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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 UGS for sponsorship of production of this document, enabling us to communicate our analysis in this format.

1 Introduction

Since we first looked at the issue of migrating from 2D to 3D design, we have found that many companies are using 3D as a stepping stone to a full Product Lifecycle Management (PLM) implementation, even in smaller or mid-sized companies. Improvements in software capabilities together with better packaging and easier deployment have eliminated many of the obstacles to PLM investment by mid-sized companies.

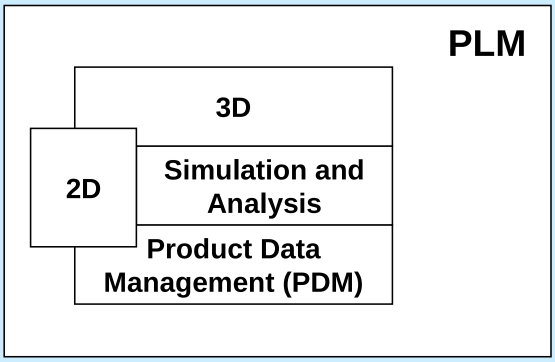
PLM enhances the value of engineering data by integrating design, analysis, workflow and data management, enabling wider and controlled reuse of available information. PLM used to be seen as a technology available only to large companies. A PLM project needed significant IT resources. For all but the largest companies, the technology was previously out of reach.

Now, there is a new situation. Preconfigured applications and affordable pricing put PLM within the reach of all companies. But to achieve the full benefits of PLM, it is essential to be working with 3D CAD data. Cambashi estimates that just over 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.

Use of 3D is a key step towards effective PLM. 3D CAD systems help designers in their own work, and also in collaboration across extended teams. With 3D data, PLM makes engineering information useful to non-specialists, who are not able to interpret engineering drawings, but benefit from product visualisations linked to other product and operational information.

These capabilities are important not only inside a company, but also in interactions with suppliers and customers. Increasingly, PLM is required for a company to be fully integrated into the collaborative procedures of a modern supply chain.

Terminology



In this paper, we use the broad terms "2D" and "3D" to cover both design and manufacturing applications.

We recognise the typical deployment roadmap as above, in which initial investment in 2D is extended with 3D, PDM and, in many cases, simulation and analysis.

We distinguish PDM from PLM as follows. We use "PDM" to describe the more inward looking, engineering centric approach to access control, version management and maintenance of datasets across one or more applications. We use "PLM" to extend this to include a more outward looking, business centric approach which enhances integration of engineering applications, and extends this integration to other business IT systems, supporting technical collaboration between companies.

We also use "PLM" in line with industry practice as an umbrella term, describing the whole product data IT environment.

So why are so many of the world's designers and engineers still using 2D tools? 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 and PLM technology?

This white paper presents our conclusions from the perspective of a designer or engineer currently using a 2D CAD system and interested to know how 3D CAD and PLM will change the job. How will these technologies make the job more effective and more rewarding while encouraging innovation and reducing mistakes?

Two companion white papers address the viewpoints of:

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

2 Advantages of 3D Solid Modelling

2D CAD systems improve drawing productivity, but not a lot else. They allow faster drawing creation and modification, but 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. A set of drawings almost always contains ambiguities. Even well defined drawings can be misinterpreted. Extraction of data from drawings – for example, to feed downstream processes such as engineering analysis, purchasing and manufacturing – takes time and is subject to mistakes.

In today's competitive climate more and more is demanded of designers and engineers. Their job is to come up with products that sell. A very high proportion of total product costs – from materials and manufacturing processes to ongoing support and recycling – are influenced during design, so there is high value in getting design decisions right. When time-to-market is a business critical parameter, quick and accurate design decisions are vital to business performance. Designers and engineers need tools that support and encourage right-first-time, innovative design creation and communication.

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.

3D solid modelling technology is one of 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. Non-geometric data is added to create a digital product model, which provides the basis for design review and directly feeds engineering analysis and manufacturing software. The result is faster, more complete, more accurate consideration of more design options, leading to better products delivered earlier.

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.

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 2D/3D argument, offering the CAD user flexibility in mode of working and offering engineering management a way of ensuring smooth transition into 3D solid modelling.

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. Working with a digital product model enables measurement, analysis and assessment of design options in ways that may not be possible with physical prototypes. For example, imagine studying the duty cycle of a mechanism. A 3D digital product model will allow some components to be made transparent, or a view from inside a casing to be calculated, thus enabling other components to be studied in a way that cannot be achieved using a physical model.

3 Design alone is not enough

Typically only 20% to 40% of a design engineer's time is spent designing. A large proportion of the remaining 60-80% is finding, collating, communicating, reporting and managing related technical and administrative information. This overhead is increasing, driven by increases in:

- product complexity,
- design process complexity, and
- the number of groups participating in the design process.

