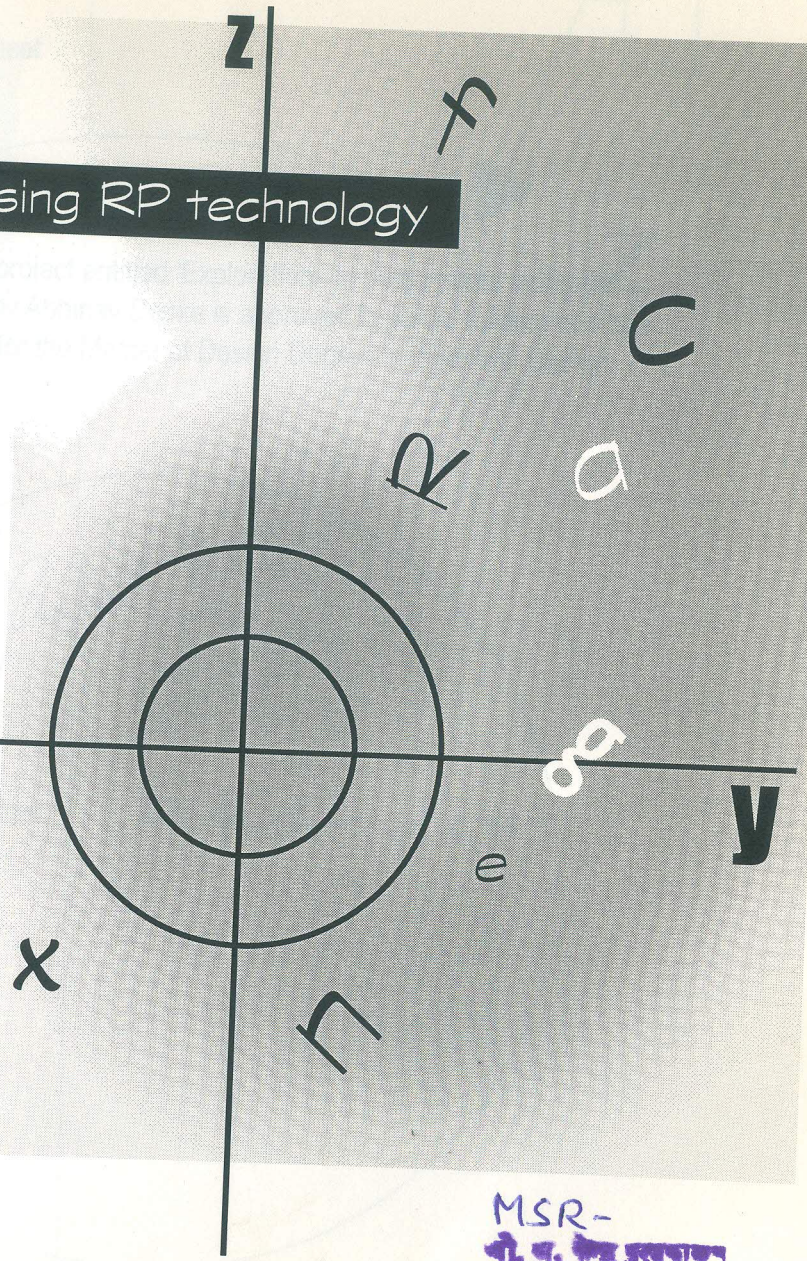


Explorations in bottle forms using RP technology

by
Abhinav Dapke

Guide
Prof. V.P. Bapat

Industrial Design Centre
Indian Institute of Technology
Bombay - 400 076



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48th PD/96-98 Batch

SPECIAL PROJECT

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Approval sheet



The special project entitled 'Explorations in bottle forms using RP technology' by Abhinav Dapke is approved in partial fulfillment of the requirements for the Master of Design Degree in Industrial Design

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Guide

Babbar V

Internal Examiner

12.6.98

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Acknowledgment

I am greatly indebted to my guide Prof. V. P. Bapat for his guidance and support at every stage of the project.

I would like to thank my friends Natraj, Tushar, Ashwin, Amit and Utkarsh for their help.

I also owe my sincere thanks to the IDC faculty and staff, to my batchmates who have encouraged and helped me throughout the course of the project.

Abhinav Dapke
96613010



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Contents

- Introduction
- Application of RP
- Classification of RP systems
- Fused Deposition Modeling (FDM)
- Geometric Modeling
- Feature-Based Model
- RP process
- Initial explorations
- Analysis with respect to supporting elements about Fragrance bottle
- Form explorations in RP

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Introduction

Introducing new products at ever increasing rates is crucial for remaining successful in a competitive global economy, decreasing product development cycle development cycle times and increasing product complexity require new ways to realize innovative ideas. In response to these challenges, industry and academic have invented a spectrum of the technologies that help to develop new products and to broaden the number of product alternatives.

Most designers agree that "getting physical prototypes fast" is critical in exploring design concepts. The sooner designers experiment with new products, the faster they gain inspiration for further design changes.

The key idea in rapid prototyping is the decomposition of a difficult problem of manufacturing a complex 3D component into several simple problems of manufacturing its 2D slices. It involves cutting the computer model of the complex 3D component into thin slices which are physically realized in some manner. These slices are stacked and joined, giving us the required physical prototype. During the **Art to Part** conversion in RP, none of the traditional manufacturing steps such as process planning, tool design and

Application of RP

movement of material for machining are required. What required is only designing the part and generating with the help of software (using different operations).

For Designer

Designer always prefer to present form ideas in mock-up models or prototype of product, for final presentations. Quick RP models become very handy for this purpose. With RP technology, several different variations in design models can be made simultaneously and the best one can be selected.

Other applications

Models for market research

Rapid tooling

Tender model

Wind tunnel model

Model for stress analysis

Medical application

One of the broadest ways of classifying RP systems is by the initial form of the material.

Classification of Rapid Prototyping Systems

On this basis, the systems can be classified as:

Liquid-based Processes: Liquid-based RP systems begin with their material in a liquid state. Through a process commonly known as curing, the liquid is converted into a solid state. The important processes under this category are Stereolithography (SLA) and Solid Ground Curing (SGC).

Solid-based Processes: The material in these processes can be either in the form of a wire, a roll, laminates and pellets. The important processes under this category are Laminated Object Manufacturing (LOM) and Fused Deposition Modeling (FDM).

Powder-based Processes: These processes use powder in grain-like form. Principal processes are Selective Laser Sintering (SLS) and Three Dimensional Printing (3DP).

Fused Deposition Modeling (FDM)

Extruding freeform shapes was developed and commercialized by Stratasys, Inc. (U.S.). This approach, called Fused Deposition Modeling, deposits a continuous filament of a thermoplastic polymer or wax through a resistively heated nozzle. An explanatory sketch of the FDM process is shown in Fig. 1-1. The material is delivered as a wire into the extrusion head and heated to slightly above its exits the nozzle. It is possible to form short overhanging features without the need for explicit support. In general, however, explicit supports are needed. These are drawn out as thin wall sections that can easily be removed upon completion.

Materials

The aim of RP is to rapidly produce product. At the moment, this product is made, for the most part, of inferior material that permits the user to show notion, or perhaps generate a few other parts suitable for limited testing.

Material: ABS

Strengths

Variety of materials can be used and the material change over, which involves only changing the head, is very fast and simple.

No post-curing is required.

The part building can be carried out unattended. The material has a large shelf life and remains unaffected if not removed from the packing provided.

Weaknesses

Surface finish and delicate features are inferior to other processes.

The process is slow on the bulky parts.

The strength is low in the vertical direction.

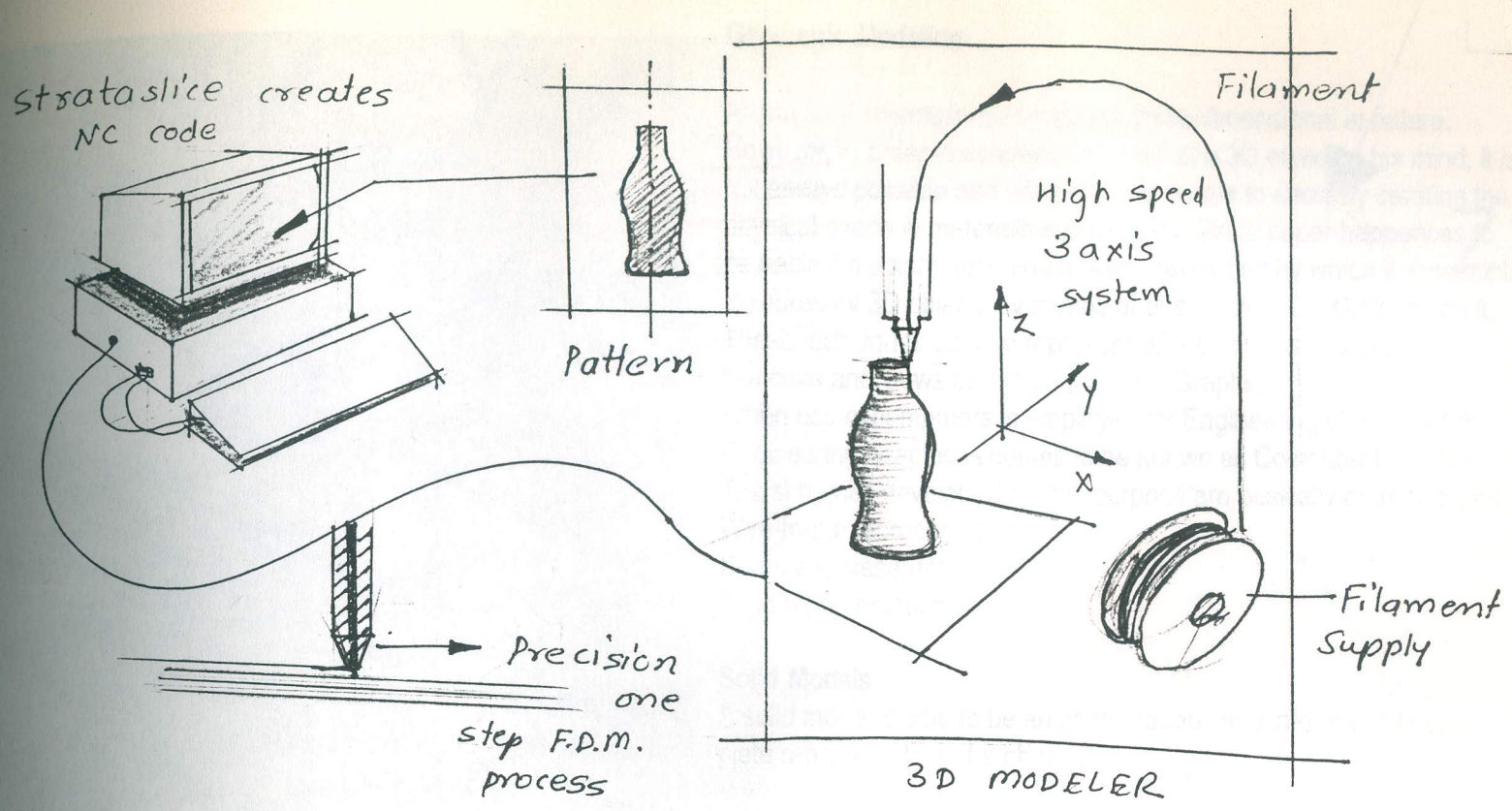


Fig. 1-1 Schematic of the FDM process.

Geometric Modeling

All physical objects in the world are three dimensional in nature. However, in order to convey one's idea of a 3D object in his mind, it is not always possible and often not practicable to show by creating the physical shape in materials such as clay. Since paper happens to be easiest medium, techniques were developed by which it is possible to represent 3D objects by means of one or more 2D sketches on it. These techniques used to represent 3D object in terms of 2D sketches and views called Engineering Graphics.

When use of computers is employed for Engineering Graphic work, Engineering Graphics comes to be known as Computer Graphics. The schemes developed for this purpose are basically of three types:

Wire-frame representation

Surface representation

Solid representation

Solid Models

A solid model is said to be an unambiguous and informatively complete representation of a physical object.

Solid Models Representation

Constructive Solid Geometry models (CSG)

Boundary Representation models (B-Rep)

Feature-Based models

Spatial Decomposition models

The word features refers here to the manufacturing features such as holes, slots, bosses etc. The dimensional are always stored as parameters inside this models. If a hole is to be called a hole, the full

Feature-Based Models

circular cross-section of it must be within the object. Therefore, the parameters of any feature can not take any value, these values have to be within certain constraints. These constraints may be geometric relations such as perpendicularity, parallelism, concentricity etc. or they can be dimensional values such as lengths and angles. Therefore the term Feature-Based Model actually refers to Feature-Based Constrained Parametric Model. By changing the values of the parameters within the constraints, one can actually design a family of parts rather than a part in the same time. This leads to the possibility of productivity improvement of manyfold if proper planning is done by the user.

Procedure for constructing a Feature-Based Model

Choose a sketch plane.

Sketch a rough 2D sketch on the sketch plane. This gives roughly the topology

Just constrain this sketch in the following three levels:

- Use the rules defined internally

- Add more relational constraints

- Add dimensional constraints.

Convert this 2D sketch into a 3D feature such as extrusion, sweep, cutout, slot, hole etc.

The first feature created in this manner is called base feature.

- Use the above steps to create all other features.

Advantages

The boolean operation are explicit.

By changing a few parameters, the object can be changed unambiguously since all the dimensions are related to each other by these

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Feature-Based Models

parameters. In this way, a family of parts can be designed with the same effort required to design a part in CSG modeling.

It enforces just dimensioning.

It can do automatic dimensioning.

Due to the presence of constraints, even if the dimensions are changed, the topological relations are preserved. For instance, a through hole remains as a through hole even if the thickness of the plate is increased.

Creation of 2D sketches and their conversion into 3D using familiar features makes this approach more elegant and natural.

Limitations

Solving constraints requires considerable amount of geometric acumen.

User should plan well in deciding the right parameters to exploits the benefits of this group design philosophy.

Any RP process consists of five basic system elements that affect the prototype obtained
data creation, common data exchange format, model validity and repair, compensation and support structures.

RP process

Data creation

The first step in the overall RP process is the creation of geometric data, either as a 3D solid using a CAD workstation, or as 2D slices using scanning device. The model is valid if for each point in 3D space the computer can determine uniquely whether that point lies inside, on, or outside the boundary surface of the model, and if the region around the point is well behaved. This fundamental property makes possible the automatic geometric manipulation operations that give RP its appeal as an automated process.

