CADFind 3D Sketch & Search
The Next Step in Design Reuse

1 CADFIND 3D DEVELOPMENT

There are major benefits to be gained from design re-use but a significant obstacle has been that no system existed that made the process of re-use efficient and cost effective. CADFind, which is the product of many years of research and development at Aston University, allows a designer to find existing parts in a way that matches the way designers think – visually. It is integrated into the designer's CAD system, allowing simple 'one click' searches that use the solid model, or 2D sketch that an experienced designer can produce in a few moments. The process is so simple that it can be included as a standard procedure whenever the creation of a new part is contemplated. Maintenance of the CADFind part database is equally simple – a new part can be added to the system with a single click once the CAD model or drawing has been completed thus making it very cost effective to implement and maintain.

Whilst the number of 3D models in existence is extensive, there are probably even more 2D drawings held by companies. This is not only because some firms use 2D systems, which they do, but because of the many older legacy 2D drawings that still exist. Re-use of these legacy drawings will continue to be a significant source of potential savings for many years to come.

The original version of CADFind was unique in dealing with the complex problem of graphical coding and searching of 2D drawings. It has now been developed to handle 3D solid models so that it can provide a dual capability to graphically search for current 3D models as well as legacy 2D drawings. Since CADFind can hold a mixture of 3D models and 2D drawings in the same database, a CADFind search can return matching 2D drawings and 3D models in the same pass. CADFind 3D for Solidworks is tightly integrated into the 3D CAD system and allows the user to perform searches using the models or drawings produced in Solidworks.

2 THE RETRIEVAL PROBLEM

Design re-use is commonly associated with standard components such as fasteners, spring pins etc. and the proliferation of such parts can be controlled by the implementation of preferred item catalogues, whether manual or computerised. Computerised versions which form part of CAD systems go beyond making the catalogue easy to access by also providing CAD models of the components which can then be inserted into the model as required. To help find suitable parts the standard components are parameterised, for example the parameters for fasteners might be thread size, head type, thread length etc. More than this, some systems actually prevent the designer from using components which are not in the catalogue.

However strict this approach, it is ineffective for the many company specific parts e.g. clips, brackets, spacers and pins which, whilst common, are not easily standardised or parameterised. There are many stories of new components being designed when one already

existed which would do the job. Before long there are a number of components, all slightly different, but performing essentially the same task. Each component has its own (different) part number, process route, stock policy, spares record etc. Hence, more significant than the design time are these inevitable downstream activities associated with each component that is designed.

A US Department of Defense Standardisation Program estimates that re-use of existing parts would save $20,000 each time a new design was avoided, or $33,000 if new manufacturing tooling was required for the part. Another American study found that 20% of parts could be re-used unmodified and that another 18% could be used with some modification.

This means that the potential for operational savings is huge. Even applying the lower (20%) figure to a company that creates 6000 new parts a year would mean that 1200 of them were unnecessary. Further, even if the Department of Defense costings were over stated by a factor of 1000%, savings of 1200 x $2000 = $2.4M would be made per year.

Whilst design re-use is seen as "a good thing" and the potential benefits significant, the tools to assist in the process have not changed radically even with the advent of computerisation – they just do the same thing quicker.

Part numbering systems exist in most companies and they can be used to retrieve information about parts. But since these systems exist primarily to provide a unique identity, they offer very limited search facilities. Product data management (PDM) systems do allow searches on other fields, properties or special keywords and most CAD systems allow text searching on the drawing description.

For common company-specific parts text search techniques suffer from a lack of specificity and a risk of ambiguity in the naming practice. It is not going to be easy to find the bracket you want if there are thousands of components with "bracket" in the title. In addition such a search will completely miss those items which are brackets, but are not named as such e.g. support etc. Computerising such a flawed process does little to improve the situation. While rigorous application of naming conventions can improve matters, it does not provide a means of retrieval which matches how designers think. Designers do not think in textural descriptions, they want something that "*looks like this*".

So why do designers and draughtsmen keep designing rather than use existing parts? Where the designer perceives it is easier (even if it isn't) to create a part rather than search for a similar one, component proliferation will result. Developments in computer aided drawing and design systems have continued to make the creation of new drawings even easier, thus exacerbating the problem.

What the designer requires is an easy means of retrieving suitable existing parts that is significantly quicker than the alternative of creating a new one!

