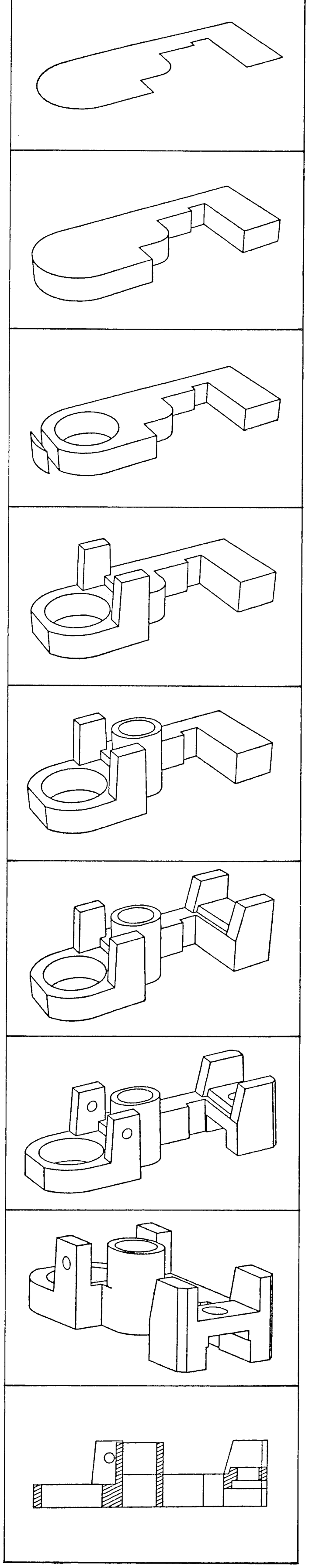
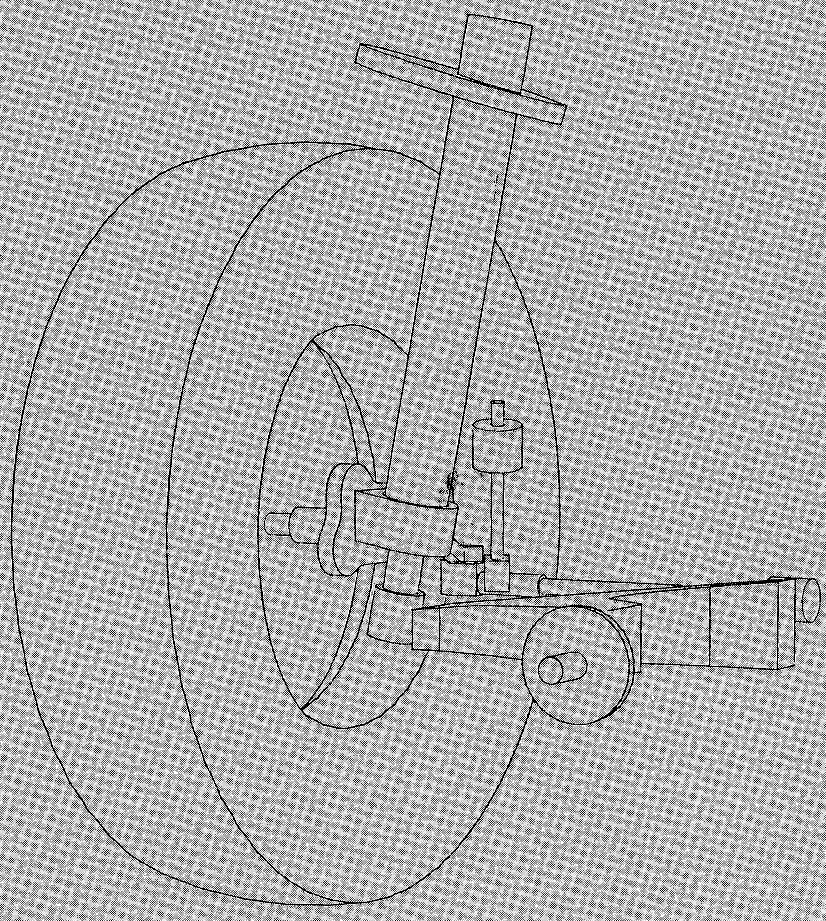


ROMULUS

solid geometric modeller



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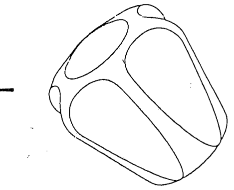
ROMULUS: a solid geometric modeller



In many areas of industry there exists a growing need for methods of processing information which is related to the shape of mechanical components. An important reason for this stems from the increased use being made of computers in design and manufacturing processes.

