Sketch Input of Engineering Euclidean Solid Models

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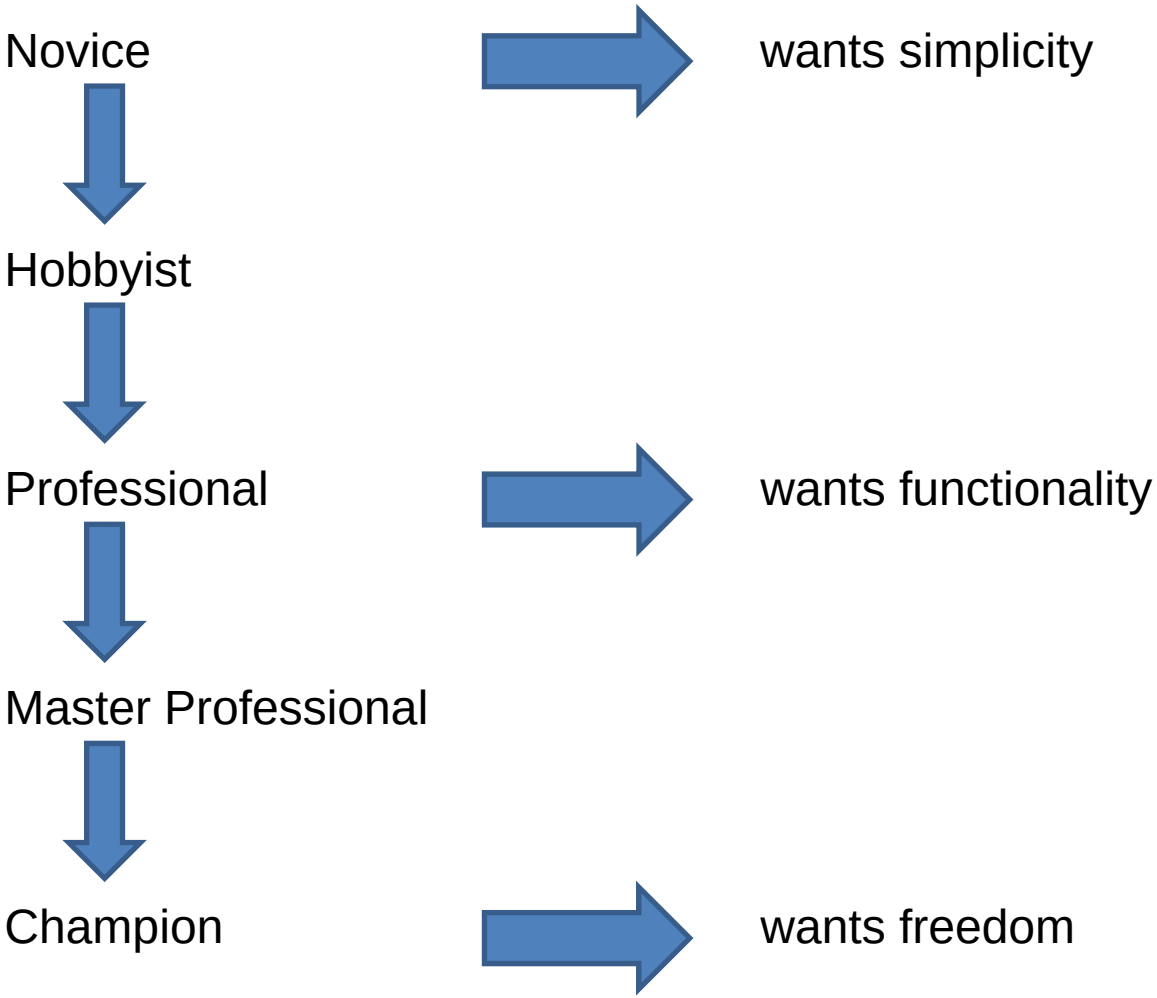
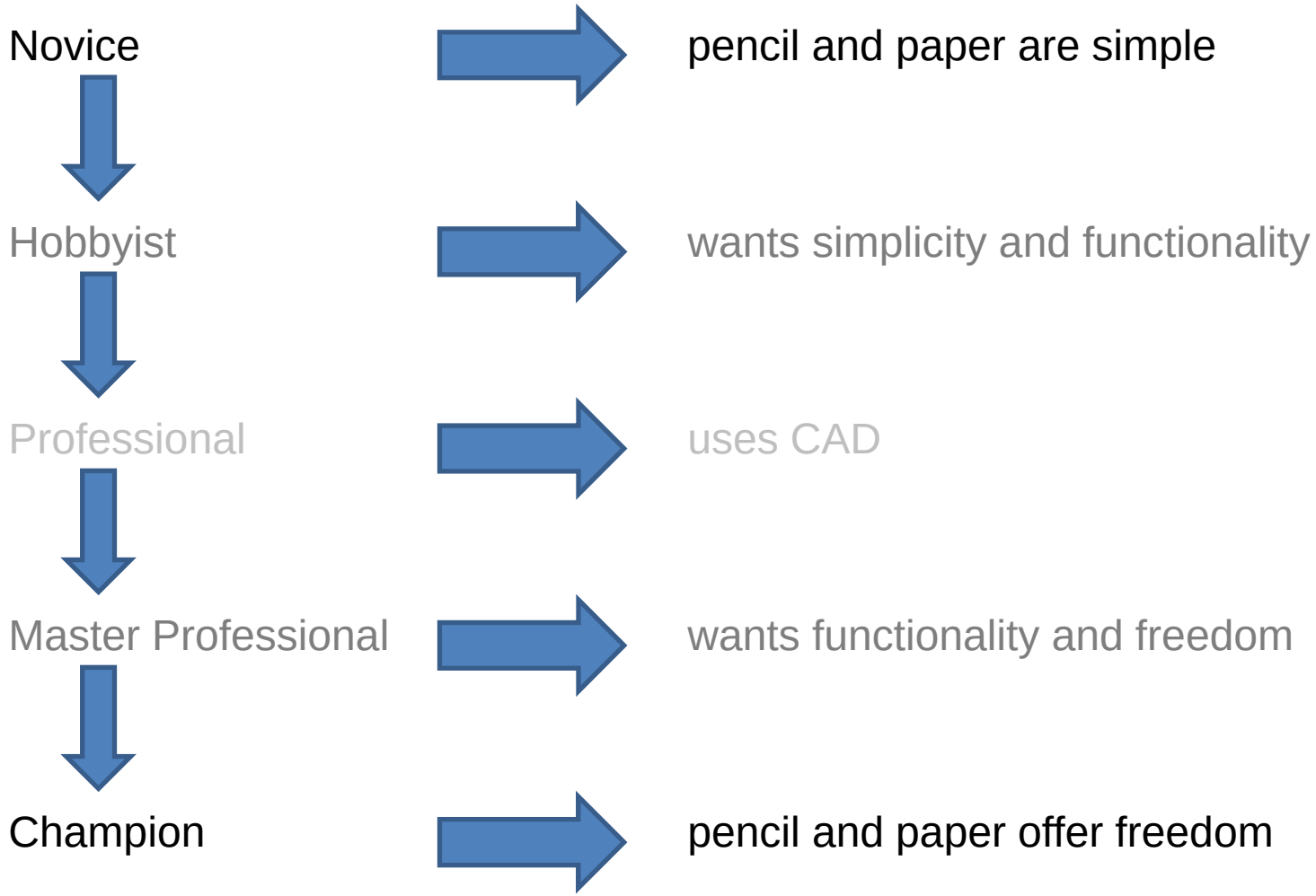