Data exchange between Modeler and RP machines

RP machine vendors accommodate this variety of geometric mathematical forms and data formats be expressed in neutral format.

Model validity and repair

CAD post-processors approximate the internal CAD geometric forms with a simplified mathematical form (triangles), which in turn is expressed in a specified data format: STL. Unfortunately, this approximating operation, if not done precisely, sometimes introduces undesirable geometric anomalies such as holes or overlapping portions in the boundary surface.

Orientation/ Scaling/ Nesting

Given a valid model, a series of geometric operations must be performed on the model (model preparation) to ensure that physical part will meet the input specifications.

Compensation

In some of the RP processes, the model shape may need to be altered to compensate for anticipated downstream physical anomalies introduced during fabrication, such as shrinkage, warpage, curl and

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RP process

deformation.

Support structures

Support structures are needed in liquid-based processes to prop up overhanging portions of the 3D part, to attach the part to the workspace platform, and to internally buttress hollow parts. Parts and supports may need drain holes. Support locations for overhangs can be determined by checking the direction of surface normal and by z-axis projections of the model. Software exists to automatically generate support structures that attempt to use the least possible amount of material.

For very precise parts with many thin protrusions, the compensation and support structure generation operations may need to be iterated, because the support may distort the previously compensated part.

Slicing

to obtain the necessary motion control trajectories to drive the actual solidification mechanism in the RP machine, the prepared geometric model is sliced into layers of possible different thicknesses, and the slices are scanned into lines in reverse the layer-to-layer physical building process.

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Initial Explorations with RP

RP (parametric Technology) having different feature options for the construction of the part. In initial stages, those options were considered for generation of bottle shapes.

Most useful operations for bottle shapes Creating Features

Basic Form Features

Extrude: The extrude option creates a feature that is formed by projecting the section straight away from the sketching plane. It is the most basic and frequently-used form option.

Revolve: The revolve option creates a feature by revolving the sketched section around a centerline from the sketching plane into the part. When sketching the feature, the first centerline sketched is the axis of revolution. The section must lie completely on one side of this centerline and must be closed.

Sweep: A sweep is created by sketching or selecting a trajectory, then sketching a section to follow along it.

Blend: A blended feature consists a series of a series of at least two planer sections that joins together at their edges with transitional surfaces to form a continuous feature.

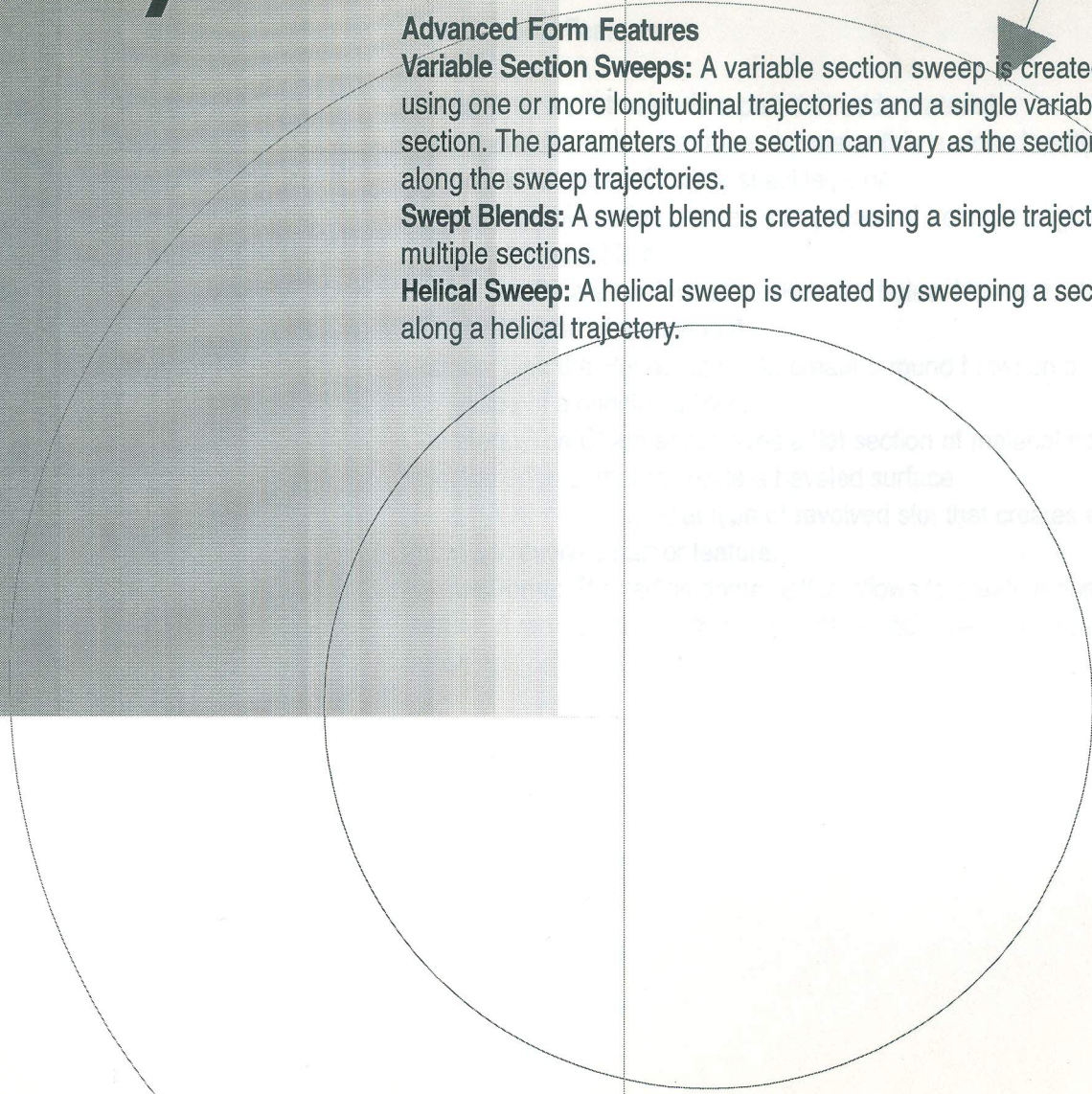
Initial Explorations with RP

Advanced Form Features

Variable Section Sweeps: A variable section sweep is created by using one or more longitudinal trajectories and a single variable section. The parameters of the section can vary as the section moves along the sweep trajectories.

Swept Blends: A swept blend is created using a single trajectory and multiple sections.

Helical Sweep: A helical sweep is created by sweeping a section along a helical trajectory.



Initial Explorations with RP

Construction Features

Protrusions: A protrusion is a part that adds material.

Slots and cuts: A slot- Remove material within a closed section, A

Cut- Remove material from a specified side.

Holes: The Hole option creates many types of holes - trough, counterbore, and blind.

Shafts: Shafts are analogous to sketched holes. However, shafts add material instead of removing it.

Rounds: Use the Round option to create a round between surfaces, or in place of a middle surface.

Chamfers: The Chamfer removes a flat section of material from a selected edge/corner to create a beveled surface.

Necks: A Neck is a special type of revolved slot that creates a groove around a revolved part or feature.

Radius Dome: The radius dome option allows to create a dome feature. A radius dome deforms a surface and is parameterized by one radius and one offset distance.

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Initial Explorations with RP

Offset: An Offset option creates/ offsets a feature on a surface.

Toroidal Bend: The toroidal bend option bends solids, non-solid surfaces, or datum curves into toroidal shapes. The first bend is a sketched section that defines the sectional curvature of the toroid shape. The second bend is determined by two parallel planes that define the radius of the toroid.

Shells: The shell option removes a surface from the solid, then hollows out the inside of the solid, leaving a shell of a specified wall thickness.

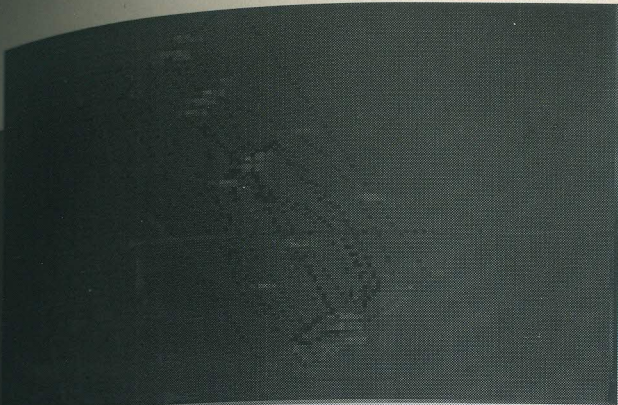
Patterning features

Patterns are multiple features created from a single feature that behave as one.

variable
within
sweep
&
cut/slice

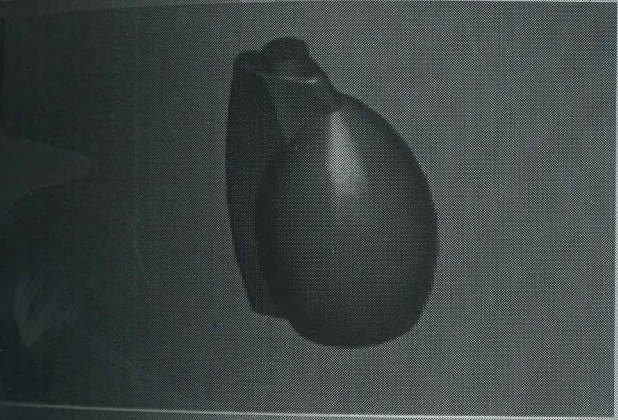
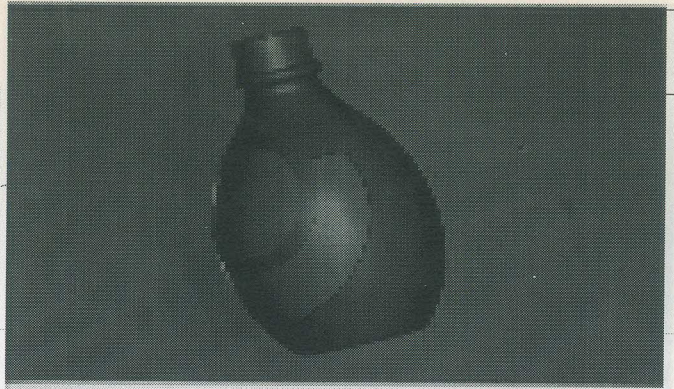
Toroidal
Bend





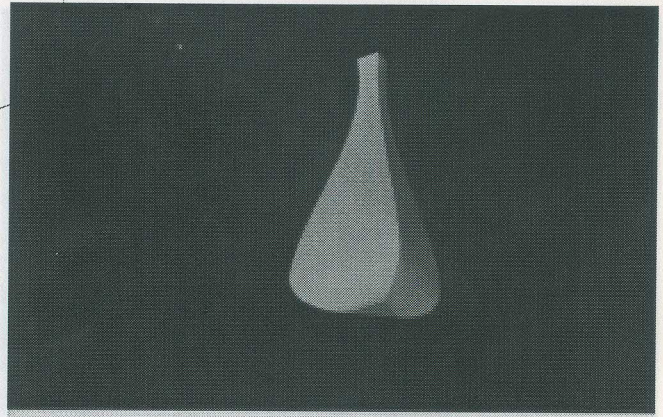
Free form
(3D curve)

Revolve
+
offset(-)