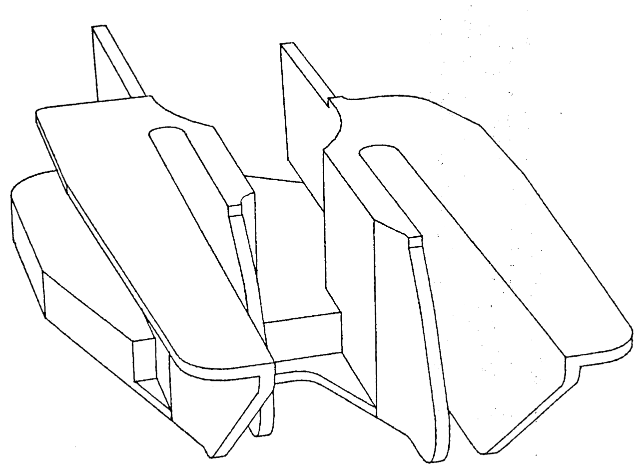
The conventional way of conveying shape information in the form of engineering drawings has serious drawbacks in connection with the use of computers. Not only are drawings usually unsuitable for direct entry to computers, but they depend upon human interpretation to recognise three-dimensional solid shapes from combinations of two-dimensional projections.

Computer drafting systems can be extremely effective in speeding up the production of engineering drawings, but in general these systems choose a form for representing shape information within the computer which is biased towards drawing production.

For general computer utility it is necessary to adopt a form of shape description which is neither biased towards particular applications nor dependent upon human assistance for interpretation. Thus a method is required which describes three-dimensional solid shapes completely and unambiguously. Systems having this property are generally referred to as *Solid Geometric Modellers* and the stored definitions as *Models.*

Romulus is a solid geometric modeller. First introduced by Shape Data in 1978 and now substantially enhanced, it places a tool in the hand of the engineer to model a very wide variety of component shapes and to perform geometric computations on them.

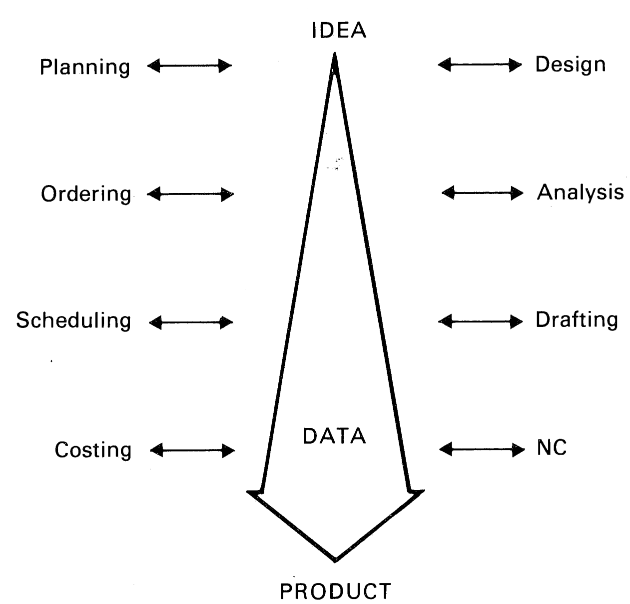
As shape information forms only part of the complete description of a component or assembly, Romulus data structures are designed so that non-geometric information such as material type, surface finish, part numbers, screw thread details and so on may be incorporated into the model. Thus complete product descriptions may be built up in the computer.



Data flow

Romulus models component descriptions in a very general manner which is independent of any particular application. Thus a single universal product description can be accumulated as a product proceeds from initial design to manufacture, providing a consistent source of information for everyone working on a product.

Contrast, for example, conventional NC languages which are used to capture geometric information for a single application — NC machining. With Romulus it is no longer necessary repeatedly to input geometric information for separate processes as the one Romulus model can serve as the common source of information for many processes. The flow of common data provides the thread that links the interdependent processes which culminate in manufacture.



