2D CAD: FROM DRAUGHTING MACHINES TO MACHINES THAT DRAUGHT

The evolution of CAD has followed an interesting path, migrating from aircraft to automotive to architecture to animation to artificial intelligence, gaining richness en route. Computer Aided Design also used to be known as Computed Aided Draughting, and this is an indicator of CAD's two-dimensional origins. The first CAD packages were largely replacements of the drawing board, producing predominantly orthographic and isometric drawings. The huge advantage of CAD was its ability to duplicate elements allowing for quick modifications of part drawings, easy sharing of files, and dramatic reduction in the time taken to produce and edit drawings. There was also a key advantage in electronic storage of files, meaning that files could readily be duplicated and shared (particularly important when the design team are working in different locations and manufacture is occurring overseas). The need for plan chests full of drawings in each location quickly became a thing of the past.

It is rare to see drawing boards and draughting machines these days, but not so long ago design studios were full of them – many manufacturing companies, engineering firms and architects offices had vast rooms filled with draughters labouring over their technical drawings, with plan chests full of blueprints and detailed drawings of every single part of a product or building. Thankfully, but also sadly for the loss of this artistry, those days are gone and technical drawings are now almost exclusively computer generated. This has dramatically accelerated the design detailing and development process. Many CAD packages now include standardised parts files, so designers can simply 'drag and drop' items into their design drawings. For instance, standardised items such as doors, windows and various building panels can be retrieved from a directory and dropped into architectural plans; or in engineering, standardised pipes, tubes and mechanical fixings can be quickly inserted into drawing files. This not only speeds up the process of producing detailed drawings and plans, but also ensures dimensional accuracy. Many parts manufacturers also provide digital drawing files of their stock, so that designers can accurately accommodate these parts in their designs with the assurances that everything will fit.

Importantly, producing drawings in CAD means that the same computer file that produced the drawing can also be used to generate cutting paths for the manufacture of items, thus resulting in a far more efficient and accurate process. This translation from CAD draughting to digital making is often referred to as CAD/CAM, where CAM stands for Computer Aided Manufacture. Many 2D CAD applications now incorporate 3D capabilities, but the development of 3D CAD systems have, by and large, superseded their 2D cousins.

3D CAD: FROM AIRCRAFT TO AUTOMOTIVE AND BACK

The development of commercial 3D CAD software has an interesting past. Aircraft designers during the 1940s would use small wooden strips, called *splines* to create templates for aircraft. The thin wooden strips were bent and held in place at key points (nodes) and the timber's natural stiffness ensured that a smooth curve resulted. These 'splines' were then traced onto paper to create the templates for the construction of the aircraft. This was very much a hands-on craft technique, but the principles behind the construction of these spline curves remains the basis of much of modern CAD systems. In the late 1950s and early 1960s, mathematical definitions of these curves were developed by the French mathematicians Paul De Casteljau and Pierre Bézier. Both worked in the automotive industry (De Casteljau for Citroën and Bézier for Renault) and, as is typical of the secrecy of the automotive industry, worked independently without knowing of each other's work. Bézier published his work in 1962 and his name is best remembered because the early vector-based graphics and animation tools used Bézier curves to generate lines or motion paths in the computer. A Bézier curve consists of a line defined by two end points plus a series of nodes on that line that can be moved using control handles to redefine the curve. Bézier curves are still an integral way in which computer models in CAD are drawn and defined today.

A mathematical definition of such curves allowed computers to quickly crunch the numbers to generate and manipulate the lines, allowing precise representation of exterior surfaces. Commonly, 3D surfaces in CAD are referred to as parametric surfaces, and they can be mathematically represented by NURBS, or Non-uniform rational B-Splines, which are like rubber sheets stretched over the surface. Imagine then, a grid of lines projected over this sheet with control points to allow the surface to be stretched and manipulated by the designer to create complex free-form surfaces. This is how dynamic models can be created, by patching together a series of these NURBS surfaces.