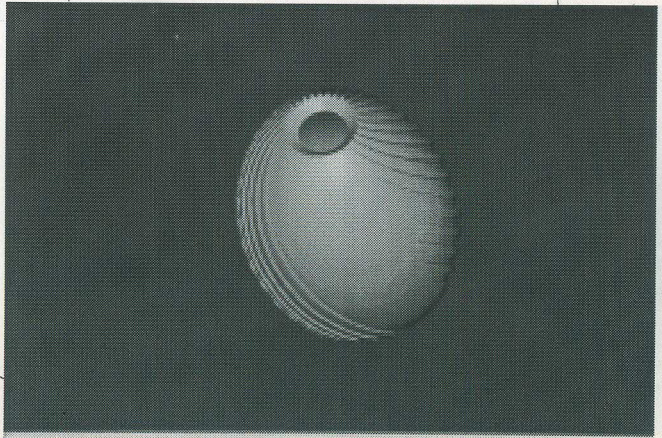
Free form

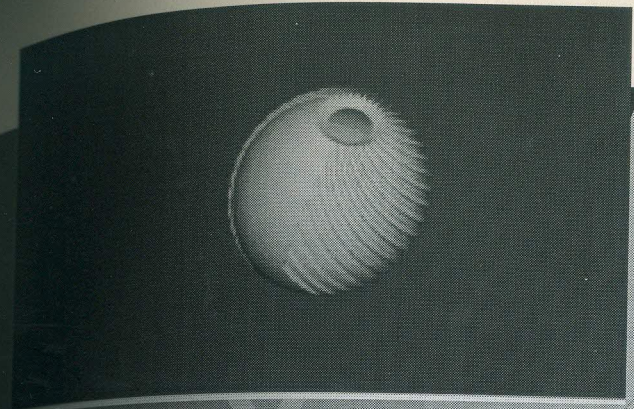
Blend



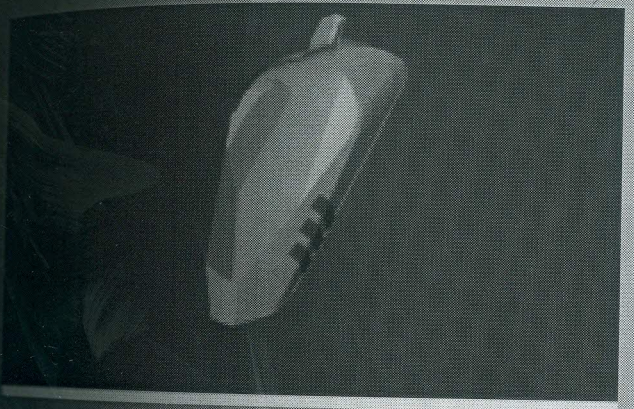
Variable
section
sweeps
+
cut/slot

Toroidal
Blend





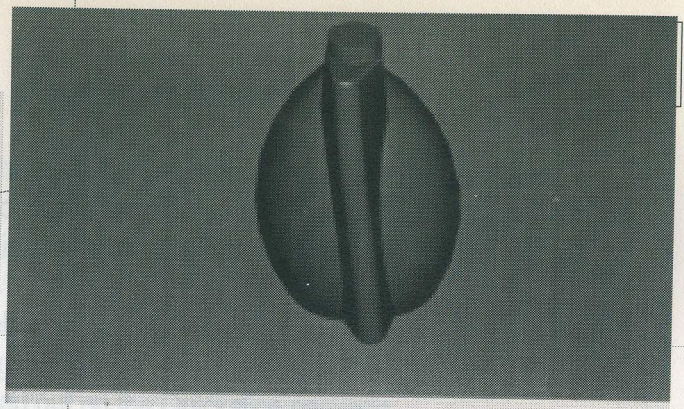
Toroidal
Blend
+
pattern



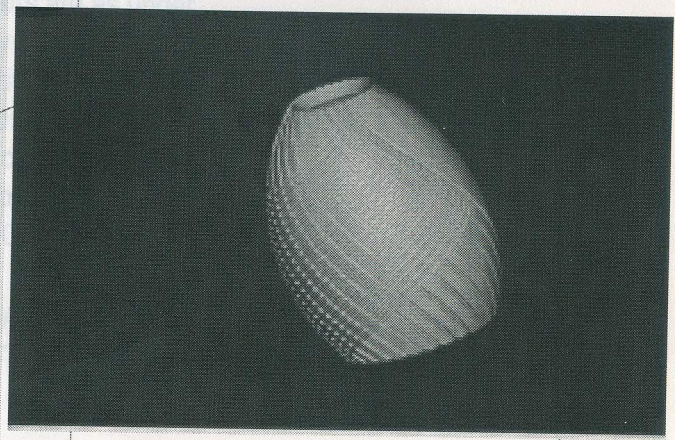
Variable
section
sweeps
+
offset



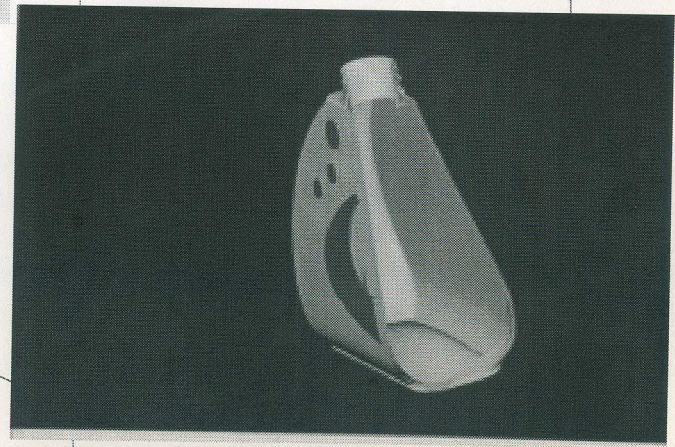
Variable
section
sweeps
+
offset
+
Shell



Free
form
+
Revolve



Toroidal
Blend
+
offset
+
Pattern



clip
+
shell

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Analysis with respect to supporting elements.

Overhang features of the part required supporting elements. Analysis was done so as to find out particular angle or curve beyond which supporting elements are required in bottle.

Spherical shell

as shown in fig. 1-2

Slicing is carried out on the Quickslice package.

Constant factors are as under

Part geometry

revolving section geometry- arc

base cut radius- R10 mm

height of object- 105 mm

Slice dimensions

chord height- 0.02 mm

angle- 0.5

support quality- medium 50%

Variable factor radius (A)mm

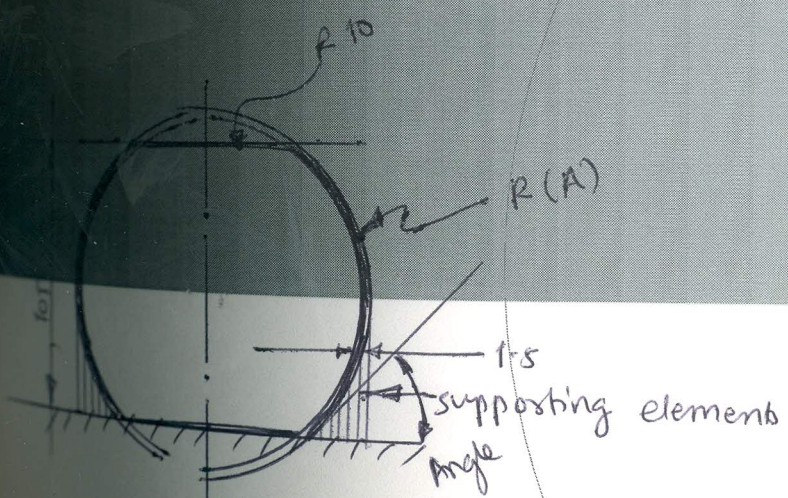
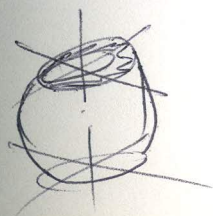


Fig 1-2



an average center of the world before than
 section of radius 59.6 and thickness of 1.5 mm
 the pathway that leads to the world of fragrance.

Analysis with respect to supporting elements.

The results are as under-

First stage

- R100 no support
- R80 no support
- R60 no support
- R40 support required

Second stage

- R50 support required
- R55 support required
- R56 support required
- R57 support required
- R58 support required
- R59 support required

Third stage

- R59.5 support required
- R59.6 support required
- R59.7 no support

Conclusion

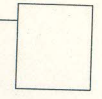
It is found that an angle of 41° from horizontal plane is the optimum angle. If you reduce this angle, supports are required. Minimum distance from average centre of bottle should be more than 10 mm, for revolving section of radius 59.6 and thickness of 1.5 mm

A fragrance bottle is the pathway that leads to the world of fragrance.

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X



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about **Fragrance bottle**

It has an identity from other bottles being more decorative, having combination of opaque and transparent body, symmetric and unsymmetric forms etc.

It like a small unit of that environment.

Many forms are inspired from nature.

Even after the perfume is over, the bottle still occupies the prominent position in the user life as a decorative article.

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Elements of fragrance bottle

Different factors of fragrance bottle that affects bottle identity are-

- bottle shape
- neck and cap
- combination of transparency and opacity
- layer difference on the surface
- variable wall thickness
- inner shape
- colours
- graphics
- text /logo
- additional features like chain etc

For this project, only the bottle body is considered for form generation in RP.

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about Fragrance bottle

Some visual characteristics of bottle in term of masculinity and femininity are as follows-

Masculine

straight forward, well defined, proportions of body to cap maintained, more symmetrical, rigid, rugged, follows grid pattern, more normal to ground, thing borrowed in abstract form, cap is mostly straight and related to bottle body, graphics- maintained in format, less decorative etc.

Feminine

curved, soft body, proportions of body to cap- varies, more unsymmetrical, less grid formatted, straight and slant line, many things adopted from nature which are more soft, more elegant- flower, birds etc., cap- any shape or derived from bottle body, nontraditional text font, more additional feature, more decorative etc.

(Analysis of visual characteristics was done with reference to-
The H & R book
Fragrance Guide Masculine Notes
and
Fragrance Guide Feminine Notes
- JOHNSON LONDON)

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Form exploration in RP

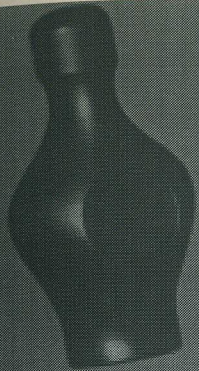
Considering different constraints such as minimizing supporting element, size of bottle, thickness of wall etc. some forms were generated.

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X

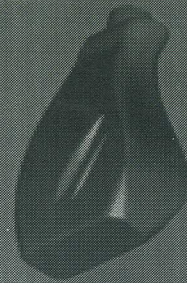
Variable
section
Support
+
offset
+
radius

Variable
radius
Support
+
offset
+
radius



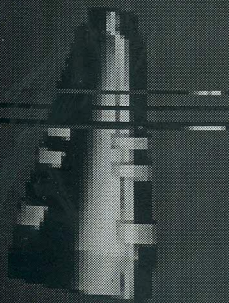
Revolve
+
Cut

Variable
Section
Sweeps
+
Cut/slot
+
Protrusion
+
Radius



Variable
Section
Sweeps
Curved
path

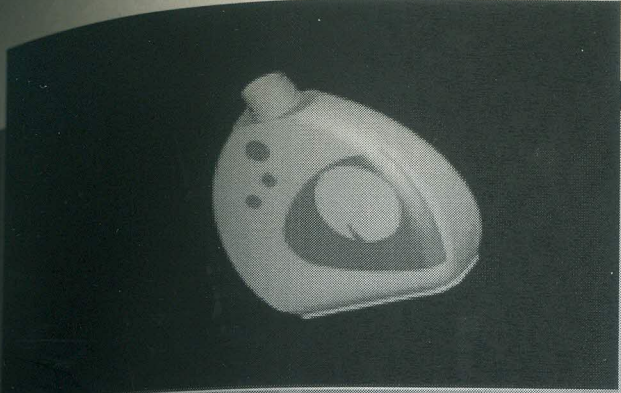
Variable
Section
Sweeps
+
Protrusions



Variable
Section
Sweeps
+
Offset
+
Cut/slot

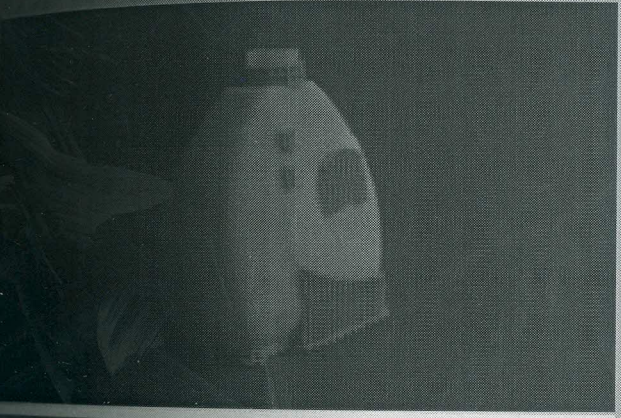
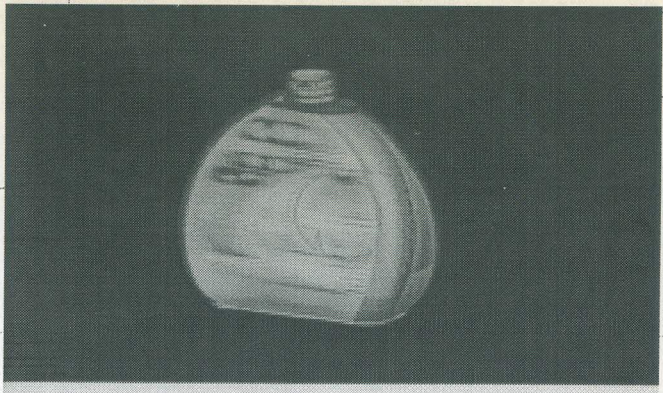
Variable
Section
Sweeps
+
Offset
+
Protrusion





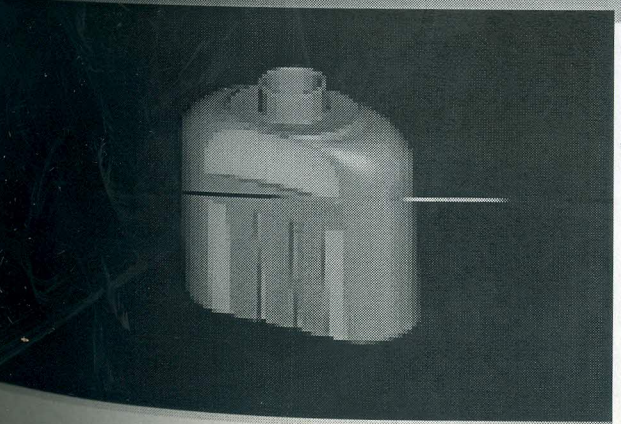
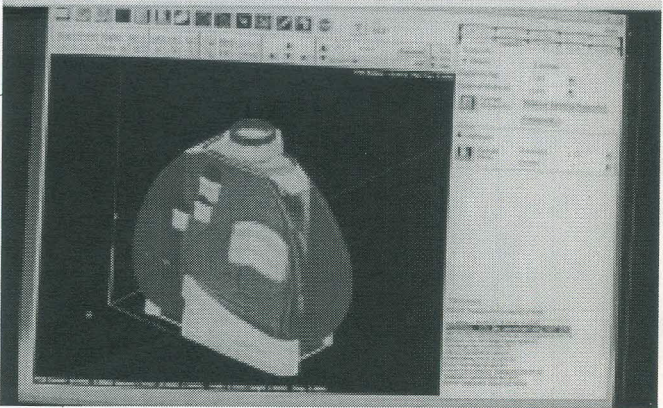
Variable
Section
Sweeps
+
Offset
+
shell