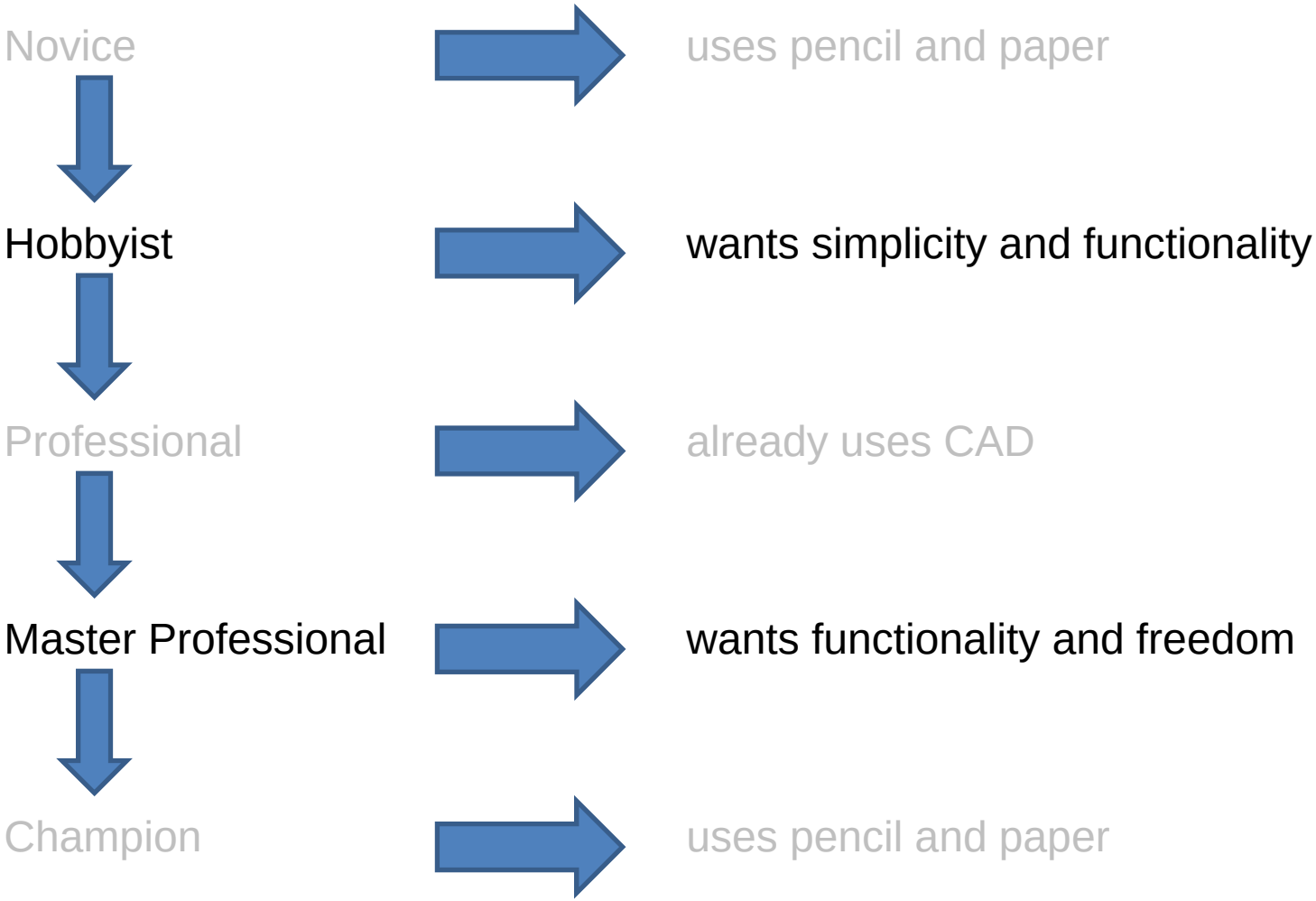
Who Creates Solid Models?