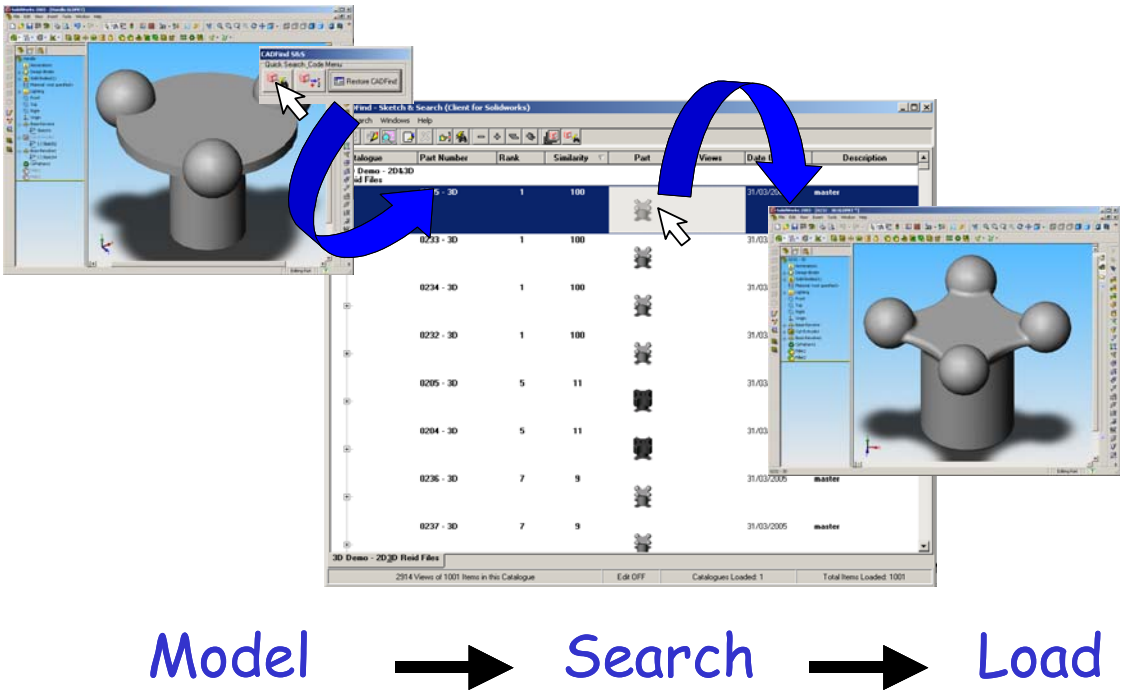
3 KEY FEATURES OF CADFIND 3D

3.1 Simple User Interface – one click searching

To use CADFind 3D, the designer first creates a simplified model in their own CAD system (at present only Solidworks is supported). The simplified model is the first stage to creating a

detailed model and would include key features but omit fillets, chamfers etc. For a trained CAD user this can be done in a few minutes depending upon the complexity of the component.

From the floating CADFind menu the search button is clicked, CADFind then automatically processes the solid model, searches its database and then displays a list of parts in similarity order. With a similar part found the user can right click on this part and load the part into their 3D solid modelling system. The process is illustrated below.



CADFind's unique ability to handle both 3D models and 2D drawing means that the search will also find 2D drawings which match the 3D model.

Even in a 3D environment, searching using a 2D sketch can sometimes be preferable. CADFind handles this just as easily as 3D. The user sketches one or more views of the desired component and, again, just clicks the search button on the CADFind floating menu. As with the 3D model search, CADFind will match on both 2D drawings and 3D parts.

Obviously, better quality models and sketches produce a better initial retrieval performance but equivalent performance can be achieved by using multi-pass searching (see Section 4.3 below).

3.2 Set-up and Running Costs

Successful retrieval of a similar part requires that previous designs have been coded. Conventional drawing retrieval systems that use manual coding can rarely process more than 100 parts/day using skilled engineers. To put this into context, coding 50,000 parts would take 4000 man hours so that it would take in excess of 2 man years (!) of effort to create the

system database (or catalogue). In addition to this, any new component or changes to an existing part will require significant ongoing expenditure to maintain the database. Historically the initial setup and running costs were a significant reason for companies either not implementing such systems or abandoning them later.

In CADFind the coding process is simple, automated and quick (less than 30 seconds); it is achieved in one mouse click of the floating CADFind menu. Therefore after completing a component, the designer could code the 3D model as a standard part of the design release process. Hence ongoing coding costs are minimal.