To free the design engineer from this burden, leading 3D CAD systems now offer both built-in data management, to cover basic requirements, and integrated PDM capabilities, to cover more demanding cooperative design environments. These capabilities minimise administrative overhead by automatically tracking revision status; maintaining correct links between parts, assemblies and drawings as the design develops; managing change orders, and controlling the product structure so that all Bill-of-Materials (BOM) information is up to date and complete at all times.

The combination of 3D solid modelling and PDM drives productivity and effectiveness of the whole product development process, especially in concurrent and collaborative engineering environments, where easy access to up-to-date, shared information is critical for multiple teams.

PLM solutions extend the managed, reliable product data environment provided by PDM to create a comprehensive software environment to capture and manage every aspect of product development – from initial requirements to end-of-life.

For the company these capabilities translate 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.

4 Using the new technologies

Early 3D systems were limited to simple products and individual components, often with the focus on downstream tool and die making. Modelling of large assemblies needed large computer systems and was restricted mainly to the automotive and aircraft industries that could afford the investment. This created an image for 3D which is no longer true. Windows-based mainstream systems support not only component modelling but also large assembly modelling, and these systems are affordable by companies of all sizes.

Assembly modellers deliver two key functions: creation of 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, co-ordinating the creation of complex geometry by the whole team. The integration of geometry with other information - from requirements and design intent to test specifications - gives a solution real value to the product development process.

For the individual design engineer who is unfamiliar with 3D CAD the leading questions, and our responses, are shown below.

"How does it work?"

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.

Assembly models can be created both 'top down' - 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 - and 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.

In some cases, software products in this area provide a combination of wizards, templates and preconfigured workflows that implement best practice distilled from industry. This embodiment of design processes helps automate standard tasks.

"Can I learn to drive it?"

The description above does not do justice to the powerful range of commands, intelligent workflow aids, automatic modelling features and easy-to-use interaction 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.

"How can I move from 2D to 3D?"

Making the transition from a 2D CAD system to 3D modelling has been made a lot easier by the 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

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.

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.

This integration of 2D and 3D is important not only in component modelling, but also in assembly modelling. Reference lines on drawings become reference planes and functional surfaces, from which preliminary 3D space layout can be derived. A "zero-D" approach can allow the designer to define a part structure (assembly, sub-assemblies and components) without being required to define geometry first. Use of parametric capabilities will maximise the extent to which the model can be updated automatically when something is changed. Much like a good dimensioning scheme, it is the skill of the designer that ensures parameterisation is based on reference and datum geometry, and uses meaningful parameters to derive other geometry.

"How do I work with all the non-geometric information?"

Local working practices can standardise the use of the wide range of available options.

Some environments may need only basic facilities. Text annotation connected to models, and design rules built into parameterisation schemes may be sufficient. Naming conventions to link components with other documents could be enough in very straightforward situations.

However, for most companies, especially companies involved in projects with increasing amounts of collaborative work, this is the area in which PDM capabilities become critically important. PDM can manage access, support version control, drive workflows (such as review and approval of Engineering Change Requests), maintain related data, link multiple files and versions into consistent datasets, and provide visibility of the status of items.

To allow PDM solutions to do this, users must follow the access and update processes defined by the PDM configuration. For users who are familiar with direct access to every file held by the computer, this can feel like a constraint. However, when the PDM solution makes it easy to answer a question like "Which assemblies must have their test specification changed when we bring in the new version of this component?" most people become instant converts.

"Can I use analysis tools?"

Although some situations need specialists, it is increasingly possible for generalist engineers to use simulation and analysis software. Of course, individual professionals must decide when they need specialist support. However, improvements in software capability make it much easier for non-specialists to execute routine simulation and analysis procedures, translating 3D data into the required formats, setting up load and simulation conditions, and reviewing results.

5 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, and integrating or leading to PLM capability;
- integrated Web publishing, usable from within the design session.

The use of 3D as a stepping stone to full PLM implementation is an important strategy for many companies as they begin to grow their ability to benefit from new design tools. This makes the PDM and PLM capabilities of a proposed solution significant even if the intention is to focus on 3D design at first. In this context, it is important to consider the extent to which a system offers preconfigured and integrated modules for PDM and PLM. There is usually a time and costs advantage in adapting local working practices to match the industry standard information structures and working practices that are available in integrated modules, even if this requires designers and engineers to make small adjustments to the way they work.

6 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;
- Integrated analysis capabilities allow generalist engineers to do more analysis themselves directly improving overall quality and reducing the need for physical prototypes, while making better decisions about when to call in specialists;
- Integrated and preconfigured PDM and PLM options exist, and can introduce valuable industry standard practice in ways that are easily assimilated by design engineers.