Who Sketches Solid Models?

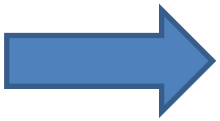


Who Wants Sketch-Based Modelling?



Sketch-Based Modelling has Two Targets

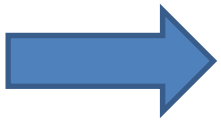
Hobbyist



Wants:
- Cheap tool (preferably free)
- Simple user interface
- Reasonable functionality

See, for example, Sculptris
http://www.drpetter.se/project_sculpt.html

Master Professional



Wants:
- The freedom of pencil and paper
- The power of pencil and paper to communicate
- The functionality of CAD
- More functionality

This is the subject of today's talk

SBM for Engineering Design

An engineering designer wants:

The freedom of pencil and paper:

- views of the object (orthographic, detailed, pictorial)
- scaffolding; highlighting; hidden lines; axes; hatching
- overtracing (autocorrection, thinking, decoration)
- annotating

The power of pencil and paper to communicate:

- design intent
- annotations: dimensions; cut views with hatching; icons; symbols …

The functionality of CAD

- standard computer operations: load, save, edit, copy, cut, paste …
- standard geometry operations: sweep, extrude, flip, repeat …

More functionality

- design intent

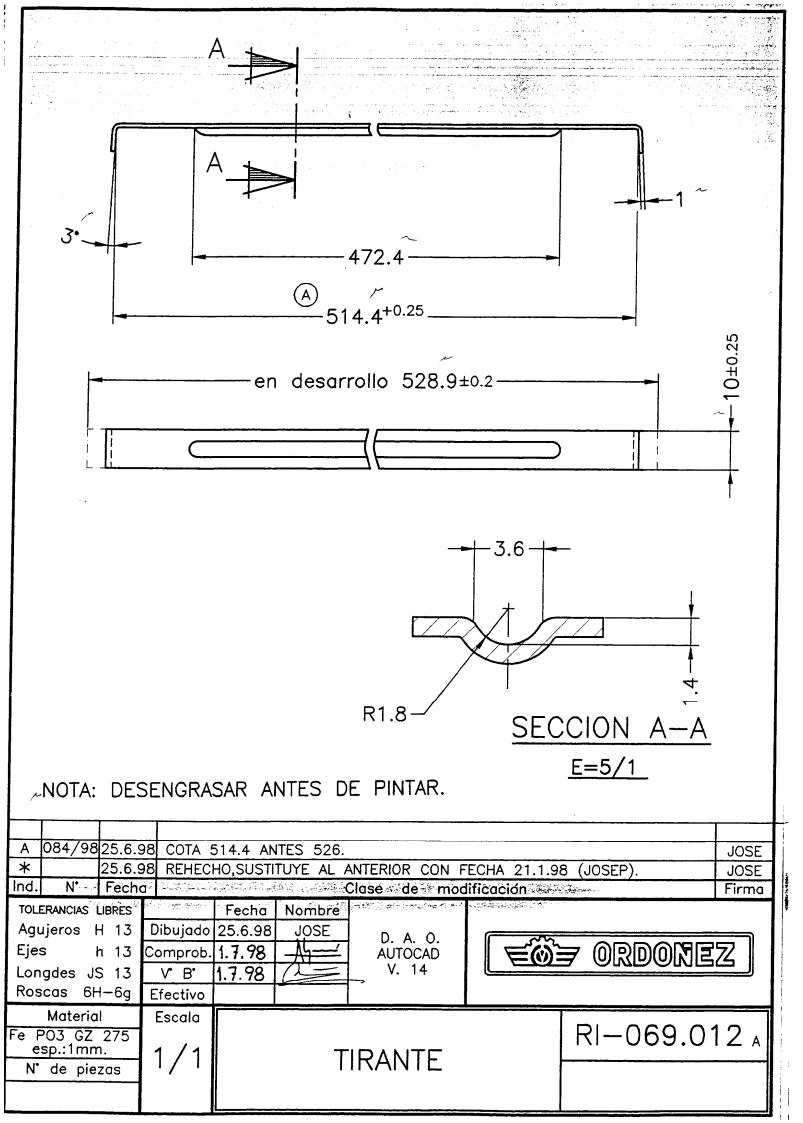
More freedom

Annotations

Engineers annotate their sketches

Other engineers read and understand the annotations

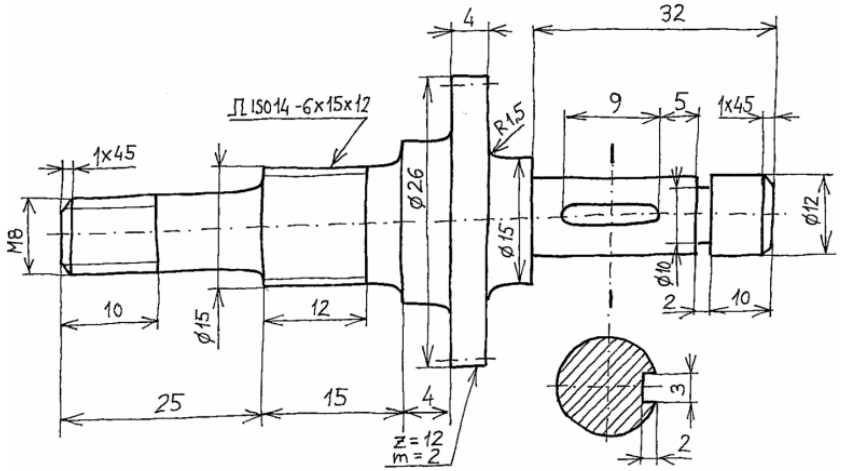
Computers can store annotations but (currently) do not understand them