With one-click coding no skill is required to code at rates of up to 1000 parts per day. Hence a company's range of 3D designs can be coded cost effectively and quickly.

Even those users who create exclusively 3D designs are likely to have a large legacy of 2D CAD drawings. A pure 3D system would therefore be unable to realise the full benefits of design reuse, since all the knowledge represented by 2D legacy parts would be totally ignored. The coding of 2D drawing is generally much more complex than that of 3D models and therefore requires more intelligence both from the computer program and the operator (see Section 4.4 below). For this reason Applied Search Technology Ltd developed and proved their 2D system first. Experience suggests that since legacy drawings are unlikely to be modified and, in many companies, no new 2D drawings will be produced the coding of a company's 2D drawings will be a one-off exercise. AST offer a Bureau Service to speed up the process of creating the legacy database(s) and in many cases this will also prove to be the most cost-effective approach.

Even if 3D modelling is the normal way of working some new 2D drawings may still be produced. This does not mean that the Bureau Service will be needed to code this modest number of 2D drawings. The Master version of CADFind can code 2D drawing perfectly well but a small amount of manual pre-processing of the drawing is needed first. Appropriate editing tools are provided in CADFind's own CAD window to make this a straightforward process. On the other hand, where a company wishes to process its own legacy 2D drawings, or where production of new 2D drawings is the norm, then it may be more cost effective to use the ProMaster version of CADFind which can automate the coding process.

4 HOW IT WORKS

4.1 CAD Integration

CADFind has been developed to allow tight integration with the Solidworks 3D CAD system. Solidworks was chosen for its open Application Programming Interface (API) and popularity in industry. The tight integration enables the designer to create the part within the SolidWorks CAD system and use CADFind to search for matching 3D models and/or legacy 2D drawings straight away.

4.2 Searching

As explained above the user creates a simplified 3D model of the desired component and then clicks the search button on the floating menu. When the search button is clicked the model is automatically processed to generate a computer code which encapsulates the geometric and other features of the component. This is then used to find similar parts in the catalogue.

CADFind uses fuzzy search techniques to calculate the similarity of each part in the database to the target drawings and then presents the best matches sorted in order of similarity. The similarity calculation considers not just the matching features but also takes into account the degree of mismatching too. The computed similarity value or index is displayed to the user.

The complete search process is very quick. Tests on a database with 8000 parts from a collaborating company show that the total search time was less than 6 seconds. Of this, 3 seconds is for coding the source model and 3 seconds is for the scan of the database. The latter comprising re-calculation of all the similarity coefficients, re-indexing and updating the image display. These times were taken from a standard personal computer which was much less powerful than the typical CAD workstation likely to be used by most designers.

Some items may be retrieved which, to CADFind, look similar based on their geometric and other features, but to the user are not. Normally the number of parts involved is very small so that this is not a serious inconvenience for the user, who can simply ignore them. In this way the final arbiter of similarity is the user. This is how it should be because similarity is always context dependent and thus can be said to be 'in the eye of the beholder'.

4.3 Multi-Pass Searching

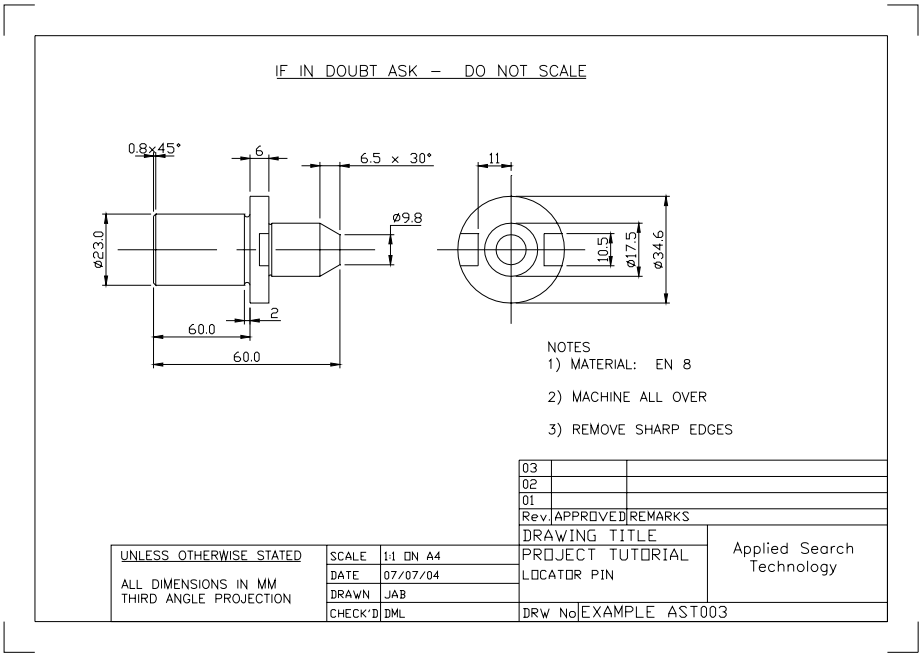
Depending upon the level of detail in the model, the initial search may only return a limited number of similar items even where there are many matching items in the database. However, to achieve a better performance it is not necessary for the user to spend valuable time adding more detail to the sketch or 3D simplified model. The rapid searching time of CADFind (it can search 28,000 views from 8000 parts in under 3 seconds) means that a multi-pass search technique can be used to achieve a retrieval performance from a simplified model equivalent to that of a detailed model with minimal effort on the part of the user.