Triangular
faces



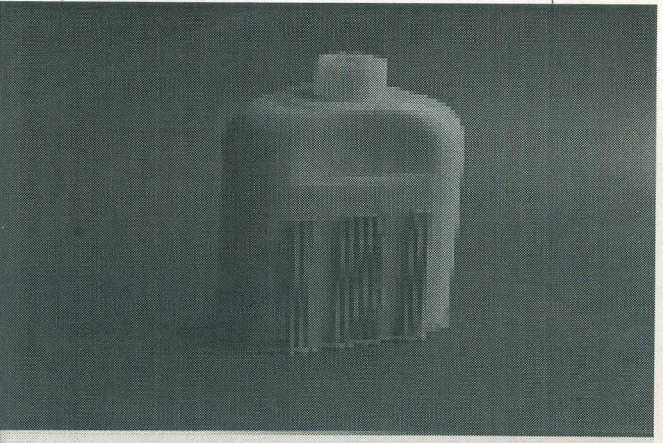
Actual
Output
with
Support

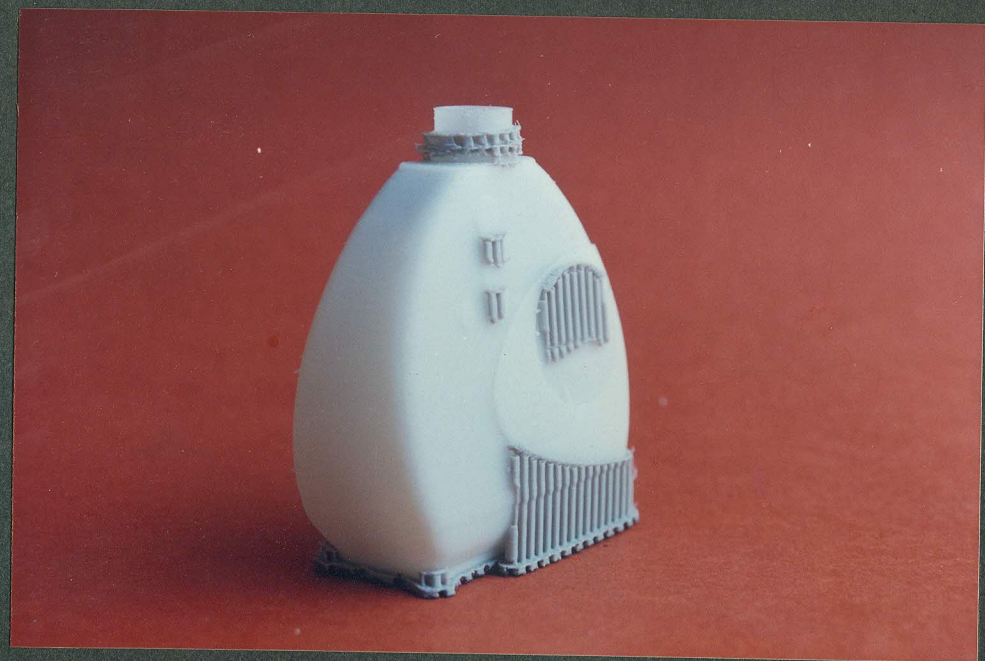
Support
Analysis



Variable
Section
Sweeps
+
Protrusions

Output
with
Support







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- K. P. Karunkaran, V. P. Bapat and B. Ravi

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Parametric Technology Corporation

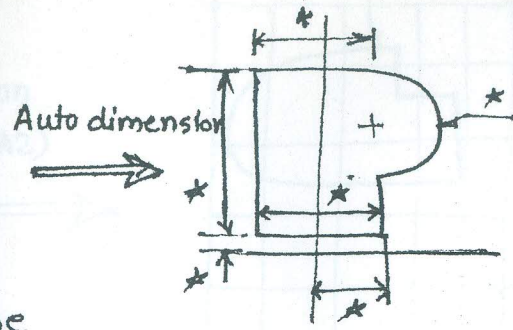
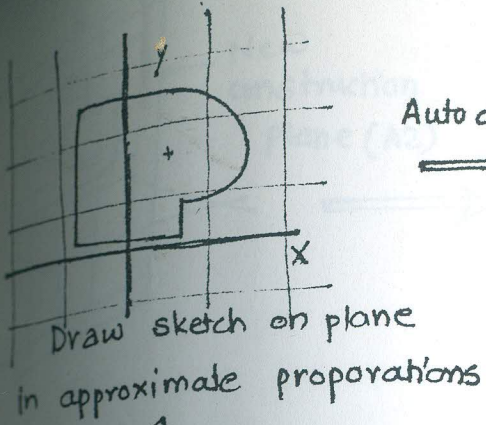
Pro/ENGINEER

Part Modeling User's Guide

Release 17.0

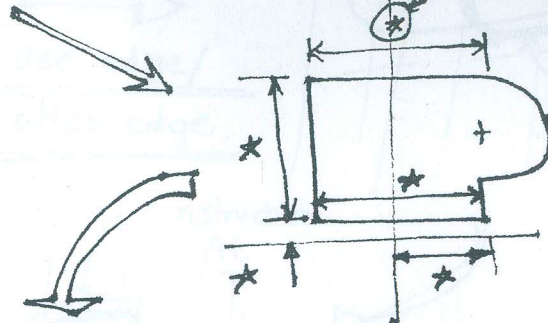
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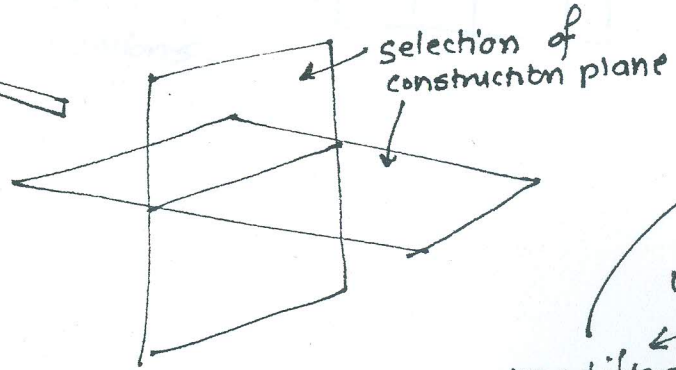
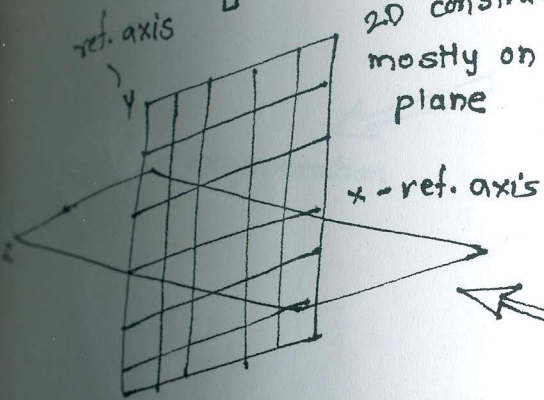
Gives dimensions from
respective reference

on modification
respective changes
or preparation
* in form/sketch



Feedback in terms of
alignment, open-close section,
reference plane, axis, curve, intersection
underdimension, zero dimension

2D construction
mostly on flat
plane



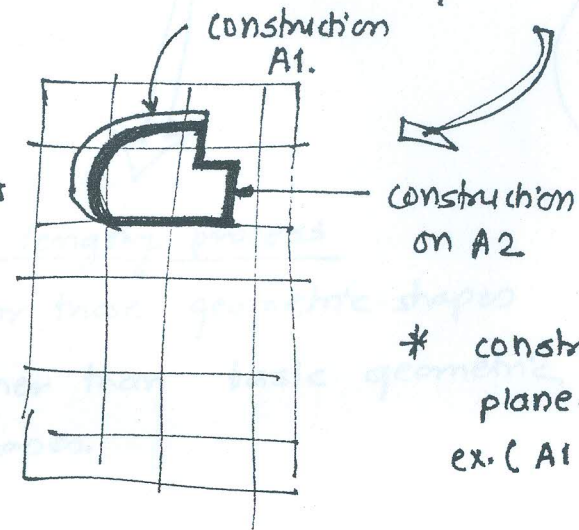
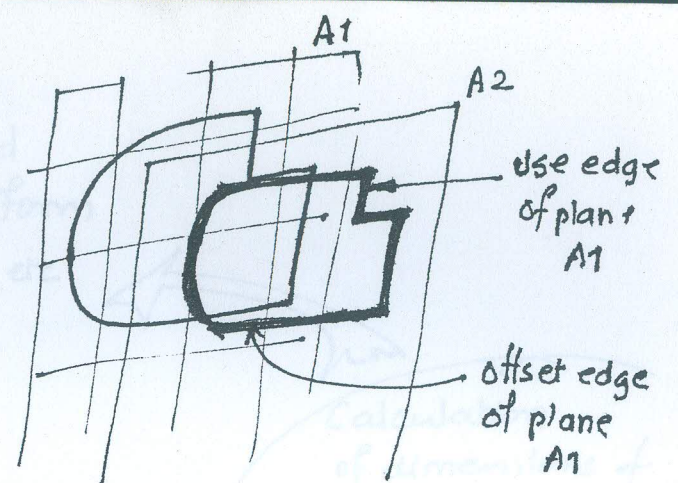
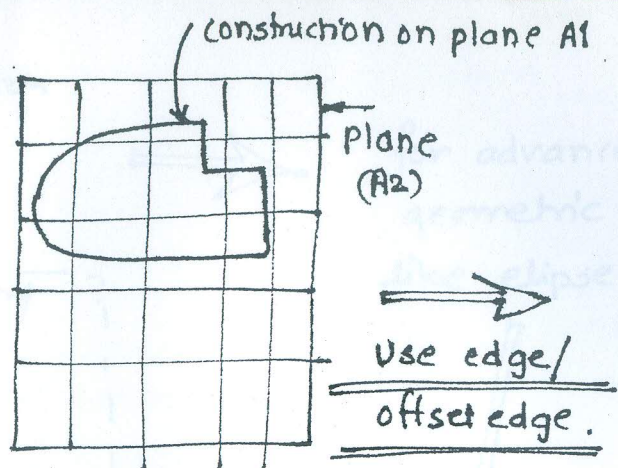
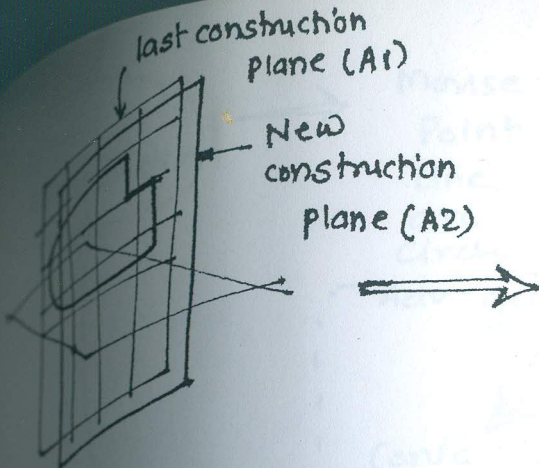
Regeneration
of section

Unsuccessful
modification

successful

section-saving
possible.

2D geometry



* construction on same plane - possible ex. (A1)

intersect
Trim
divide
Mirror
OR
Modification
other dimensions
(

Regeneration

2D geometry

Sketch
2D construction

on flat
plane
possible/
more easy.

Mouse sketch
Point
Line
arc
Circle

Adv geometry
Conic
co-ordinate system
Spline
Text

for advanced
geometric form
like ellipse etc

Calculation
of dimensions of
arc should be
done - outside
the system.

lengthy process
for those geometric shapes
other than basic geometric
shapes.

2D section

Move

Scale

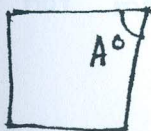
Rotation

No direct
commands
for
total section/geometry

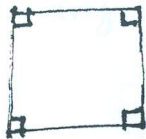
2D section

Critical dimension / alignment
should be emphasised

ex.



If not
given \rightarrow if
output



Free form

3D construction

3D datum curve

datum points in space

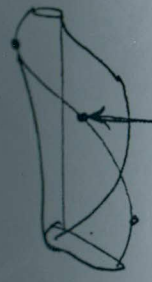
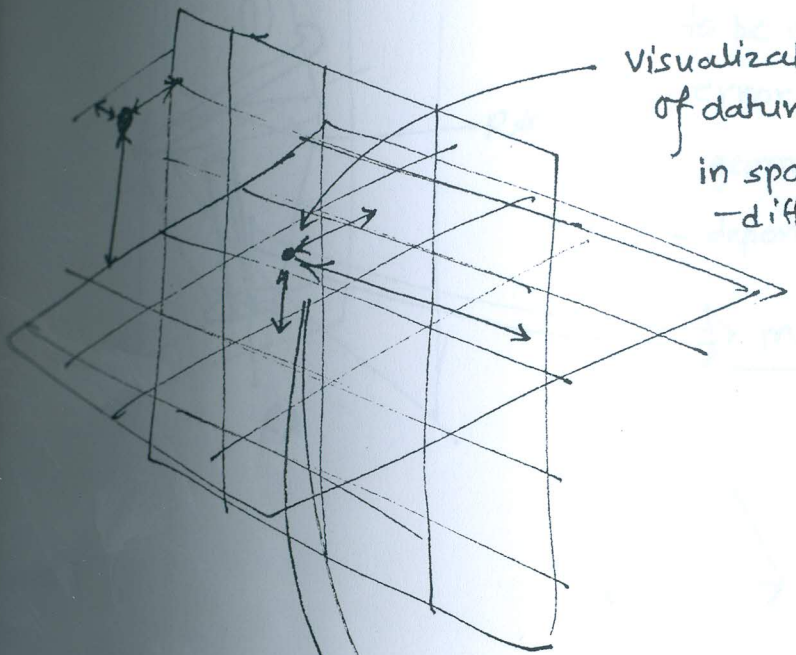
X, Y, Z, co-ordinates.

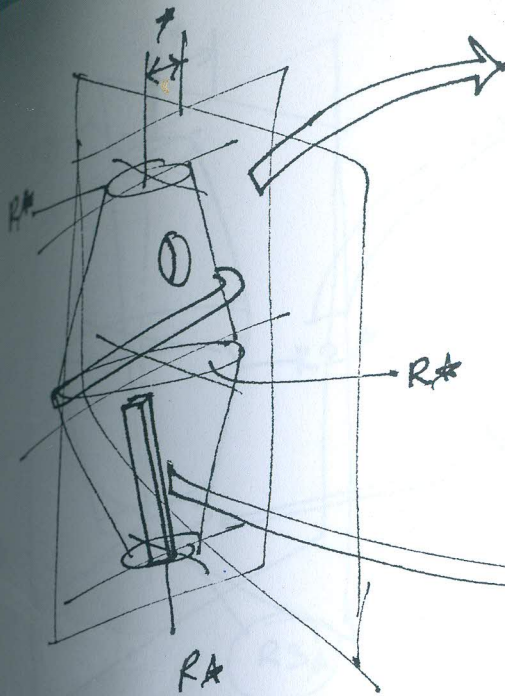
Visualization of datum points in space - difficult.

for particular curve position of point in terms of X, Y, Z co-ordinates requires - graphical drawing on paper

Modification in position in 3D Space - Visualization difficult in terms of different bottle forms.

Modification takes place - by changing X, Y, Z dimensions not modify directly by moving pts in space visually.