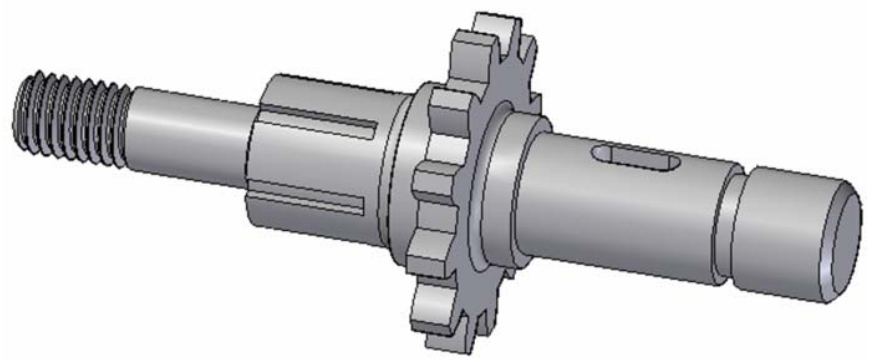


Annotations

The most interesting annotations are those which tell us something about the resulting solid model

Can we understand them and apply them to the model?





Annotations

Annotations can tell us various things about the model

Annotations convey information to other designers:

. What is the function of the part?
. What is the geometry? (e.g. dimensions and angles)

Annotations convey information to the machine shop

. How is this part to be manufactured?

Annotations convey information to the assembly line

. How does this part fit together with others?

Annotations are one expression of design intent

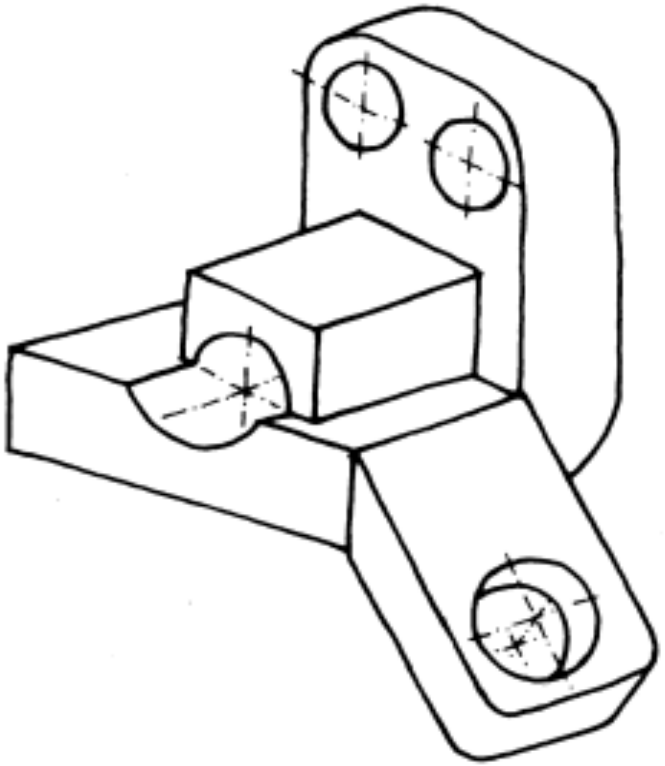
Design Intent

What does the designer *mean* by the sketch?

Designers use sketches to communicate with one another

- Other designers can deduce meaning from sketches
- Can we teach a computer to do this?