Figure 3. Wall-E Paper Mechanics, 2008. UV layout and paper cut-out, flat shade render, and textured HDRI rendering. Paul Kouppas

Once the overall surfaces of the object are created, a material editor is used to create textures that can be mapped onto those surfaces for rendering. So once the CAD model has been created, the object can be rendered to appear matte or shiny, hairy or smooth, coloured or plain, translucent or opaque. Many animation and visualisation packages call their desktop a ‘scene’, allowing the designer the ability to stage their models with cameras, lights, and other digital assets (sometimes referred to as actors). Each of these digital assets must be controlled through a variety of settings to allow for various lighting conditions and viewing angles so that the computer knows how to render the surfaces, cast shadows and add reflections to create life-like visualisations.

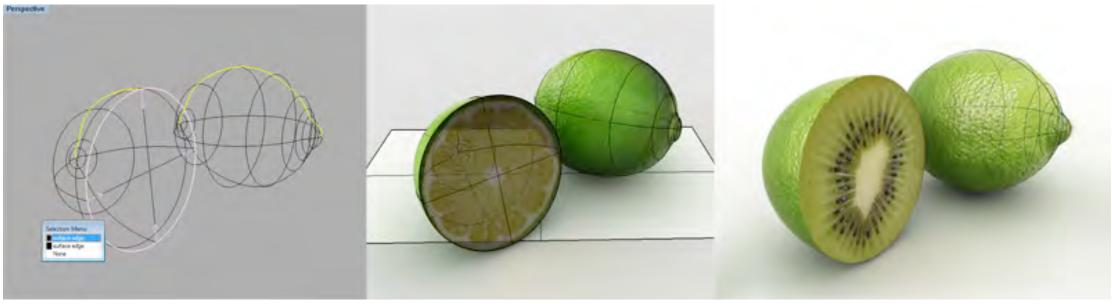


Figure 4. Kiwi-Lime, 2009. Simple NURBS demonstration surface model constructed from single Bezier curve and ‘revolve’ or ‘lathe’ technique, photo textures applied allow for a convincing rendering. Paul Kouppas

Much of the development of early CAD systems was either in research groups at Universities, or by in-house teams at large automotive and aircraft manufacturing companies. There were two reasons for this – firstly, the sheer cost of computers in the 1960s was prohibitive for smaller industries to adopt CAD, and secondly, the engineering requirements of both automobiles and aircraft required the ability to manufacture complex 3D surfaces. The pioneering developers of CAD systems included from the automotive field, General Motors, Renault and Ford, and from the aircraft industry, Lockheed and McDonnell-Douglas. Throughout the 1970s many other automotive and aircraft manufacturers developed their own CAD programs, but because of the nature of those industries and the commercial sensitivity of their processes, these CAD systems were specialised and bespoke. It wasn’t until 1980 that standardization began, with the introduction of the Initial Graphic Exchange Standard (IGES) – a standard still in use today that allows complex 3D curves and surfaces to be transferred between different CAD systems.

The French aircraft manufacturer Avion Marcel Dassault, began developing a 3D CAD application in 1977 for the development of the Mirage jet fighter aircraft. It was soon realized that the software application they had created could have commercial value, and in 1981 a subsidiary company, Dassault Systemes, was established. A year later, in a sales and marketing partnership with IBM, one of the most successful 3D CAD applications, *Computer Aided Three-dimensional Interactive Application*, or *CATIA®* for short, was released. Dassault Systemes, remains one of the leading CAD software providers, and includes SolidWorks® and

CATIA® in their portfolio along with several other computer software tools to manage the complete product lifecycle.

FROM AIRCRAFT TO ARCHITECTURE

Because CATIA was initially developed for handling the complex nature of 3D aircraft surfaces, it was readily adopted by other transport design disciplines, such as automotive, rail and marine craft design. Architects have also utilised the software for its ability to handle complex geometry and surfaces. Most notably, Frank Gehry's *Gehry Technologies*, has developed *Digital Project*™, a suite of software for 3D building information modeling, built upon the CATIA engine, precisely because it can handle the complex free-form surfaces typical of his buildings.