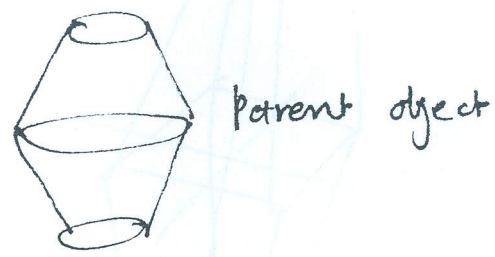


modification of parent object

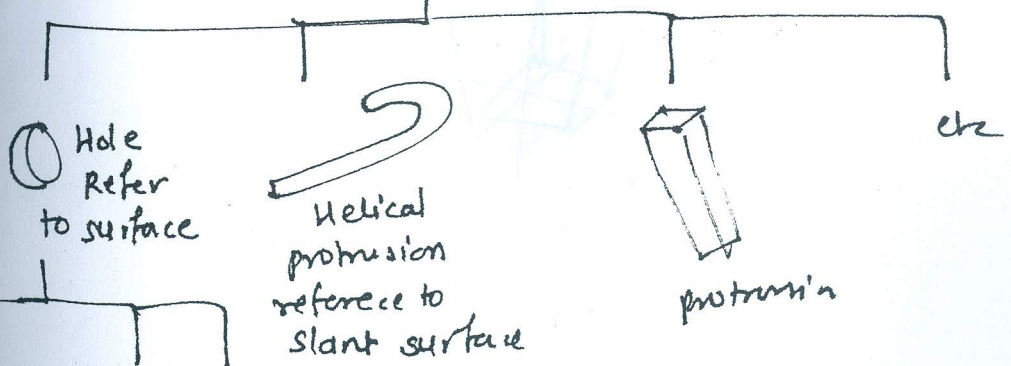
- possible if child object is not direct referred from parent object
- otherwise many times depends upon type of operation to be done or type of relation between parent-child error occurs - it doesn't allow you to modify the geometry
- depends upon no. of operations done on object

modification of child object is possible

level 1



level 2

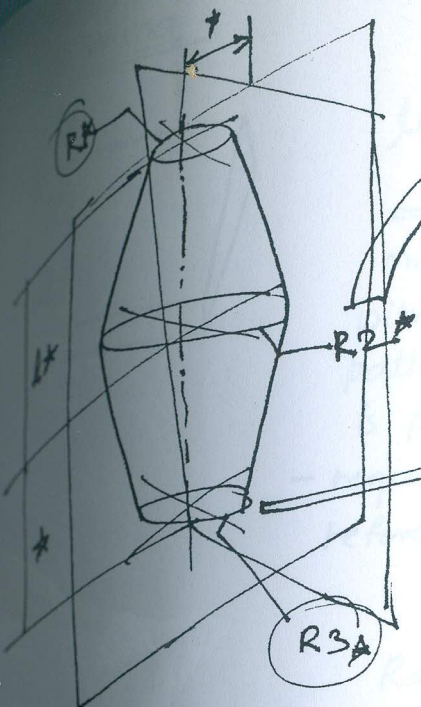


level 3

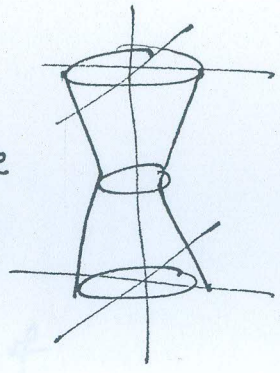
Modification on latest level level (no = max. value) is possible

But to modify object at upper level (ex. level 1) is difficult.

error occur in terms of child reference, location, alignment, dimensions, directions, etc.



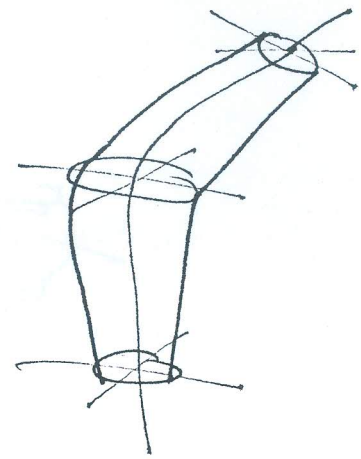
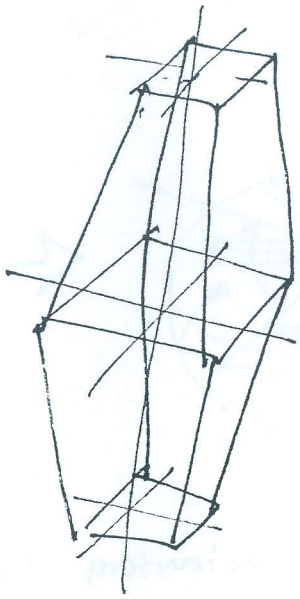
Any dimension can be modified
as per need during operation sequence



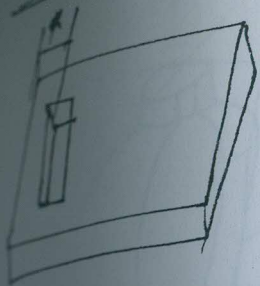
Section, path/ trajectory, location, direction
can be redefined during operation sequence



modified.
path



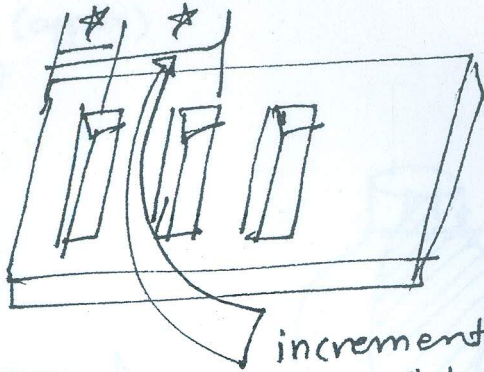
Patterning



Linear

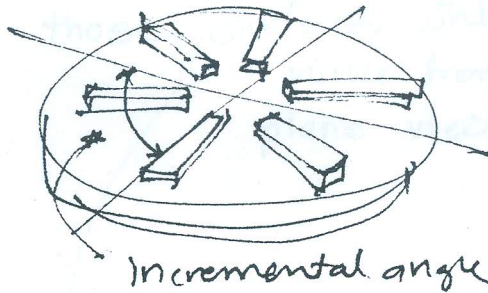
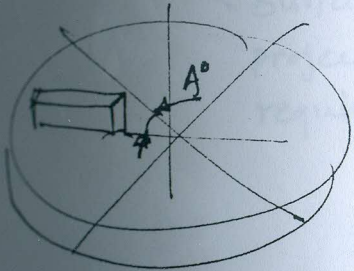


multiple slots
with the help of
pattern command
is possible
- requirement -
reference dimensions.



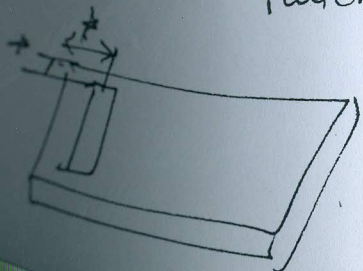
incremental value of
Slot.

Radial

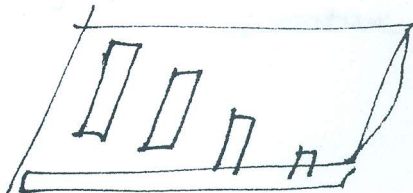


Incremental angle

Patterning - slot, cut, protrusion, extrusion, revolve etc. is possible.



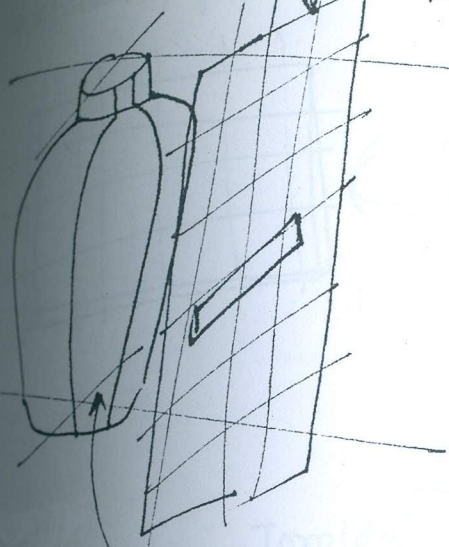
multiple
dimensional
change - patterning.



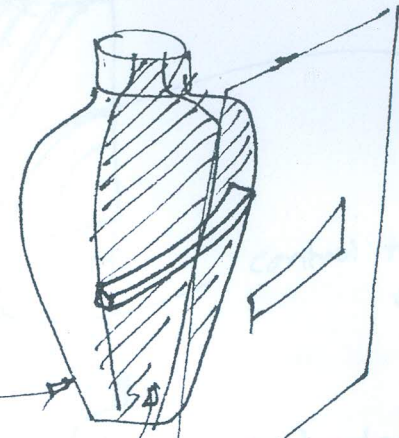
change/increment
in its reference dimensions
gives many alternatives.

Tweak - offset

flat, parallel (approx)
to that object

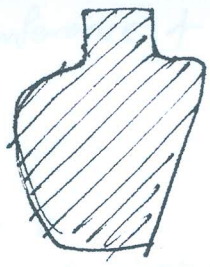


Surface on which
projection or slot/cut
required



It is possible or only
those surfaces which are
visible from that projected
plane view

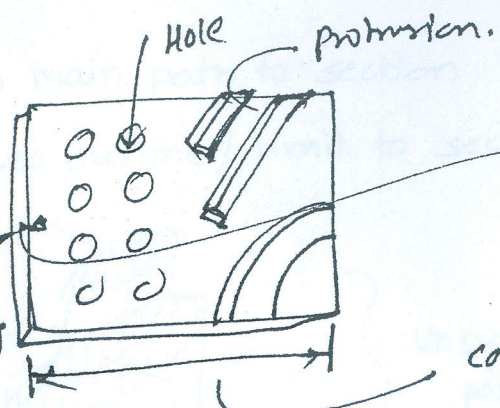
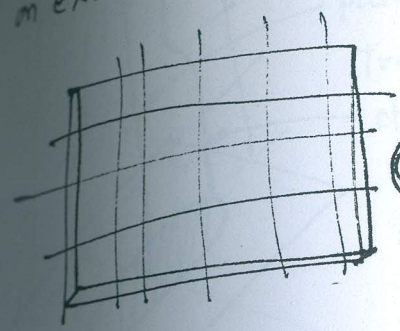
Projected
Plane
view



So continuation of projection or slot throughout
object body is not possible with this function.
Curvature

Toroidal Blend

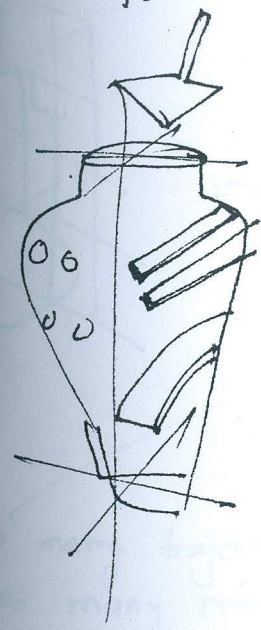
in extruded / protruded section



control the circumference of shape

Toroidal Blend - with shape of

protruded sheet is wrapped around sketch in revolved manner



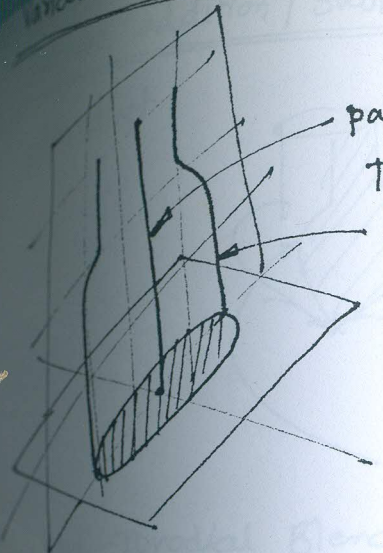
shape of bottle / section of bottle is circular (symmetrical in both plane). any other sections are not possible.

usually drawn on AutoCAD
to find depth of factory in
space requires
calculation - still
- less control on quality

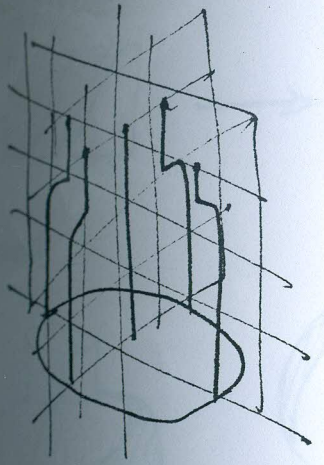
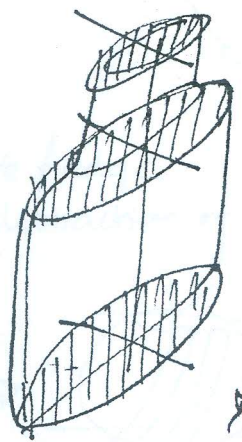
variable section Sweep

Subtractor (Manipulation)

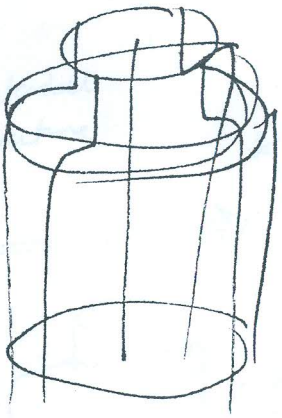
path / x-vector — gives main path to section
Trajectory — gives main path to section
other trajectory — gives outline / limit to section



Vars.
Sec.
sweep.



Vars.
Sec.
sweep.



Unsymmetrical shapes possible.
You can have as many as limiting trajectory to define shape

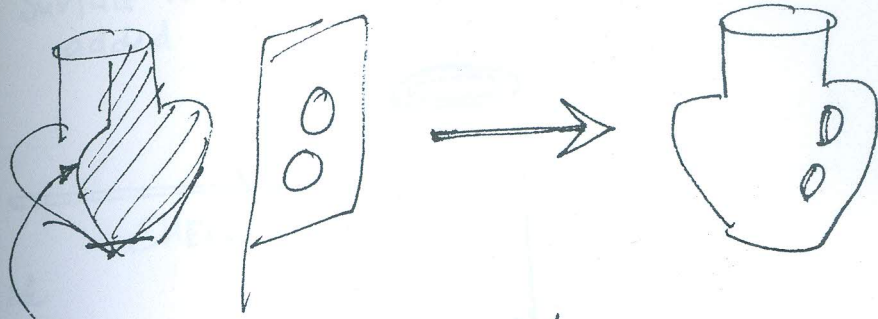
- ~~To draw~~ Trajectories usually drawn on flat plane.

- But to draw trajectory in 3D space requires more calculation - visualization
- less control on form (visually)

To draw many trajectories requires many reference plane
So construction geometry is more.