Processes interacting with a product database

Since the model is maintained in a database, it can be associated with other stored information. Thus component lists, catalogues etc. which normally use part numbers or references to drawings can have explicit references to the model of the component itself. This allows a more unified approach to such things as costing or quantity estimation since all aspects of the component, its weight, material, or availability can be brought together in one database.

Possibly the greatest benefit of the one database is the reduction in errors so commonly made when data is prepared manually for passing between departments, or when it is generated from separate, possibly inconsistent, databases. The result is a saving in cost, and it derives from the use of consistent, up-to-date information.

Romulus system

Romulus provides a vital service for the building and interrogation of product databases. It may be used stand alone, or built into other systems. This is illustrated below with six connections to Romulus:

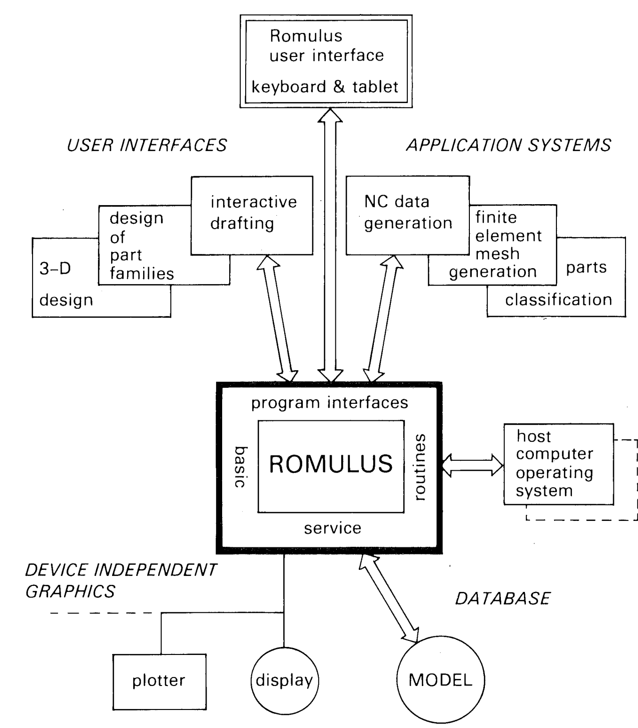
DIRECT USER INTERFACE: a powerful, general purpose set of commands for building, interrogating and manipulating component definitions.

USER INTERFACES: component definition facilities tailored to particular industries and to particular styles of working which have evolved in individual companies. So far interactive drafting interfaces have proved the most popular.

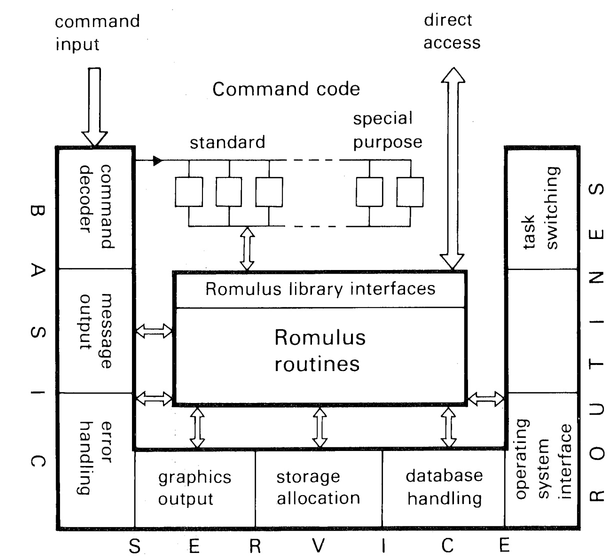
APPLICATION SYSTEMS: these make use of stored component definitions. They may also add information to them.

DATABASE: provision is made for interfacing to a variety of data management systems besides Romulus's own.

DEVICE INDEPENDENT GRAPHICS: drawings from Romulus's range of picture generating facilities may be output to any type of graphical device.



Looking in more detail the Romulus system structure is seen as shown below. The system may be interfaced either by communicating via the command input and message/graphics output channels, or by making direct calls to a Romulus subroutine library.



ROMULUS ROUTINES: the heart of the system, being the total set of routines for building, interrogating and manipulating models.

COMMAND CODE: Romulus provides a standard set of driving commands (the Direct User Interface). Special purpose commands tailored to particular needs may readily be added.