Design Intent



An engineer looking at this sketch sees:

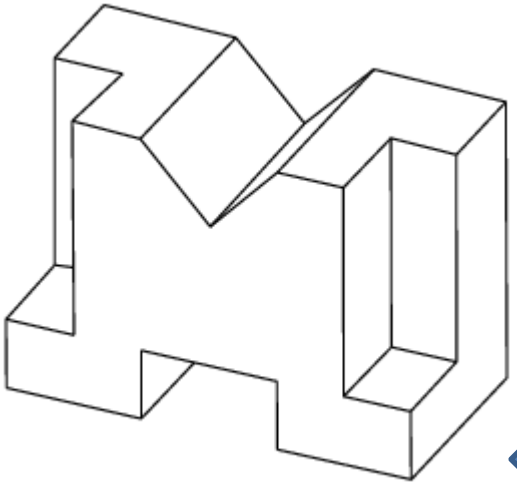
Geometry
… which constraints are important?

Features
… how can the part be manufactured?

Purpose
… what does it do?

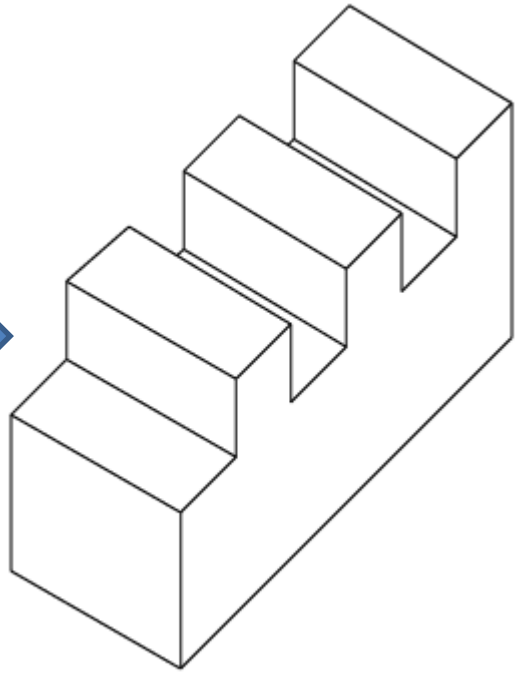
Design Intent includes all of these

Design Intent: Geometry

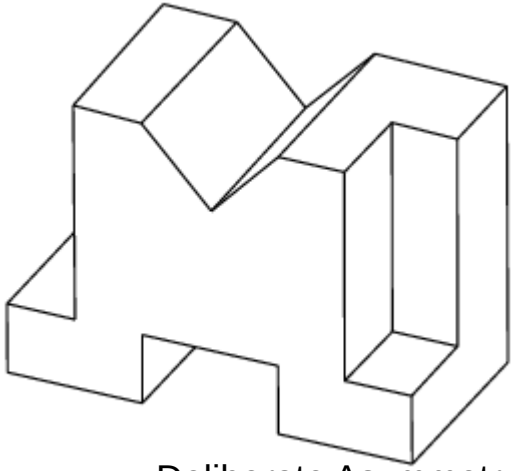


Symmetry

Right
Angles

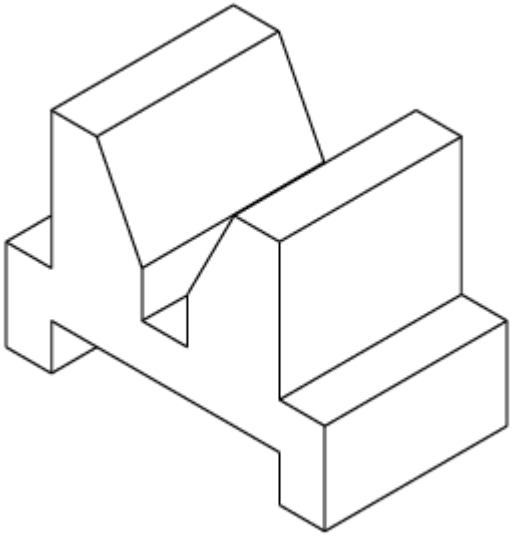


Regularity

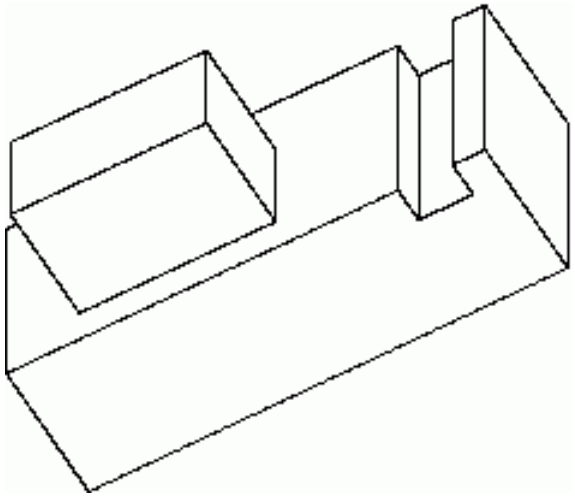


Deliberate Asymmetry

Design Intent: Manufacturing Features

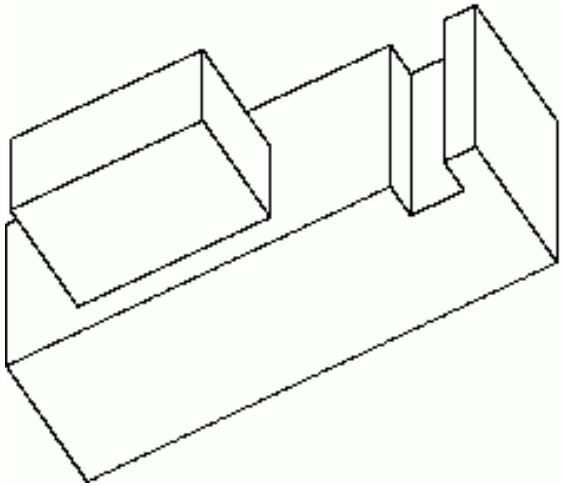


Extrusion



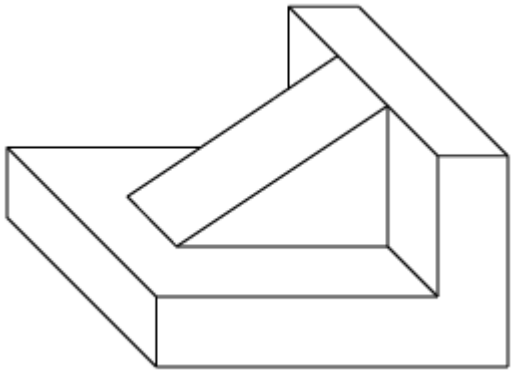
Slot (milled)