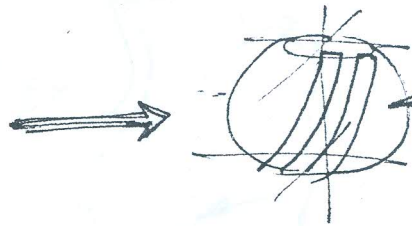
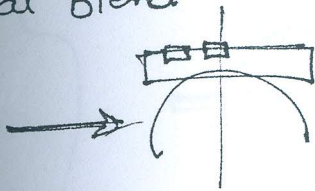
Surface addition / subtraction (manipulation)

with offset

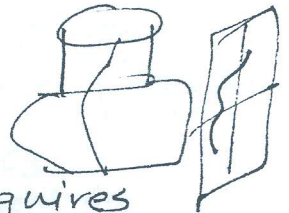


Beyond this curve / edge addition / subtraction of solid is not possible

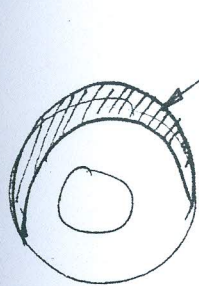
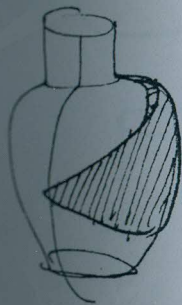
With Torodial Blend



only with circular cross-section



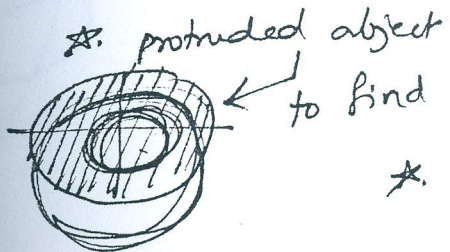
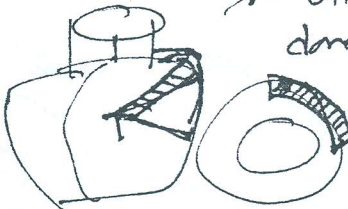
Next...



To add material along curvature of bottle.

* To draw datum curve requires flat plane.

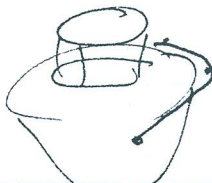
In this case, curved surface
* off with offset only half part can be done but with uniform thickness throughout.



* protruded object

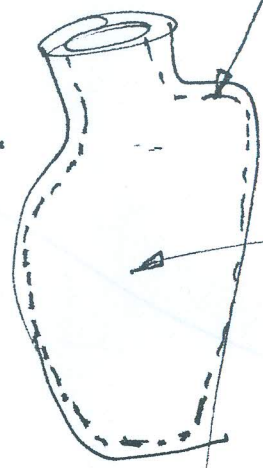
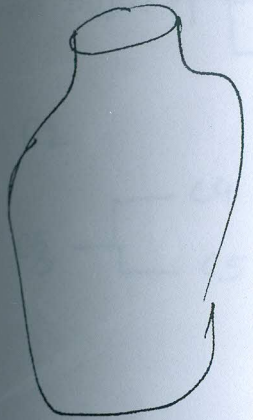
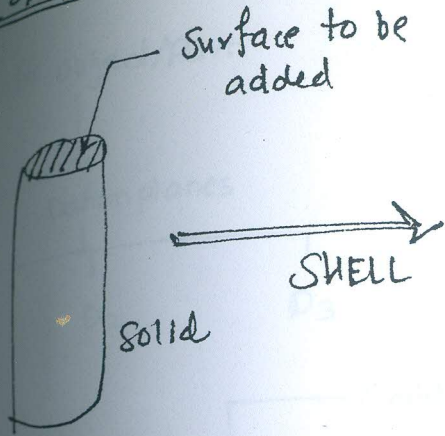
to find out location of new protruded part / feature

*

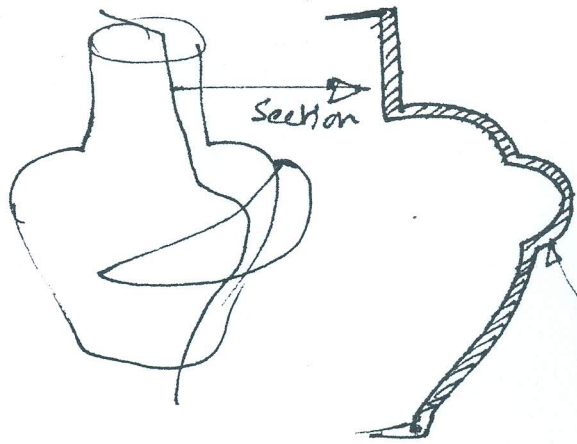


3D form - Variable section sweep requires datum point is space with calculated X, Y, Z, co-ordinate.
- tedious job.

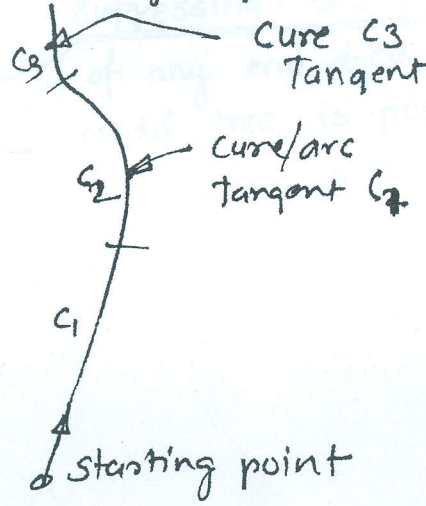
Shell



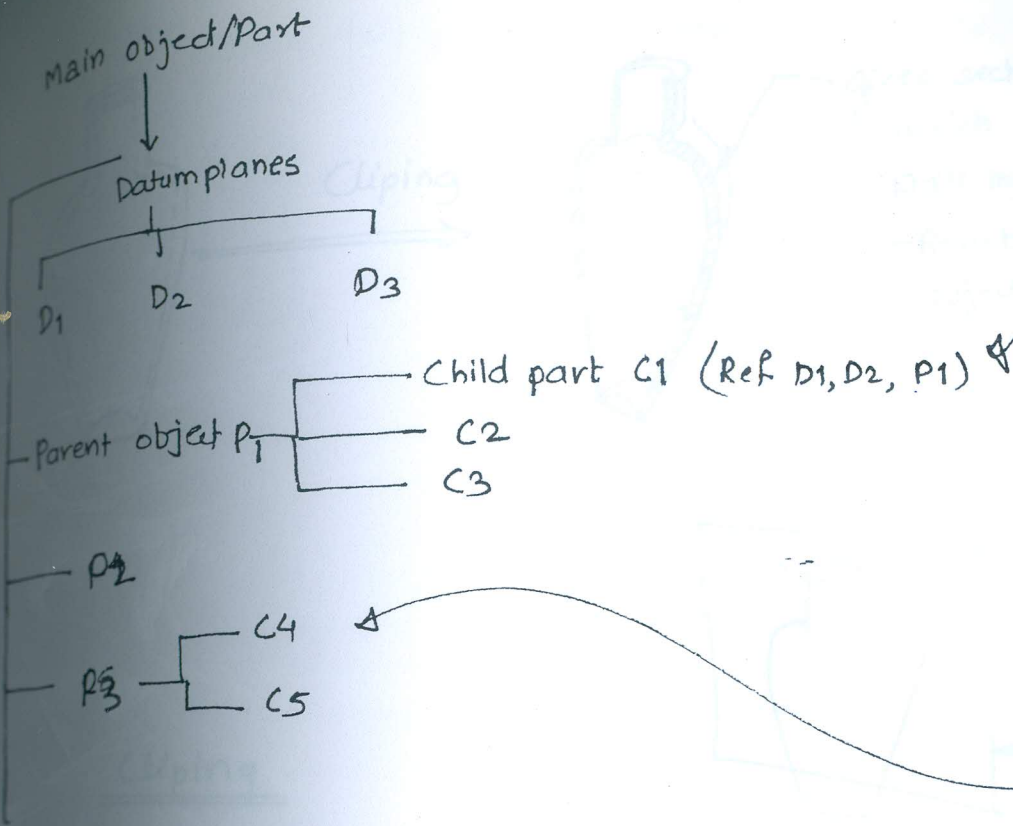
Variation in thickness is possible.



But, for shell operation tangency condition is required



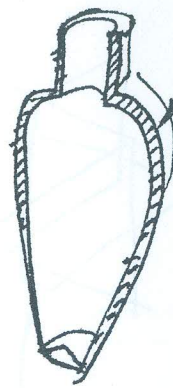
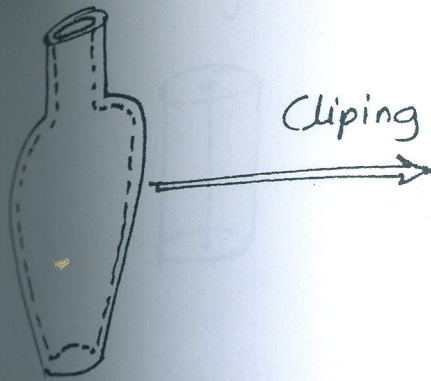
Projections, slots/cut on solid body are considered for shell operation



Reroute / Reorder of the operation sequence is possible if that child object/parent object is ~~not~~ directly referenced to any other object — otherwise, ~~so that~~, further operations gets trapped between those references. (error)

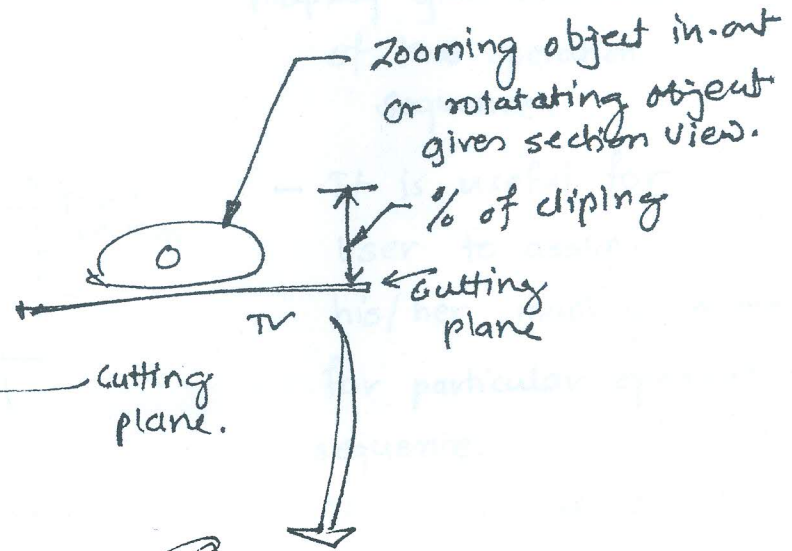
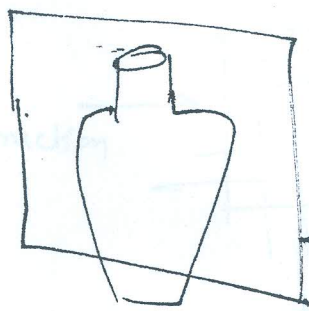
Suppressing / resuming of any end object in that model tree is possible
 ex. suppress C4
 ex. suppress P3 (i.e. P3, & C4, C5)

are small programs or operation paths
assign this part with some chart names

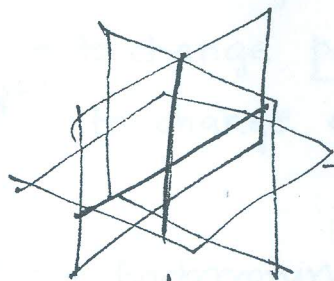
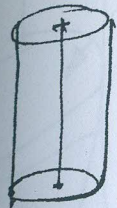


gives sectional view
which gives idea about
wall thickness - variations.
- Rotation, ~~scale~~ zooming of
object in clipping is possible.

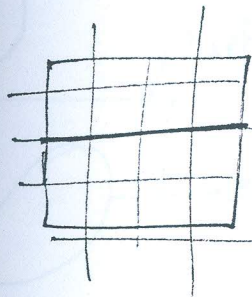
Clipping



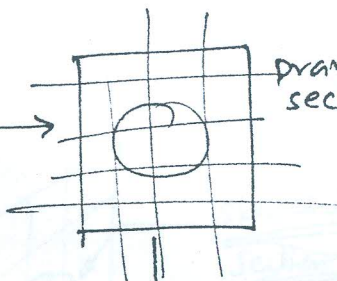
Mapkeys - are small programs or operation paths
- assign this path with some short names.



Creation of datum plane.

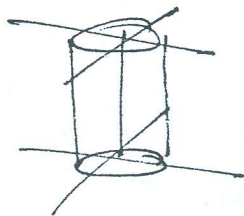


Selection of 2D construction plane



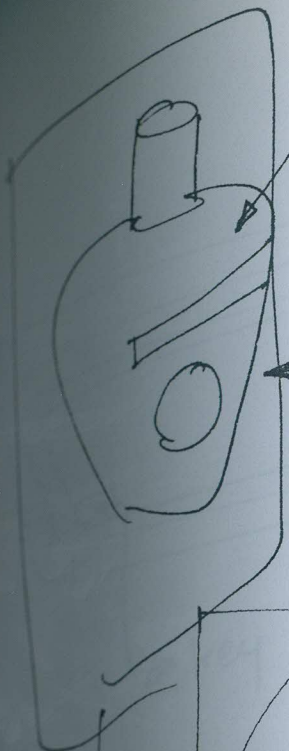
Draw section

extrusion



'DP' as mapkey.
no need to follow menu sequence
or search operations
mapkey gives end result
of that operation
sequence.

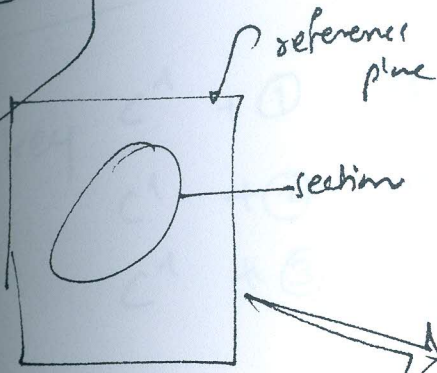
- It is useful for
user to assign
his/her mapkeys name
for particular operations
sequence.
It reduces search time.



Colour change possible
 - to change part colour
 - to change surface colour.

