CADFind – Design Retrieval
The Comprehensive Solution

1 CADFIND DEVELOPMENT

There are major benefits to be gained from design reuse 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 (3D or 2D) 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.

While the number of 3D models in existence is extensive, there are probably even more 2D drawings held by companies, not only because many firms continue to 2D systems, but because there is a large number of 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 a stand alone system and unique in dealing with the complex problem of graphical coding and searching of 2D drawings. The system now been developed so that it handles 3D solid models and is tightly integrated with 3D and 2D CAD systems.

From with their own CAD system (3D or 2D), the user can easily retrieve parts whether they were created as 3D solid models or 2D drawings. These developments provide increased search capability combined with ease of use.

Legacy drawings are not just confined to CAD produced computer drawings; many are held as traditional paper drawings or as is often the case, scanned images of these drawings. The 2D capability of CADFind combined with modern scanning technology enables these drawings to be held within in the part database just the same as computer produced parts. The user searches in just the same way using either a 3D solid model or 2D sketch from within their own CAD system. If desired, the scanned part can be used to find similar parts.

2 THE RETREIVAL PROBLEM

Design reuse 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 e.g. for fasteners the parameters 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, pins which, while 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 Defence Standardisation Program[1] estimate 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[2] found that 20% of parts could be re-used unmodified and that another 18% could be used with some modification. More recently, Kevin Ison[3] of AutoDesk said that "in conversations with customers over a range of manufacturing sectors we've learnt that anywhere from 60-90% of product designs are used again"

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.

While design reuse is seen as “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 when there are thousands of components with bracket in the title (as well completely missing 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.

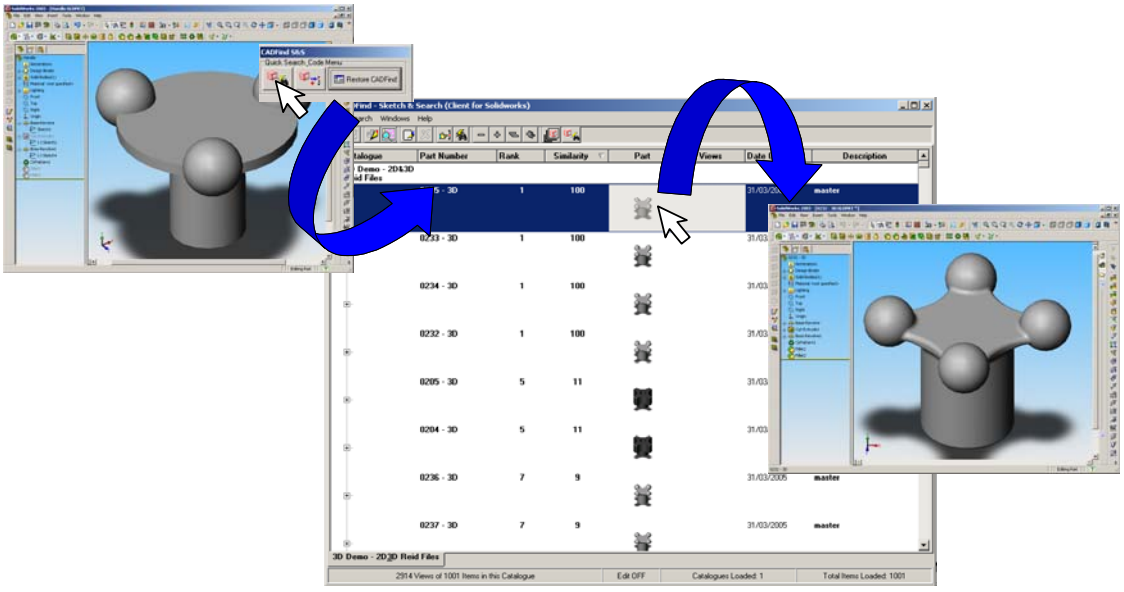
What the designer requires is an easy means of retrieving suitable existing parts that is significantly quicker than the alternative of creating a new one!

3 KEY FEATURES OF CADFIND

3.1 Simple User Interface – one click searching

To use CADFind, the designer first creates a simplified version of the part in their own CAD system (a solid model in a 3D system and sketch in a 2D system). The simplified part is the first stage to creating a detailed model or drawing 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's then automatically processes the solid model or sketch, 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 CAD system. The process is illustrated below for a 3D solid modelling system. If a 2D system were being used, the engineering drawing could be loaded.



