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Evolution from 2D to 3D

A Design Engineer's Perspective

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Cambashi researches the use of Information and Communication Technology (ICT). Our goal is to understand

- the business reasons that drive ICT investment decisions,
- the technology that addresses these issues,
- the market mechanisms that bring users and vendors together, and
- the impact of deployment of applications and infrastructure.

Our work in the Manufacturing Industry sector has grown from a focus on design engineering to include industrial automation and business systems. The ideas and opinions expressed in this white paper are Cambashi's own, based on our continuous programme of independent research and monitoring of the Manufacturing Industry sector. We wish to thank EDS PLM Solutions for sponsorship of production of this document, enabling us to communicate our analysis in this format.

1 Introduction

From recent studies Cambashi estimates that about half the mechanical and electro-mechanical engineering designers in the world are now using 3D CAD technology, including solid modelling, while the other half are still designing using 2D systems. Recognising that 3D technology is now very well developed, and that the benefits of using it are universally accepted among a broad range of engineering firms, we found this result surprising. Other findings, however, support the conclusion that 3D CAD has not penetrated as deeply as we had expected. For instance, data extrapolated from Gartner and Credit Suisse First Boston reports that 400,000 individual users are expecting to make the change from 2D to 3D over the next few years.

So why is it taking so long? What are the factors causing engineering companies to hesitate in adopting technology that is widely recognised as critical to engineering company profitability? Is making the change considered too difficult, too costly or too risky at the present time? And, if so, are those perceptions based on inadequate knowledge of current 3D technology?

Cambashi has analysed these questions and checked out the experience of some engineering companies who have made the transition from 2D to 3D. We have also examined the technology of recent 'hybrid' 2D/3D mainstream[1] CAD systems to identify how the design of such systems supports easier transition from 2D to 3D than was the case a few years ago.

This white paper presents our conclusions from the perspective of a designer or engineer currently using a 2D CAD system and interested to know whether 3D CAD will make his job easier or more rewarding.

Two companion white papers address the viewpoints of:

- the senior company management;
- the product development manager.

2 Advantages of 3D Solid Modelling

The fact that so many product development companies have stuck with 2D CAD systems so far, even though the advantages of 3D CAD are generally well known, suggests either that the advantages are not understood or not accepted. Well known or not, it is worth summarising briefly what they are.

Although 2D CAD systems allow drawings to be made faster, the output of the design process is what it always was – a set of 2D drawings. For individual components with simple geometry this is fine. But 2D drawing is not an ideal tool for representing the whole of a complex product, even for engineers, let alone customers and subcontractors. Sets of drawings are subject to misinterpretation and ambiguity, leading to errors, late

[1] 'Mainstream' is the term used for the modern generation of volume, Windows-based 3D CAD systems that have recently begun to match most of the capabilities offered by 'high end' Unix based systems.

engineering changes and time lost. Deriving information from drawings to feed downstream processes of engineering analysis, purchasing and manufacturing takes time and, again, is subject to potential mistakes. 2D CAD systems improve drawing productivity, but not a lot else.

In today's competitive climate more and more is demanded of engineers. Their job is to design and engineer products that sell, and their time is too valuable to be spent on draughting. They need new and better tools.

3D solid modelling technology supplies those tools. Using a 3D CAD system, the engineer produces a geometrically accurate, unambiguous, digital product model (or 'virtual prototype') that is utilised throughout product development, manufacturing and assembly. Interacting with the 3D model on screen speeds design thinking, encourages innovation and identifies errors as soon as they occur. The digital product model, allied to the Internet, enables the practice of concurrent and collaborative engineering, providing the basis for design review with customers, planners, manufacturers and subcontractors, and directly feeds engineering analysis and manufacturing software. The result is better products, designed faster.

2D CAD drawing does not disappear in this scenario. The best 3D CAD systems incorporate fully integrated 2D drawing facilities, used in sketching mode to help create the 3D model; and for design documentation in the traditional sense. Dimensioned 2D drawings are often still required by suppliers, contractors and statutory authorities. With a modern 3D system these drawings can be produced virtually automatically from the accurate solid model, delivering a major increase in drawing productivity when compared with 2D CAD draughting, plus assured accuracy. This hybrid 2D/3D technology has removed the 'either/or' nature of the argument, offering the CAD user flexibility in mode of working and offering engineering management a way of ensuring smooth transition into 3D solid modelling.