The process works as follows: from the items returned in the first pass the user selects the most similar part listed and then uses that item as the target for a second search. As the selected item is a fully detailed part, the second pass will usually return many more hits. Since the search times are so short, the process can be repeated several times to further refine the search.

4.4 Coding

CADFind is based on part coding systems which are a proven technology, often called Group Technology codes. The components in CADFind's catalogue are therefore stored as a code which encapsulates the geometric and other features of the component. This code employs a simple binary structure to indicate the presence, or absence, of a property and this structure helps the system achieve the very quick and efficient searches described above.

Contrary to many people's expectation, coding of 3D models is relatively straightforward compared with 2D drawings. Current 3D CAD models have a certain amount of "intelligence" embedded in them. For example the assembly/part hierarchy, geometry, features and the relationships between them are all explicitly defined in the model and thus do not have to be inferred. By comparison, 2D models are generally "dumb". Component features such as holes, slots etc are not explicit within the model; the drawing is only composed of simple entities e.g. lines, circles, arcs etc. The CADFind coding process for both types of model is currently the subject of patent applications in Europe and the United



Typical multi-view engineering drawing

States.

4.5 Coding Legacy Drawings

Typical engineering drawings of a component comprise a number of entities in addition to the basic geometry, for example in the drawing shown a drawing border, textural descriptions, dimensions and machining marks are all apparent. To code the geometrical views of the drawing requires that all this superfluous engineering data is first removed. To do this manually can be time consuming and is the major cost factor in processing 2D drawings. Such removal is not required for 3D models.

Applied Search Technology Ltd have developed computerised techniques that “filter” the drawings of unwanted entities leaving behind just the geometry required for view processing and coding. These features are only available in the ProMaster version of CADFind. The filter settings have to be tailored to a particular company’s drawings and a certain amount of initial testing is required before the process can be applied with confidence. To do this effectively requires the user to go through a short learning curve to gain the appropriate level of experience in applying the technique. It is also necessary that new 2D drawings are produced using a set of simple layer-based conventions. These requirements can be readily justified in companies that routinely produce 2D drawings but for those who have moved exclusively to 3D it is less sensible as the specialist 2D coding software, training and experience would be redundant once the 2D database had been created. For that reason AST provide a bureau coding service that is normally cheaper and quicker for most companies than doing the coding themselves.

5 CONCLUSIONS AND FUTURE DEVELOPMENTS

Part re-use is an important way of saving very substantial costs that have been estimated at over $33,000 per part and is particularly important for companies that generate a large number of non-standard or specialist parts and assemblies.

CADFind is a unique system for finding parts easily and quickly whether they are 3D models or 2D drawings. Because it matches parts on the basis of shape and geometry, rather than crude text descriptors, it works the way designers think. The intuitive ease of use offered by tight integration with Solidworks makes it quicker for a designer to find an existing part than to design a new one! For the first time a solution is offered to the part re-use problem that can be applied to all types of engineered component and a wide range of industries.

The system is the product of many years of research at Aston University in Birmingham, U.K. This work has focused on producing a system with excellent retrieval performance combined with very low implementation and maintenance costs. Future developments will continue to extend the CADFind line of products by integration with more CAD systems as well versions to suit in other types of application.