CADFind's unique ability to handle both 3D models and 2D drawing means that a search using a 3D model will also find 2D drawings and conversely a search using a 2D sketch will also find 3D solid models.

Even in a 3D environment, searching using a 2D sketch can sometimes be preferable. To do this, CADFind doesn't require the user to switch to a 2D CAD system, they can just sketch one or more views in the 3D system and click on the CADFind floating menu as before. 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 How It Works 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[4]. 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 on-going 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 on going 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 current range of 3D designs can be coded cost effectively and quickly – especially compared with conventional manual coding.

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 How It Works below). For this reason Applied Search Technology Ltd developed and proved their 2D system first. Where a company is predominately 3D focused, legacy drawings are unlikely to be modified and no new 2D drawings produced, hence 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) which in many cases will also prove to be the most cost-effective approach.

Where 2D drawings are the norm or where a company wishes to process its own legacy drawings, the ProMaster version of CADFind has the facilities to automate the 2D coding processes.

It is realised that even where 3D modelling is the normal way of working that some new 2D drawings may 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.

Traditional paper drawings can be added to the CADFind database but the processing involved means this has to be a Bureau Service. The drawings need to scanned before they can processed by AST. Once processed however, the drawings can be search just the same as computer produce parts.

4 HOW IT WORKS

4.1 CAD Integration

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

4.2 Searching

As explained above the user creates a simplified model of the desired component and then clicks the search button on the floating menu. When the search button is pressed, 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 a fuzzy search technique 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 process is very quick. Tests on a database with 8000 parts from a collaborating company show that the total time was less than 6 seconds. Of this 3 seconds is coding and 3 seconds is processing of the database comprising re-calculation of all the similarity coefficients, re-indexing and updating the image display. These times were taken on a standard personal computer which was much less powerful that the typical CAD workstation likely to be employed by most engineers.

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. If too exacting a comparison was set then possible candidates parts might not be presented to the user; what is important is to identify as many as possible of the good candidates. In this way the final arbiter of similarity is the user, which is how it should be because 'similarity' is in the eye of the beholder and is always context dependent.

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 rough 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 from the catalogue, it is detailed part, hence the second pass is done as though the user had created a fully detailed model instead of a rough one. The quality of the results is usually much higher and normally a full range of ‘hits’ are returned but, exceptionally, the

process can be repeated 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 a patent application in the Europe and the United States.

4.5 Coding Legacy Computer Drawings

Typical engineering drawings of a component comprise a number of entities in addition to the basic geometry, for example in the drawing shown below a drawing border, textural descriptions, dimensions, machining marks etc. are all apparent. To code the geometrical views of the drawing requires that the superfluous engineering drawing data is 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 has developed computerised techniques that "filter" the drawings of unwanted entities leaving behind just the geometry required for view processing and coding. The settings of the filtering requires tailoring to the particular company's drawings and a certain amount of initial testing before the process can 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, this layer filtering is only available in the ProMaster version of CADFind.

The above requirements can be readily justified in companies that routinely produce 2D drawings but for those who have moved to exclusively to 3D it is less sensible as the ProMaster 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.

Even where 2D drawings are the norm, the practices used to create existing drawings may mean that significant effort is required to make them suitable for processing by the ProMaster version. In this situation it would be more cost effective to use the bureau service where additional filtering techniques can be applied. The service would only be required once, as the implementation of set of simple layer-based conventions would allow the ProMaster to be used for coding future drawings.

4.6 Coding Legacy Paper Drawings

As already stated, the coding of paper drawings is only available as a bureau service. This is

because advanced processing techniques are required. The drawing must first be scanned by the user to an image file (e.g. BMP, JPG) and then processed by AST to produce a vectored drawing file. The limitations in current conversion techniques mean that much of the entity definition is lost such that the filtering required to removed unwanted entities has to go beyond that required for computer drawings. Once filtering is complete the drawing is coded in the normal way. Even with the application of advanced filtering techniques a small amount of unwanted entities might be left. However, the robustness of the CADFind coding and search technology mean that a few unwanted entities has little effect on the overall retrieval performance.

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, 2D computer drawing or paper drawings. We are not aware of any other system in the world (commercial or research) that can do what CADFind can. It works the way engineers do and makes it quicker for a designer to find an existing part than to design a new one! Tight integration with 3D and 2D CAD systems makes it intuitive for designers to use as a normal part of their every-day work.

The system is the product of many years of research at Aston University and that has ensured that excellent performance can be combined with very low implementation costs.