Another architect who advocates the use of CATIA, along with several other CAD tools, is Professor Mark Burry, Director of the Spatial Information Architecture Laboratory, and Professor of Innovation at RMIT University in Melbourne, Australia. He is a pioneering researcher and practitioner in the role of CAD in creative and transdisciplinary projects, and one of many case studies where this best plays out is in his career-long work on Antoni Gaudí's masterpiece, the *Sagrada Família* church in Barcelona (see www.sagradafamilia.cat/).

Gaudí commenced work on the church in 1883, but by the time of his death in 1926 the church was less than a quarter complete. During the Spanish Civil War, many of Gaudí's models of the building were destroyed, and so the completion of the church has relied on in-depth research, interrogation and interpretation of Gaudí's processes in order to complete the design according to his intent. One of the design processes Gaudí developed was to create physical models by stretching strings across a space and adding weights to the strings at particular points to pull the string to generate complex catenary structures. When the structure (or an image of it such as a photo) was inverted, the form of his buildings was revealed. In essence, Gaudí's process is not too dissimilar to the way in which aircraft designers used splines; adding extra force at particular points to change the curvature of a line. This process can be digitally modelled today using 3D CAD systems where control points are manipulated to replicate the complex surfaces that Gaudí proposed.

Professor Burry first began work on Gaudí whilst still a student, and at that time the complex structures had to be calculated and drawn by hand. This was a very labour-intensive process but perhaps too, an insightful one as it afforded a deeper understanding of the complexities of Gaudí's structures, and of the processes by which they were generated. Professor Burry is now executive architect for the project, and works with teams in Australia and Spain studying the remaining pieces of Gaudí's physical models and drawings in order to interpret and complete the design. Parametric CAD software is used to help generate digital models that resolve some of the details left behind in an attempt to present designs that correlate with Gaudí's intent. Because parametric software allows multiple points of a surface to be manipulated in relation to each other point, the 3D CAD model can be tweaked relatively quickly to best fit with the remaining physical models. With the use of rapid prototyping, the digital model can be reproduced as a physical model to help verify the design.

The use of CAD here is particularly interesting, as it is helping to reveal insights into Gaudí's 'compositional strategies', and is allowing the creative exploration and interpretation of Gaudí's work long after his death. The Sagrada Família church is still under construction and CAD is used to share information and progress across the world. From an office in Melbourne, the architect can be discussing (via video-link) a particular design feature, with the stone masons and site architects in Barcelona. In front of them both can be the same CAD model in both digital form (on screen) and as a physical representation (a rapid prototyped part).

THE ARTISTRY OF MEDIA AND MEDIATION

The ability to use CAD with other forms of computer-based communication was very attractive to the automotive industry because of its need to support international team working. Indeed, the automotive sector has been one of the pioneers of CAD, and has also been an early adopter of other technologies to streamline its business. There are several reasons for this. Automotive design and manufacture is a global business, producing vehicles for international markets. Cars and commercial vehicles must conform to different national legislation and design requirements, as well as appeal to the nuances of different cultural groups. The complexities of operating such a business with design, engineering and manufacturing teams geographically dispersed around the globe, and the necessity to ensure that all of the teams work toward the common goal, on time and on budget, requires very effective management and communication. Increasingly this management and communication is being mediated with computational tools typically referred to as Product Lifecycle Management (PLM).

The management of the lifecycle of a vehicle not only involves every stage of design, development and manufacture, but also use and after care service, and the vehicle’s disposal and recycling after life, all of which need to be planned for and accommodated in the vehicle’s design from the outset. The development of a new vehicle, from initial meetings and early concept sketches to the time the vehicle drives off the production line, takes several years and an incredible financial investment. There are many stages in the process of design and development, involving teams of specialists in different locations around the world.

CAD has a vital role to play in the styling of vehicle form and designers work using an array of 2D and 3D computer applications to produce lifelike visual representations of vehicles. The process begins with many sketches, whether traditionally with pen, pencil, marker and pastel, or on a digital tablet. After a series of reviews and critiques, refinement of the sketches will translate into exploratory CAD models. Typically, the 2D illustrations can be inserted into the background so that splines and surfaces can be created from them. Programs such as Autodesk Alias® allow designers to capture details of their 2D digital sketches to form the basis of a 3D CAD model. The two dimensional curves are given a new life, curving and bending as they are shaped into three-dimensional representations. BMW's fabric-skinned shape-shifting sports car concept, the *GINA* – '*Geometry and functions In 'N' Adaptations*' – is the embodiment of such practice. The aluminium wire frame structure accurately represents the NURBS curves used to generate the design, and its stretchable polyurethane-coated elastane skins the NURBS surfaces.