ROMULUS LIBRARY INTERFACES: these provide a direct programming interface for calling routines in the Romulus library. Two levels of the library are offered:

USER LIBRARY for implementing new special purpose commands;

OPEN LIBRARY for embedding Romulus modelling functions within other software systems.

BASIC SERVICE ROUTINES (AOS): these provide the environment in which Romulus operates. Collectively the routines are known by the name AOS. The essential task when transporting Romulus from one computer to another is to transfer AOS.

Romulus is written in standard ANSI 66 FORTRAN and currently runs on Prime, VAX and IBM (MVS) computers. Shape Data is pleased to consider transfer to additional machines.

Modelling

Romulus is a fully three-dimensional system modelling all components as three-dimensional solids.

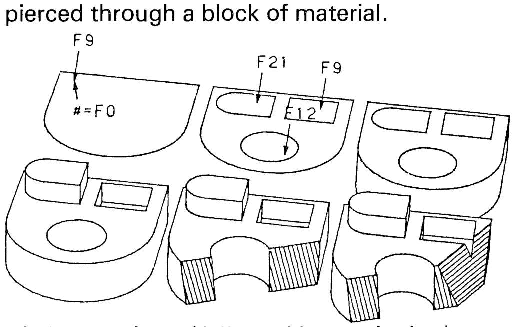
Typical engineering components, whether machined, welded, forged, cast or moulded tend to have a (possibly) large number of faces taking different geometric forms. Planar and cylindrical faces are particularly common though many others are found including cones, spheres, toruses and general sculptured surfaces. Currently Romulus handles objects with any number of faces which may be planar, cylindrical, conical, spherical or toroidal.

Internally, the solid shapes are stored as explicit representations of the bounding faces, edges and vertices. The carefully structured representation separates topology from geometry. Topological data gives the relationships between faces, edges and vertices (for example, which faces meet at a vertex), while the geometrical data gives the form of each face and edge. Available forms for faces are listed above; edges may be straight, conic sections, or other planar and non-planar curve types found at intersections between the various face types.

Romulus can model several disjoint objects simultaneously. Thus different parts of a single component can be built up separately, or the various components of an assembly handled together.

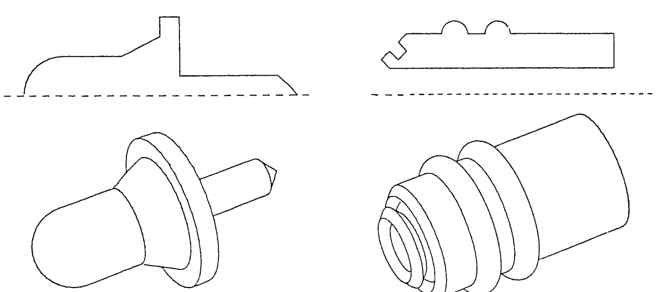
While shapes are being constructed by the execution of Romulus commands, the system ensures consistency of the model (all shapes represented obey Euler's rule). This greatly contributes to system robustness.

A variety of operations is provided for constructing objects. At the most basic level edges may be constructed one at a time, with faces being formed as edges close to form loops. At a higher level the LIFT operator allows an area defined by a perimeter (itself defined in terms of lines and arcs of circles) to be raised or lowered. An associated 'pierce' operator allows passages, including holes, to be pierced through a block of material.



LIFT operations (followed by sectioning)

With the SPIN operator either an open or closed profile may be spun around an axis to form a solid of revolution:

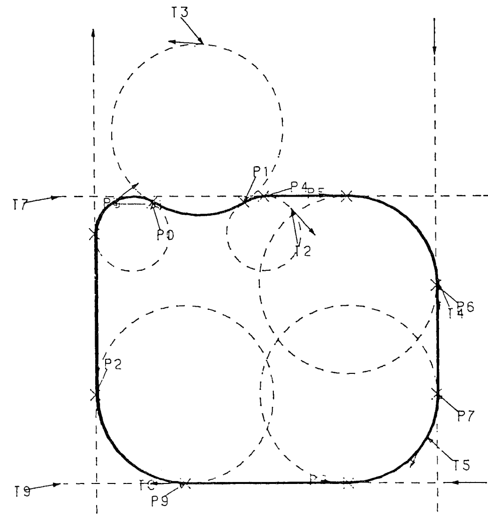


SPIN operations

The LIFT and SPIN operators are proving particularly convenient when interfacing Romulus to interactive drafting systems.