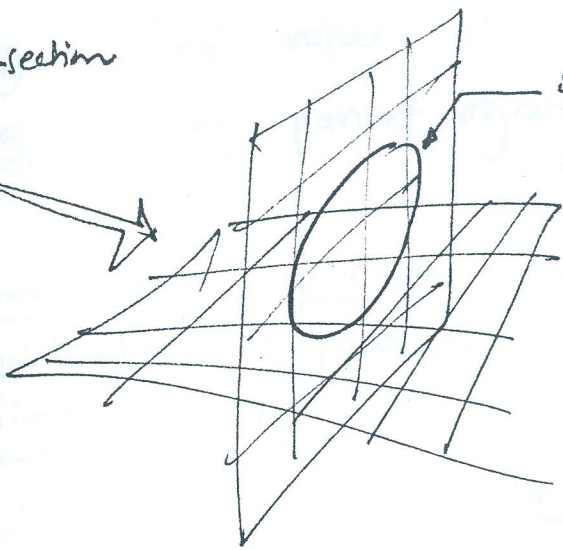
It is possible

Background colour can be changed.



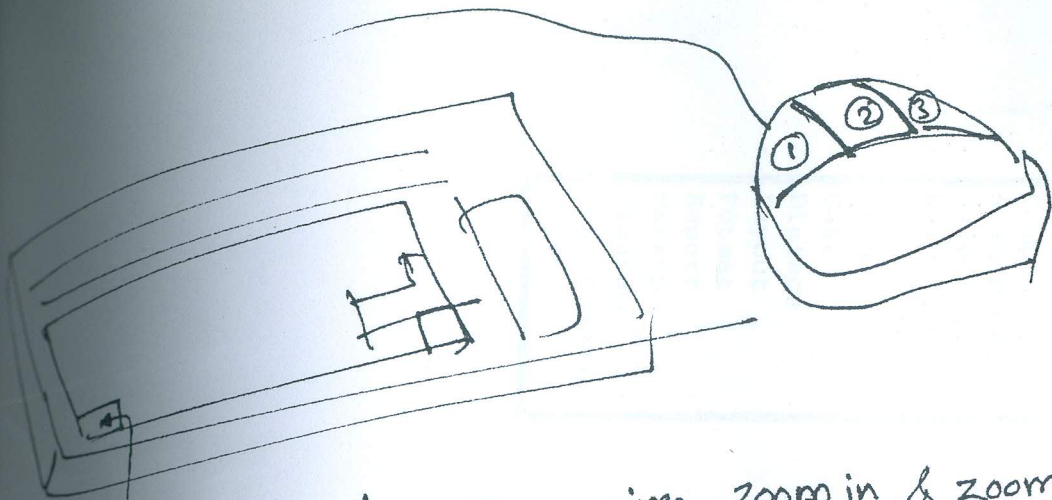
section

reference plane



sketching
Section in 3D with
 reference plane
 is possible

Rendering quality
 is not equivalent/
 comparative to other
 geometric packages
 - so additions of rendering
 best quality & helpful
 to visualize object more
 realistically.
 (Required).



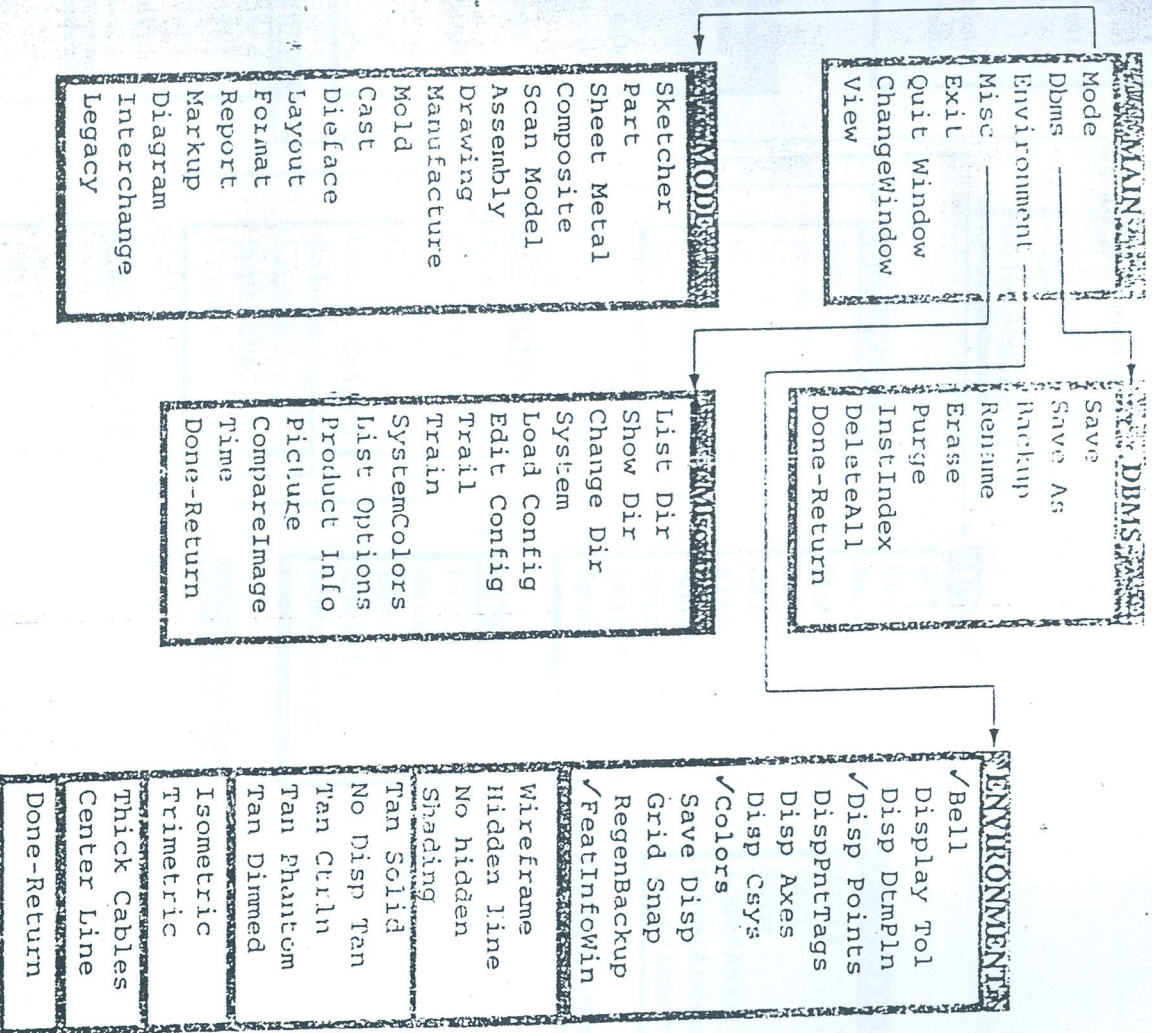
- | | | | |
|-----|-----------|---|--|
| key | $C^1 + ①$ | gives zoom in & zoom out of the object / section. | } <u>viewing</u>
<u>convenience</u> |
| | $C^1 + ②$ | gives rotation of object / section | |
| | $C^1 + ③$ | gives pan of object / section | |

~~Failure~~ On failure. - investigation, geometry check, accordingly feature modification is possible (which gives idea about object / part / operation failure / errors).

It gives an idea about -
feature information, part information, parent-child relationship.