Quality on time

An Australian manufacturer of heating and cooling equipment had to take over at short notice a sister company's air conditioning line that was suffering from quality problems. With hundreds of products and a six-month deadline the only possible way to carry out the brief in time was to move smartly from 2D CAD to 3D solid modelling, with virtually no training. Design engineers successfully modelled the air conditioning units in 3D, learning the program as they worked. They created solid models of components and assemblies, 'debugged' the designs on screen, generating the 2D manufacturing drawings and parts lists semi-automatically from the 3D models. Management estimated the job would have taken twice as long using their old methods, and the new-found accuracy of manufacturing drawings removed the previous quality problems.

In our experience 3D CAD offers the engineering designer a highly rewarding change of lifestyle. Most design engineers are creative people and 3D CAD is a powerful aid to creativity and innovation. The ability to visually evaluate interference between parts, complicated geometric features, required tolerances, mechanism motion, assembly structure and all aspects of a product's design as it evolves is very satisfying. Designing in 3D is much faster than producing a product definition through 2D drawings, so the designer spends more time on designing and less on

draughting. This, plus the ability to include more engineering and manufacturing analysis within the design loop, produces better products and greater job satisfaction.

Leading 3D CAD systems now incorporate data management capability that organises design and engineering data for on-line access and re-use. Typically only 20% to 40% of a design engineer's time is spent designing, the rest is administrative overhead. Built-in PDM capability minimises that workload, automatically tracks revision status of documents, maintains correct links between parts, assemblies and drawings as the design develops, manages change orders and maintains the product structure so that BOM's are up to date and complete at all times.

Throughput

A 100 person company making custom-engineered food processing machinery had been using 2D CAD for many years but needed to increase the throughput of its design organisation and reduce the scrap rate in manufacture. By installing a 3D solid modelling CAD system with integrated sheet metal design capability the company reduced the design and development time of a deep fryer by 75%, from five months to five weeks. Drawings are now produced from the solid model in minutes and sheet metal parts are 'unfolded' on to the flat automatically, saving many hours of labour and ensuring accurate manufacture.

The primary advantage of 3D solid modelling and 'virtual prototyping' is the increased productivity and effectiveness of the whole product development process, especially the support provided for concurrent and collaborative engineering. For the company this translates into more competitive products, reduced time to market, increased customer satisfaction and enhanced sales. For the product development organisation the primary benefit is reduced product development time – typically half the time taken when using only 2D CAD. And for the individual design engineer it is simply a much better set of tools for doing a good job faster.

3 Using a 3D CAD System

Until a few years ago solid modelling was limited for technical reasons to smaller products and individual components, often with the focus on downstream tool and die making. Modelling of large assemblies was restricted mainly to the automotive and aircraft industries that could afford the investment in large computer systems. The big change recently has been the arrival of Windows-based mainstream systems supporting large assembly modelling. Assembly modellers deliver two key functions: creating logical structures for organising and grouping parts into sub-assemblies and assemblies; and tools for creating mating conditions, rules and parametric relationships between parts. With the arrival of large assembly modelling as mainstream technology an increasing number of companies in the machinery, industrial equipment, consumer products and electronic equipment industries are migrating to 3D CAD, both as a better way of designing and a better way of keeping track of design data. Any complex industrial product involves significant numbers of people working in collaboration. 3D CAD with assembly modelling capability plays a key role in co-ordinating the work of the whole team, being as much an aid for design information management as for the creation of complex geometry.

For the individual CAD user who is unfamiliar with 3D CAD the obvious questions are:

- "How does it work?"
- "Can I learn to drive it?"
- "How can I move from 2D to 3D?"

The answers can really come only from seeing 3D in operation and trying it out. In practice it will be found that operation is intuitive, not surprisingly since most designers carry a 3D perception of what they are designing in their heads, a perception that 3D CAD strongly reinforces. The designer works directly on the image of a 3D solid model, aided by the ability to create conventional 3-view drawings and sections from any angle, at any time, at the touch of a button. Three basic techniques are used to build the model – drawing on construction planes, drawing on existing surfaces, and 'sculpting', using a variety of commands that add and subtract 'material volumes' to and from the model, and slice through it using any defined plane or surface. Various tools provide for creating and modifying curved surfaces and attaching them to surrounding surfaces to create the solid.