Automotive clay modellers will work alongside the designers to produce physical representations of a vehicle. Both the clay modellers and the designers are after Class A surfaces, where all of the curves on the surface are accurately aligned and congruent. In order to obtain this, often the CAD and clay models are developed and refined concurrently. An initial CAD model may provide the basis for the production of a clay model, which will be refined by hand, digitally scanned and re-imported to CAD software to finesse.

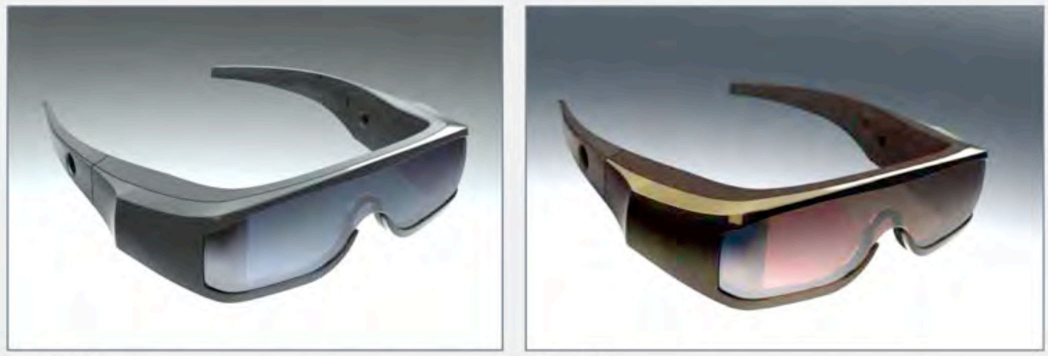
CAD AND THE SUPPORT OF TEAMS

Once the CAD model is produced, others in the design, engineering, manufacture and marketing divisions of the company can work with the CAD data to help plan and develop other essential design tasks. Mechanical engineers can use analytical software tools to asses such things as the vehicle's aerodynamics and drag efficiency, the structural integrity of the vehicle and how it will perform in virtual crash testing, and the vehicle’s vibration and handling characteristics. Ergonomists can asses the vehicle’s accommodation of the particular demographic it has been designed for – this is particularly relevant in a global market where anthropometric data varies from region to region, and cultural factors, such as the wearing of turbans by Sikh communities, also needs to be taken into account. Ergonomic software can help assess (preferably early in the design cycle) a vehicle’s design based on the 3D CAD model, and the layout of controls, seating posture, ingress and egress, viewing position, safety and comfort can be resolved alongside the designer. Colour and trim designers will take the CAD model and render different colour and material finish combinations, and prepare specifications based upon this. Manufacturing and production engineers can detail a Bill of Materials (BOM) from the CAD model that, in turn, can be used to help procure parts, liaise with suppliers, develop manufacturing plants, and inform costing and financial analysis of the vehicle’s profitability.

Consideration of environmental impact, eco-design, and design for disassembly needs to be factored into the design cycle, preferably as early as possible. Automotive Regulatory Compliance Management tools are now part of many CAD and PLM software, providing lists of suppliers, identification of recycled content in parts, and even assessing the best and worst manufacturing locations in regard to environmental and financial factors. Different legislation in different parts of the world also needs to be considered and, in conjunction with the BOM, legislative and regulatory compliance can be assessed and changes made accordingly using analytical software. This is an increasingly important factor in automotive design (and in product design more generally) particularly in Europe, where end-of-life vehicle legislation makes it the responsibility of automotive manufactures to consider how the vehicles they produce will be disposed of.