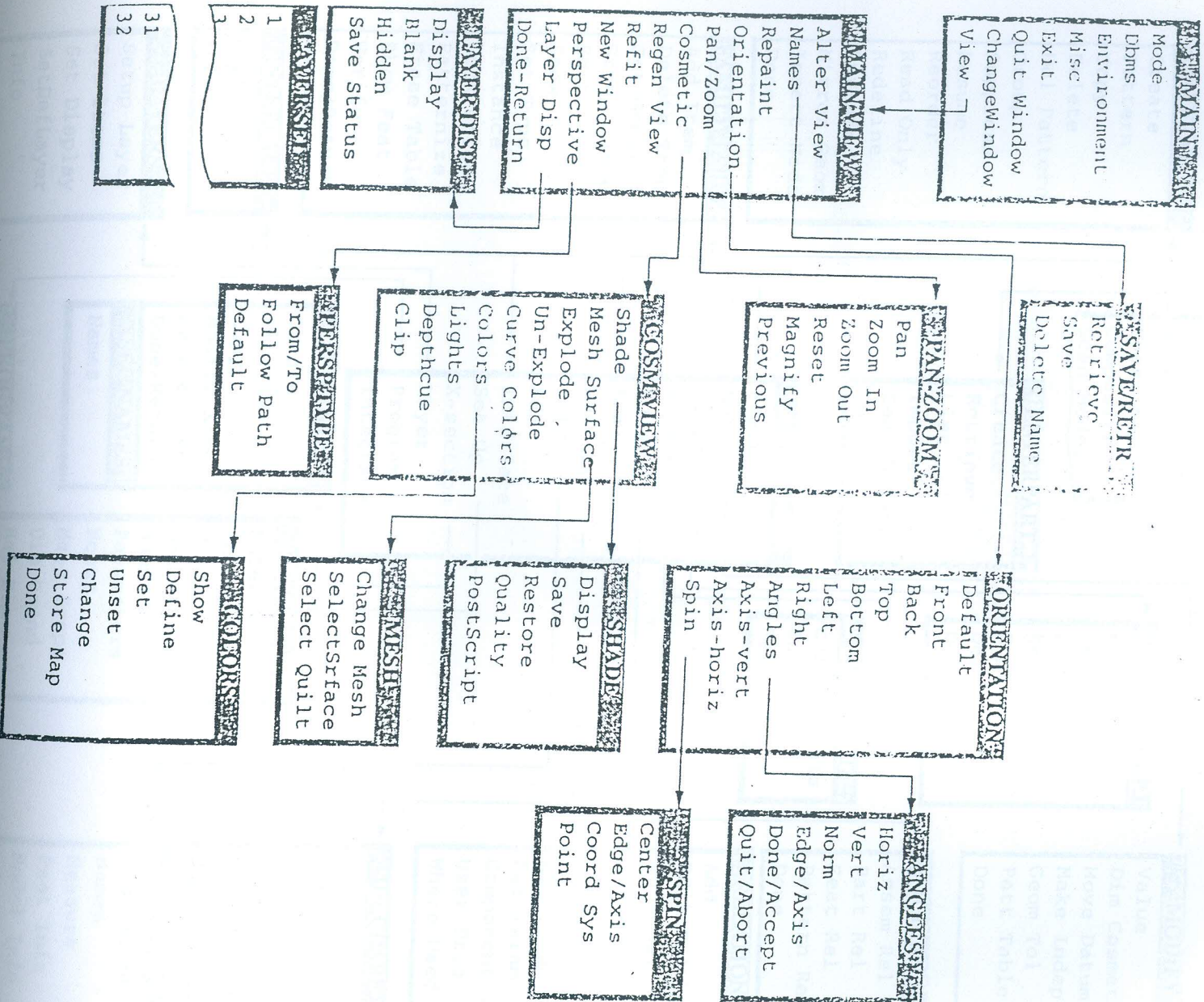
APPENDIX B: MENU STRUCTURES

MAIN MENU



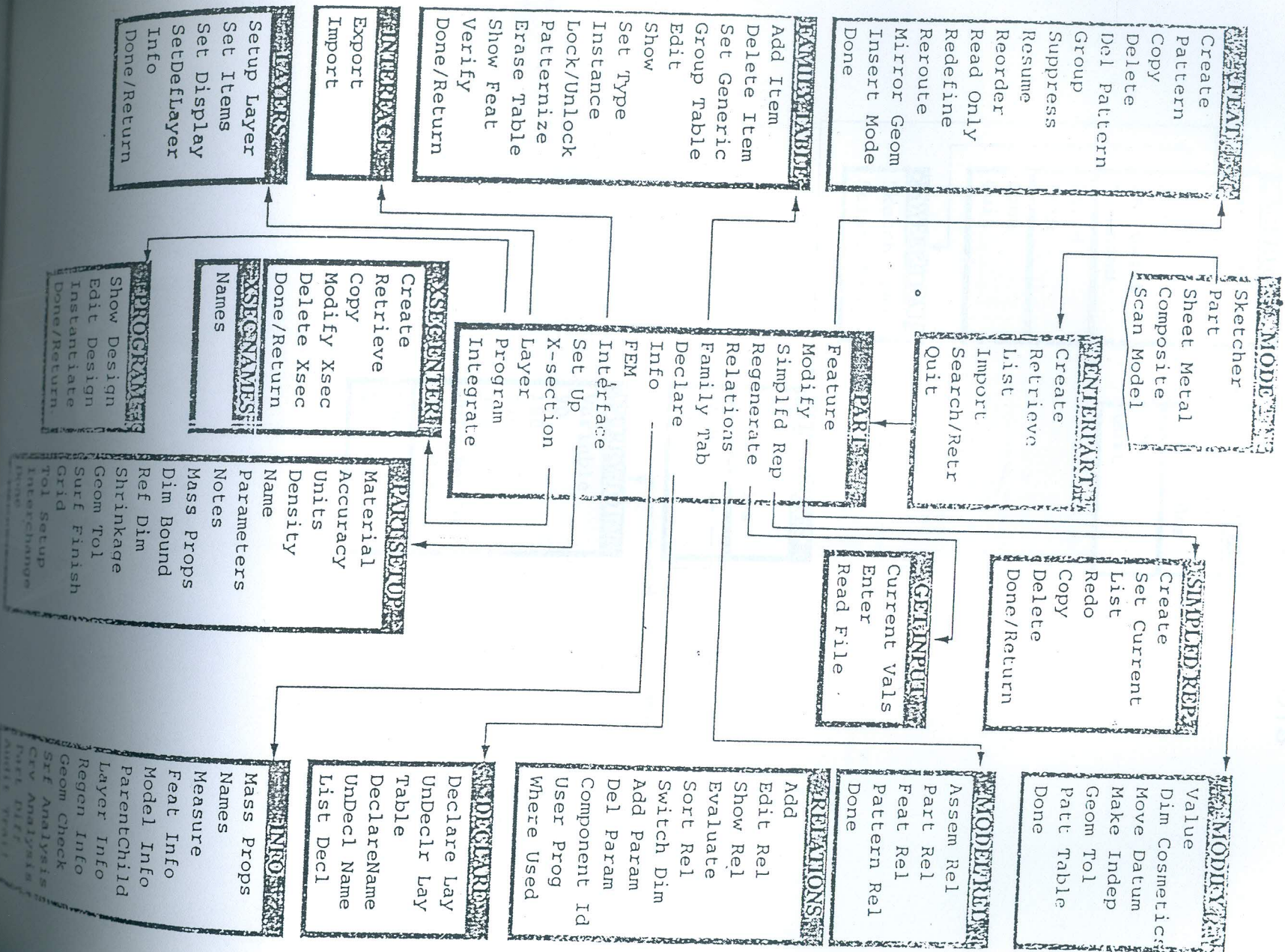
APPENDIX B

MAIN VIEW MENU



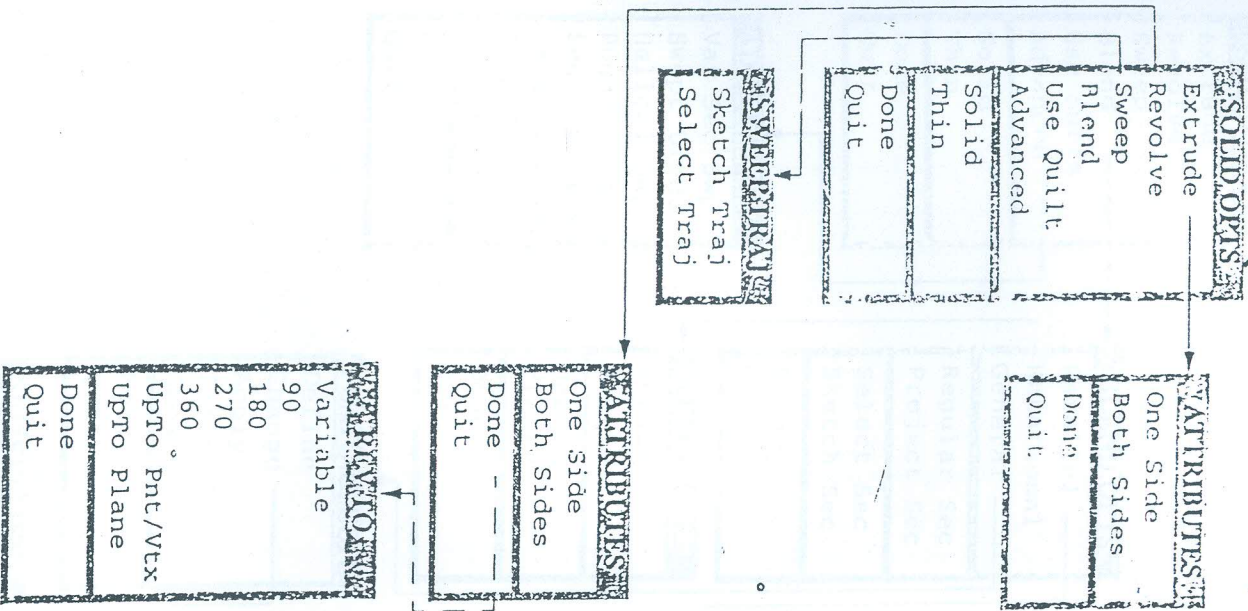
APPENDIX B

PART MENU



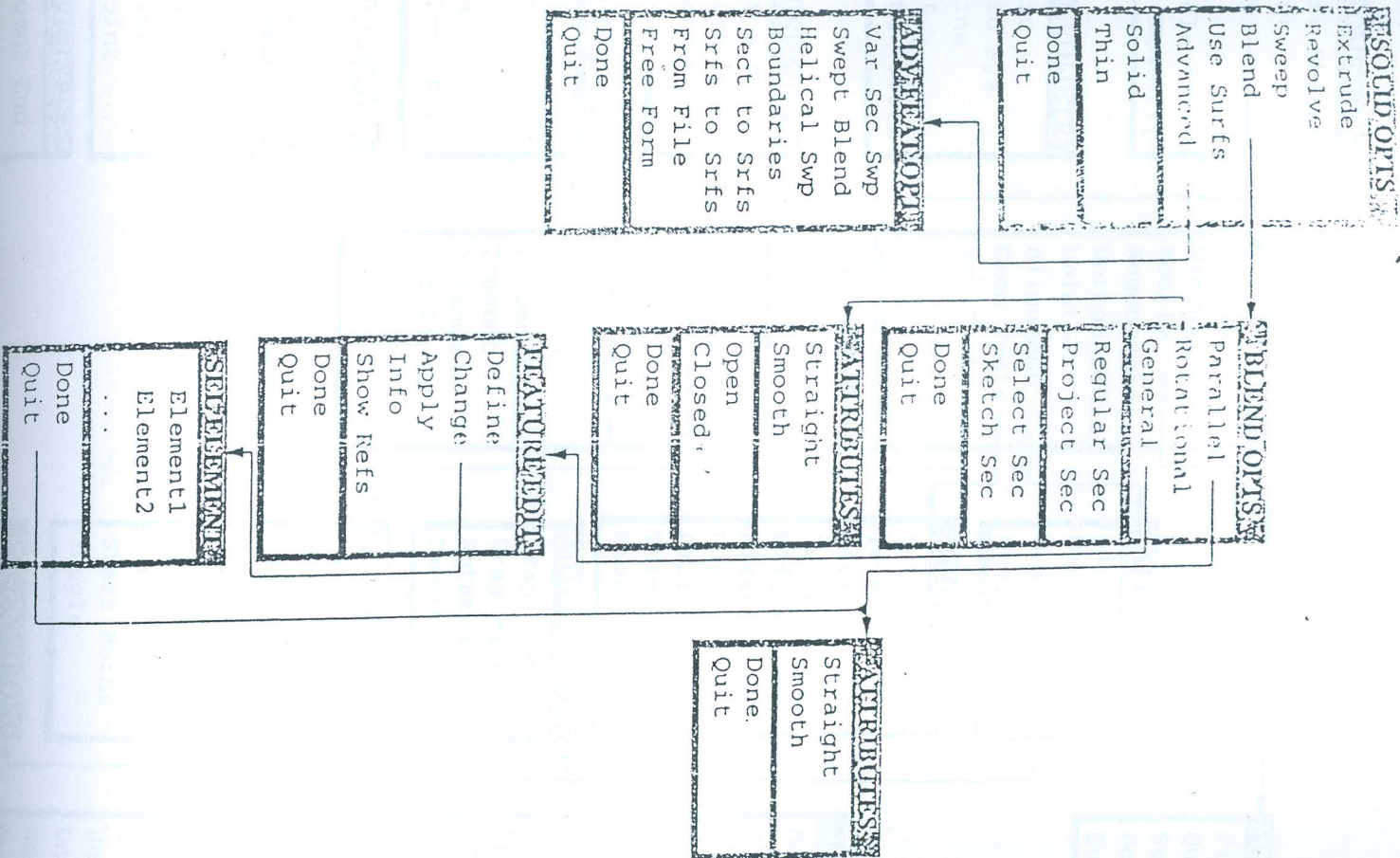
APPENDIX B

FORM MENU FOR PROTRUSIONS, CUTS, AND SLOTS



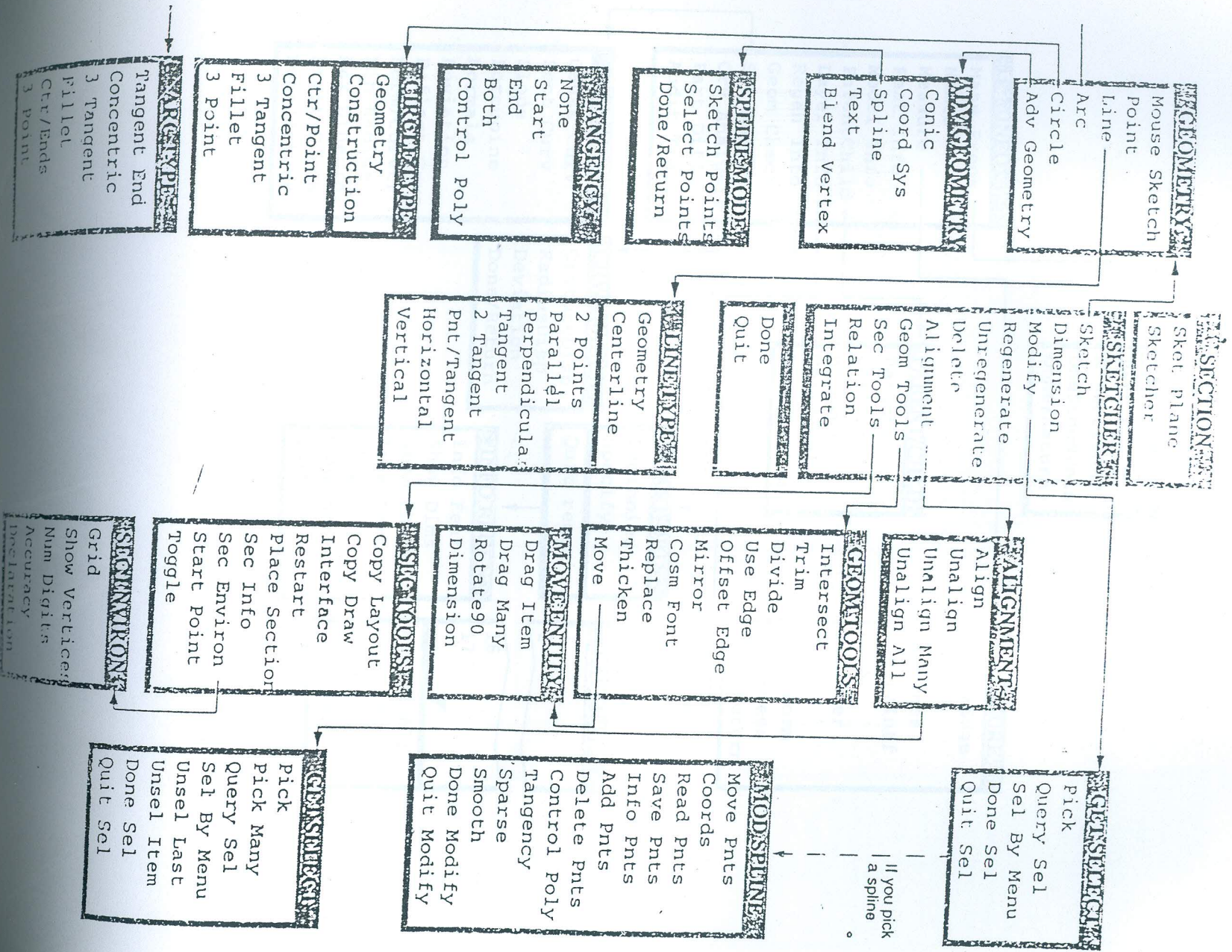
Sketch the Revolve feature

FORM MENU FOR BLENDS



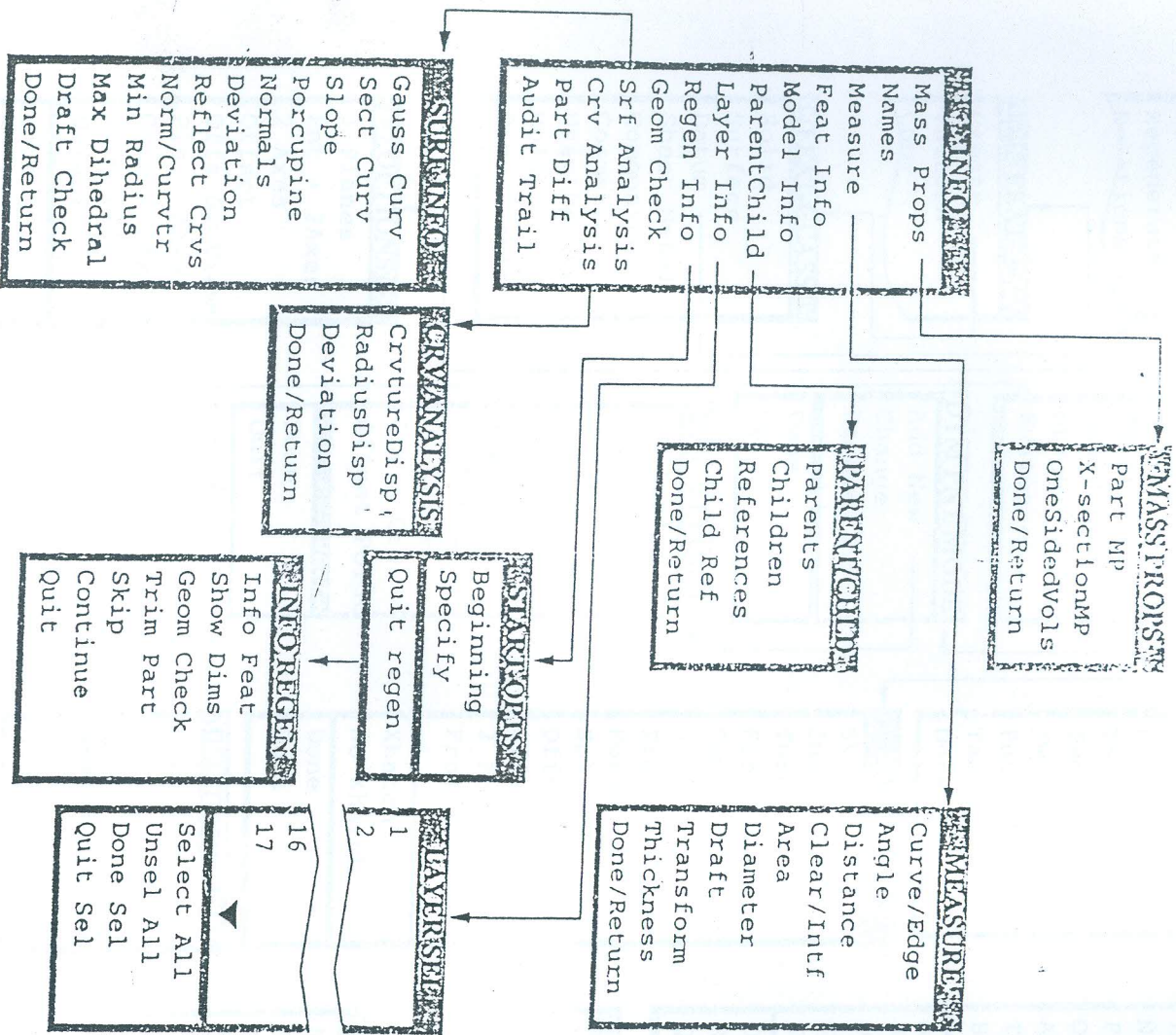
APPENDIX B

SKETCHER MENU



APPENDIX B

INFO MENU (IN PART MODE)



DATUM MENU