This elementary description does not do justice to the powerful range of commands, intelligent workflow aids, automatic modelling features and wizards that a modern 3D CAD system contains. A new user will encounter a very supportive environment but of course it has to be learned. Learning is made much easier nowadays by comprehensive on-line tutorials and in-context help. Remember that it does not all have to be learned at once - it can be taken a few steps at a time. The guideline is to start simple, learn as you go and explore new commands progressively. Then you can become more adventurous.

Making the transition from a 2D CAD system to 3D modelling has been made a lot easier by the recent emergence of hybrid 2D/3D technology in which 2D CAD is fully integrated into the 3D modelling system. As a result the individual user now has a choice of modes of working and the design organisation can arrange for progressive rather than 'big bang' changeover from 2D to 3D. Again, we recommend a step-by-step approach, not trying to abandon 2D working until exploration of 3D modelling has created sufficient confidence to start using it as the primary design tool.

2D and 3D working together

Typical of this situation was a small supplier of special purpose production line equipment for the pharmaceutical industry who faced a demand for a substantially modified version of a previous product, to be supplied, integrated into the line and tested in only six weeks. This was possible only through the use of a newly acquired 3D solid modelling CAD system. In the event, more than 50 new parts and sub-assemblies were designed, drawn and issued in only 10 days.

For the foreseeable future, product development in a 3D assembly modelling environment will still involve 2D drawings, both as a means of creating models and in its traditional role as design documentation. In particular, the designer working on complex products and large assemblies may often find 2D layout drawings useful as an aid to thinking when building assembly models. In practice, of course, many products are modifications of previous ones. In that case it is essential that the 3D CAD system be able to import legacy 2D drawings efficiently into the new 3D model.

By now it should be apparent that 3D CAD systems offer considerable choice in modes of working. Assembly modellers, for instance, enable a 'top down' approach in which design engineers start with system level functions and work downwards, progressively detailing the components and finally defining all the mating conditions, constraints and relationships between parts. The alternative approach is to build the assembly model from component level 'upwards'. In practice, design is likely to take place iteratively in both directions, and each company will determine the best approach to suit its own products, skills and organisation. Whatever approach is adopted, the combination of modern 3D CAD technology with integrated data management will ensure that the work of the whole team, whether at component level or assembly level, will be tightly co-ordinated.

4 What to look for in a 3D CAD system

The first step in understanding 3D CAD is a basic appreciation of the functions that typical systems offer. Today's mainstream 3D solid modelling products are powerful and comprehensive design, engineering and product data management systems with a wide range of productivity features that need to be understood in order to appreciate how the benefits we have discussed come about. Features that make for ease of use and ease of transition from 2D to 3D are of key importance in the present context. The following basic checklist of what to look for complements our general discussion.

Typical mainstream 3D CAD system specification:

- MS Windows-based system for low cost and company wide compatibility;
- a well designed system structure with all functions accessible 'on the fly' in a logical manner;
- a full range of 3D solid modelling tools, logically presented, with well integrated solid and surface modelling;
- hybrid 2D/3D technology, including full 2D drafting and fully integrated 'both ways' conversion between 2D drawings and 3D solid models;
- mixed 2D/3D workflows for assembly layouts and modelling;
- a full complement of productivity aids, including built-in tutorials, wizards that 'automate' frequently required operations, intelligent work flow aids and semi-automatic design tools for commonly encountered tasks such as sheet metal design, welding details, pipe routing and wiring harness design;
- ability to handle large assembly models (100,000 components or more) and to share design work between team members;
- integrated product data management supporting in-process management of design files, engineering change orders, bills of materials and 'where used' reporting;
- customisable engineering libraries for formulas and algorithms, with calculation-driven part modelling;
- animated motion simulation and interference checking;

- a rich set of interfaces to third party engineering analysis, simulation, manufacturing and specialist design software products;
- provision for access to design data by non-CAD users;
- advanced support for collaborative engineering communication, preferably utilising standardised internet and document management technology;
- integrated Web publishing, usable from within the design session.

5 Conclusions and Recommendations

- Modern 3D solid modelling CAD systems mean that engineers spend more time designing products and less time drawing. The result is better, more competitive products, produced faster;
- 3D technology provide the engineer with a more productive and satisfying design environment that increases creativity and innovation, increases the quality of output, enhances collaboration and reduces errors;
- Contrary to some perceptions, 3D technology is not difficult to introduce or to learn, modern 3D systems being replete with 'ease of use' features and intelligent aids;
- Hybrid 2D/3D technology is an important recent development that allows flexibility in mode of working, and step-by-step transition ('evolution') from 2D drawing to 3D solid modelling as the primary design method.