With the proliferation of CAD-based tools, one would have thought that manual skills such as hand sketching and hand modelling were no longer so relevant. This is far from the case. Indeed, sketching is still core to automotive design, as sketching allows relatively quick exploration of form, and is also a wonderfully emotive medium that captures the gestural energy, essence and flair of an idea. Physical making is also still prevalent, in the form of clay modelling. Whilst the automotive sector has experimented with the all-digital studio, limitations of this process were observed, and most studios will have a balance of digital and physical processes. The real success of CAD and CAM systems here has been in speeding up the process, and facilitating more fluid conversation and design iteration amongst the teams.

Increasingly in the automotive sector, project teams are distributed around the globe, with key divisions of companies located in the US, Asia and Europe. This has given rise to the ‘24-hour studio’ where designers and engineers will each build upon the work of the other. So a project might move from Detroit, USA, to Melbourne Australia, to Cologne in Germany and then back again. This has the great potential of speed up the process, but also poses problems of management and communication (in the 24-hour studio described above, language differences mean that the car *hood* becomes a *bonnet* and then an *auto haube* as it travels from team to team). Working from the same CAD model, where the parts are visually represented provides a more universal language, but also necessitates powerful computers and a fast network system to not only transfer the data but to work on it concurrently.



Dune concept #1
Front frame gloss black | Rear frame matte black | Grey tint lens

Dune concept #2
Front frame gloss dark bronze | Rear frame matte chocolate| Burnt umber lens

Figure 5. Augmented Reality Glasses, 2011. Renders of 3D Solid Model for Rapid Prototyping by Explore Engage

Augmented Reality (AR) is an emerging technology that allows for the real-time visualisation of CAD over a live video feed. It can facilitate, using immersive stereoscopic head-up displays and haptic devices, the ability for designers to virtually see a CAD model appear immersed in their field of vision so that they can move around it and see it from any angle. Haptics allow the user to seemingly feel and touch the virtual object using three-degrees-of-freedom (3DOF) torque feedback devices. The integration of such technology will allow for the designer to step away from their computers and virtually sculpt or verify a design in much the same way as automotive clay modellers do today. Volkswagen currently employs AR for training of technical experts in the field of car service; the digital projections enable the company to convey the complex technical inner life of the vehicles to the trainees much better than conventional methods. Sydney-based company Explore Engage is developing see-through AR glasses; these devices will tether to smartphones and allow the user to experience AR for a range of applications. Soon such devices and the technology will be prolific in the marketplace, so it is quite plausible that augmented reality will be part of CAD systems in the very near future.

FROM ANIMATION TO ALLEGORY

The discussion of CAD and its evolution cannot ignore the phenomenal development in Computer Generated Imagery (CGI), and its impact across the spectrum of design. In particular, dynamic CGI in the form of computer animation is perhaps one of the most interesting allegorical stories of the phenomenal rate of progress of CAD capabilities, and how computers have transformed an entire industry. The term *animation* perhaps serves as a poignant analogy in the context of this discussion: frame by frame CAD has moved on faster and faster to a point where it appears to be fluid and has come to life.

Figure 6. Puppet ‘No Strings Attached’, 2008. NURBS surface model with realistic photo wood textures, rendered using HDRI. Paul Kouppas

When *Toy Story* by Pixar hit the screens in 1995 a new era in computer animation began. It was the first completely computer-generated feature-length film, and was highly profitable – in comparison with traditionally animated films, the film used far fewer animators and was therefore significantly cheaper to make. The box office takings were also a testament to the compelling story and captivating detail of the film. Making the film took 800,000 computer hours to generate and render well over 100,000 frames, equating to 600 billion bytes of information. Prior to this date, computational hardware would have struggled to produce such a film. A whole raft of full-length computer animated films have followed and CGI animation has long since overtaken traditional animation to become the industry standard. CGI is also extensively used in live-action films and, in many case, the quality is so good it is very difficult to determine whether some scenes in films are real or not. The advertising industry has been quick to see the advantages.