Construction lines

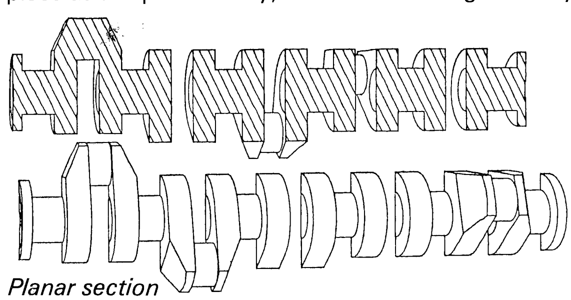
A construction line facility available in both 2- and 3-dimensions allows geometric data to be computed via graphical operations (analagous to ruler and compass but with all the geometric curve and surface forms of Romulus available) ready for the construction of bodies.



Construction lines

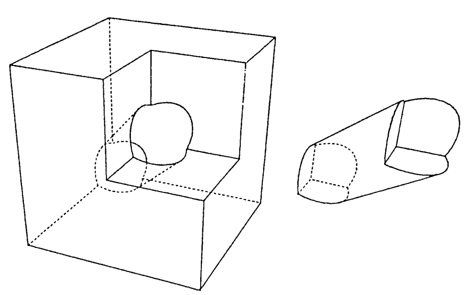
Sectioning

Automatic sectioning is a powerful feature. Romulus computes the intersection between any body or group of bodies and any plane. When this results in bodies separating into two or more pieces, the system retains each piece as a separate body, as well as the original body.



Planar section

In an exactly analogous way cylindrical sections are available using any infinite cylinder as the sectioning surface.



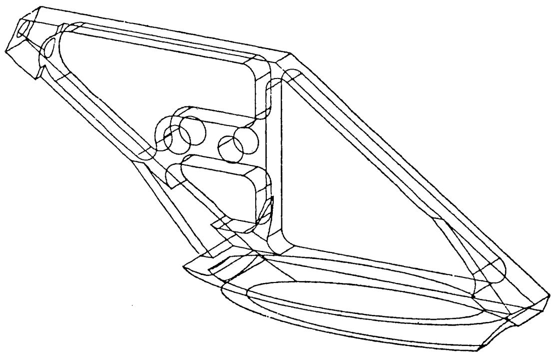
Cylindrical section

Sections are used in the generation of engineering drawings, for inspection at an interactive display as design proceeds, for sculpting (cutting portions away or 'drilling' holes), for interference checking by visual inspection and so on.

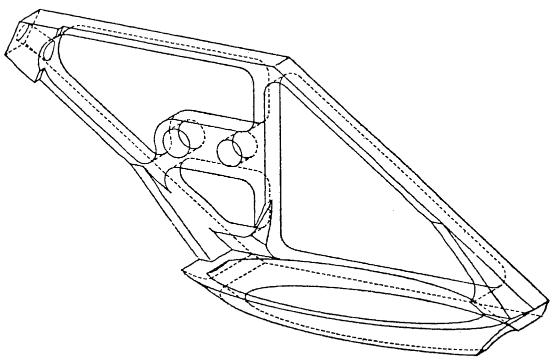
Visualisation and drawing

Romulus allows users great flexibility in specifying how 2-D pictures of 3-D models are to be drawn. Amongst the variety of drawing styles available are:

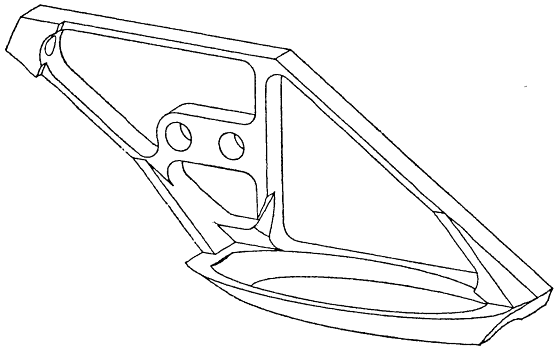
Wire frame:



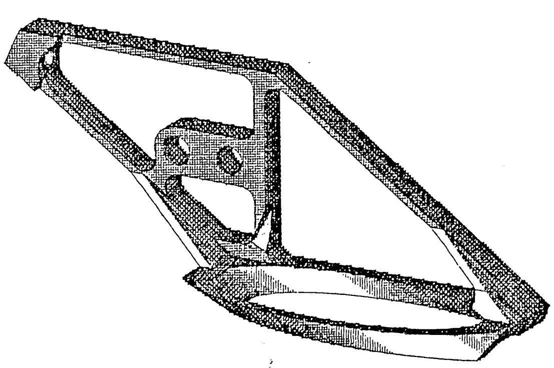
Local hidden line (with hidden lines dotted or absent):



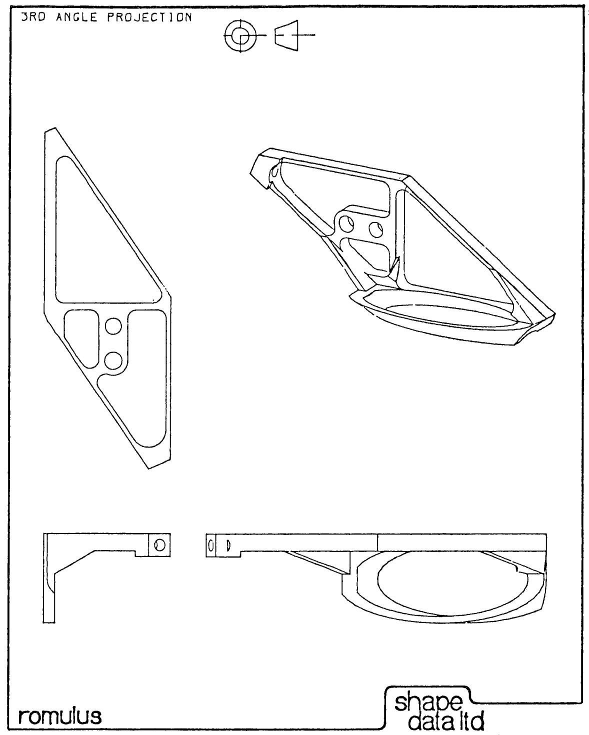
Full hidden line (with hidden lines dotted or absent):



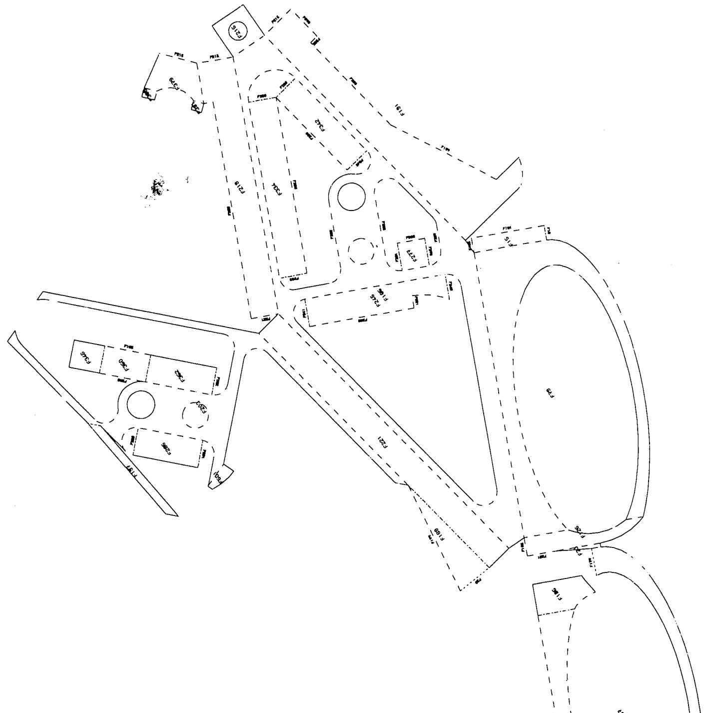
Greyscale

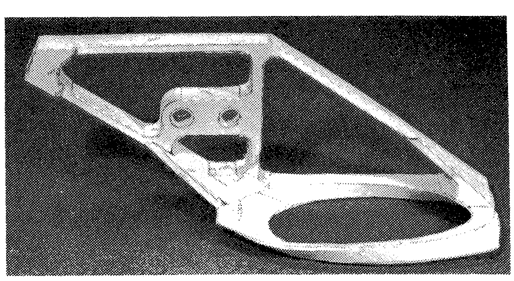


Orthgraphic first or third angle projections:



'Unfolded' — an object is plotted ready for folding and glueing into a paper or cardboard model:





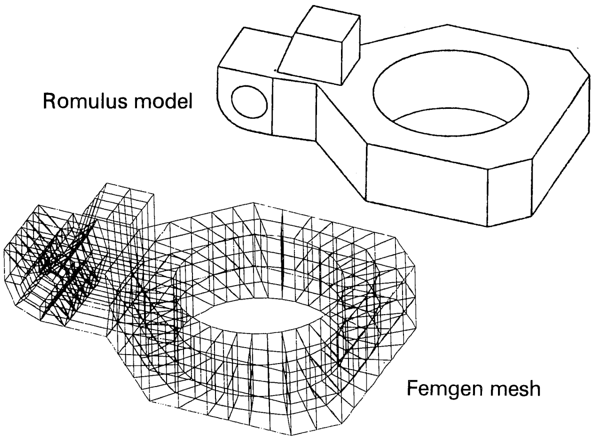
Example is headshell for Cranfield pickup arm.

Application systems

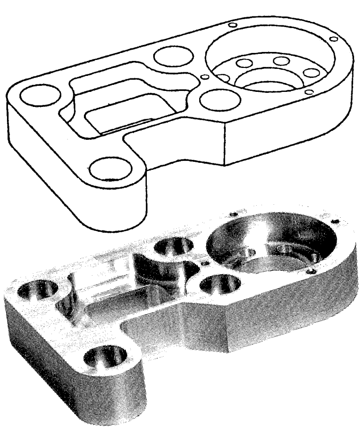
Besides Romulus's comprehensive modelling facilities and robust software design, the ability to interface the system to other software has been a key factor in its selection by industrial companies. Several have incorporated it into their own in-house CAD/CAM systems.

In addition, two CAD/CAM turnkey system vendors have so far chosen Romulus: Ferranti-Cetec Graphics Ltd of Edinburgh for their CAM-X system, and Contraves AG, Zurich for their CONCAD system.

Examples of interfaces from Romulus to well known application systems are to the FEMGEN finite element mesh generator:



and to the CADCentre's GNC graphical part programming system (this Romulus/GNC example is taken from the CAM-X system):



These developments clearly demonstrate the use of solid modelling techniques in the integration of independently developed software systems. They make the integrated data flow method of working described earlier a reality.

Mass properties

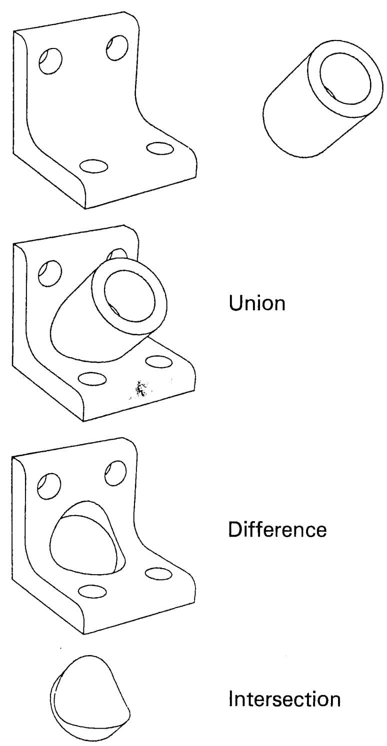
Many design decisions depend upon one or more of a component's mass properties. For any component shape Romulus will compute:

- surface area
- volume
- centre of gravity
- principal axes
- moments of inertia about any axis

This allows a designer to go rapidly around the design loop changing shapes and measuring mass properties until an optimum is reached.

Boolean operations

Perhaps the most powerful single facility in Romulus is that for performing set operations on bodies. Union, intersection and difference operations can be performed on any bodies, providing a universal method of constructing and modifying models.



This facility can be used to construct models by combining bodies, including those produced by LIFT and SPIN operations. Its numerous other applications include: die and mould design, interference checking, complex sectioning, and simulation of machining operations.

Component in front cover design sequence courtesy Messerschmitt-Boelkow-Blohm.

EVANS & SUTHERLAND shape data ltd

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