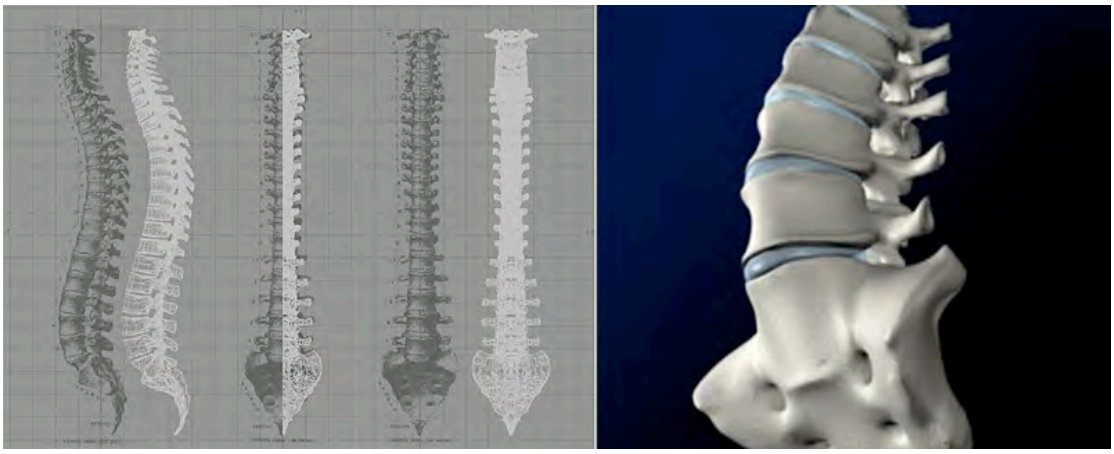


Figure 7. Realistic Human Spine Model 1999. Originally NURBS surface, converted to a polygonal model, materials applied and rendered. Paul Kouppas | Moberg Multimedia

In 3D computer animation a character is modelled, and a representation of the character’s structure, or skeleton, is generated. This skeleton consists of a number of animation variables, or *Avars*, that define the character’s motion. In *Toy Story*, the central character, Woody, had in the order of 700 avars that could be controlled to bring the character to life. Ten years later, *Aslan*, the title character in the film production of *The Chronicles of Narnia: The Lion, the Witch and the Wardrobe*, had as many avars to control his face as Woody had in his entire body. These avars can be considered much like the control points in other 3D parametric models, but interestingly the movement of the points can be programmed to move in certain ways. All of these morph and dynamically bend the 3D mesh of the character, each a reflection of a physical nuance or 'phoneme' to give life to the character. Behavioural properties can be assigned to the avars to define how these control points move – for instance, the way grass wafts in the breeze can be described mathematically and then computer models can be programmed to behave in the same way. This is giving rise to fascinating new disciplines and hybrid areas of design, linking such areas as mathematics, computing, bio-mechanics and biology. Avars can also be controlled through motion capture, whereby an actor wearing a body costume containing numerous reflective marker points acts out the role in front of the camera. The movement of the points is detected and that movement applied to the avars of the CAD model to create life-like movement. This technique has been used very effectively by a number of films, but perhaps most impressively by Weta Digital in their work on *The Lord of the Rings*, *King Kong* and *Avatar*.

FROM ANIMATION TO ARTIFICIAL INTELLIGENCE

A major breakthrough in CGI films was the enormous scale of the battle scenes in *The Lord of the Rings*, where a hundred thousand characters appeared in the panorama. The characters were predominantly produced by CGI, but each behaved with a degree of uniqueness that hitherto had not been produced before. To control and choreograph each character would have been far too time-consuming, and would have also made directorial changes extremely difficult. A solution came from one of the computer graphics software engineers working at Weta Digital, Stephen Regelous, who gave each character a 'brain'. Rather than treating the characters as particles that move in a uniform or predictable way, the characters were given artificial intelligence that allowed them to react and respond to others around them as well as to the environment they were in. Stephen Regelous received an Academy Award for his work, and the proprietary software he developed, *Massive* (Multiple Agent Simulation System in Virtual Environment), has since been used on many other films.

Massive software has also been used in real-life applications, to model behaviour of human crowds, traffic and other ecological systems. For instance, crowd planning and emergency evacuations of buildings and urban environments can be simulated entirely in CAD. This allows for architects and designers to become better informed prior to committing to a final design. It can also save an incredible amount of money save time, and of course help save lives.

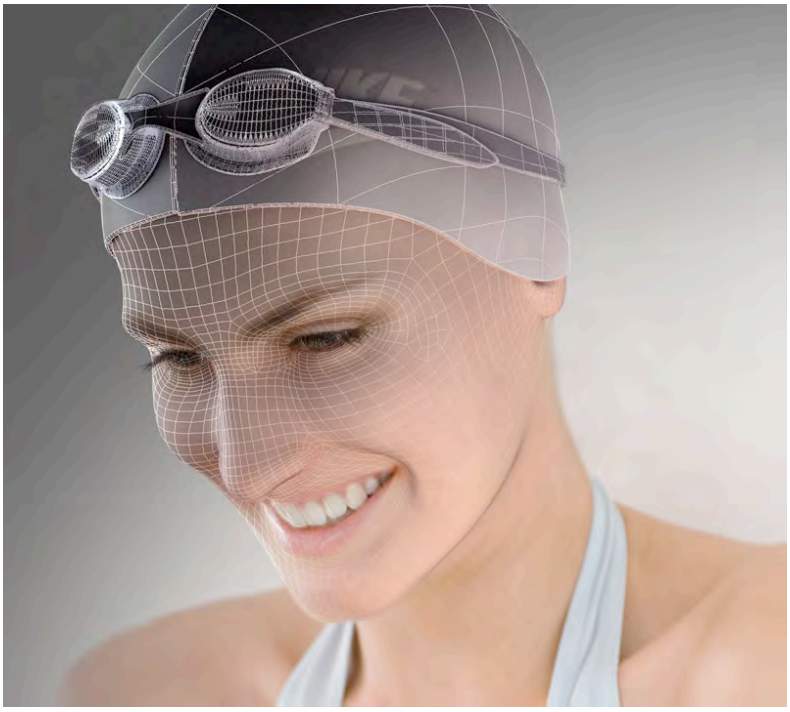


Figure 8. Swimmer with goggles, 2008. Face modelled as NURBS surface based on stock photo, and then converted to polygonal model. Evidence of organic/NURBS surface present in her cap. Model and rendering by Paul Kouppas

Modelling humans, be it their anthropometric form, their dynamic movement, or their behaviour is particularly challenging given the complexities of capturing realistic motion and expression, let alone analyse and synthesise behavioural and attitudinal responses. There are many around the world working on this though, and perhaps in the not too distant future evidence-based avatars will be incorporated into CAD software to help verify, evaluate and even perform the designing for you.

Whilst CAD has changed the way in which designers work, of crucial importance is to ensure that computers are the ones assisting designers in the process of designing. There is a very real danger in being seduced by CAD; that somehow the capabilities of CAD can compensate for a lack of design ability. As with any instrument, to master CAD requires talent and diligence. It requires creative capacity and a particularly capable designer who can use the tool and not be instrumentally designed by it.

CHAPTER SUMMARY

- The way in which CAD has evolved by jumping between disciplines is indicative of the evolution of the design professions themselves. Computers are now increasingly mediating design processes and have changed much of design practice.
- CAD quickly gained a foothold in design because it enabled easy duplication of parts, quick modifications of drawings, the visualisation and testing of models and easy sharing of files.
- CAD models can also be used to guide manufacturing. Linking CAD with Computer Aided Manufacture is referred to as CAD/CAM.

- Knowing which computing tool to use, and when, in the design process is key to addressing today’s design challenges and meeting ever-shorter timescales.
- CAD can help unleash and augment the designer’s creative capacity.
- A knowledge of animation and the ability to ‘stage’ an idea, can facilitate both a better presentation of your designs and can help you incorporate personality, expression or mood in your design ideas.
- In the designing process there continues to be an important symbiotic relationship between tangible models and digital models.
- Today CAD can be used to model complex behaviour such as crowds, traffic or ecological systems.
- CAD and CAM systems have speeded up the designing process and facilitated more fluid conversations and iteration amongst design teams.

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