Design Intent: Function



Slot:

Guides the relative movement of parts in a mobile assembly

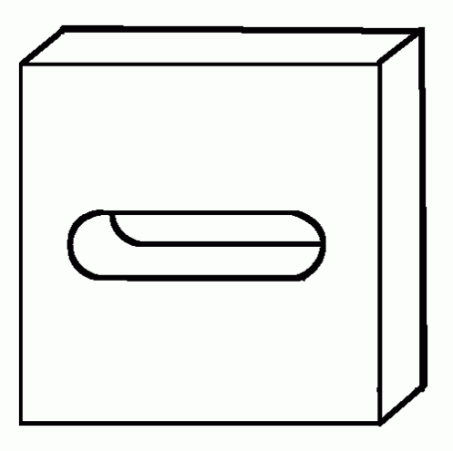


Rib:

Reinforces the structure without adding too much to weight or cost

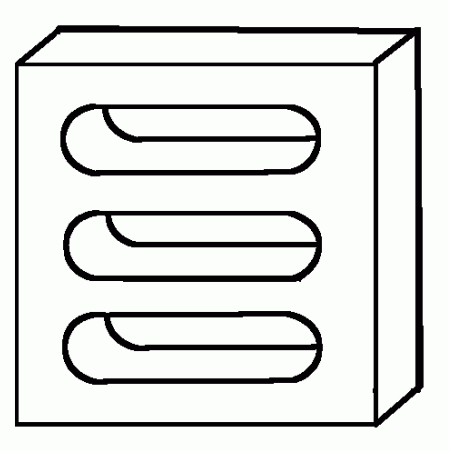
Design Intent: Context

Determining design intent is difficult:
Geometry, features and functions interact and are context-dependent



Oblong Hole:

One oblong hole is usually there to allow for misalignment of screws or bolts



Oblong Holes:

Two or more oblong holes are usually for ventilation, to allow hot air to escape …

… or maybe just to reduce the weight

Freedom and Design Intent

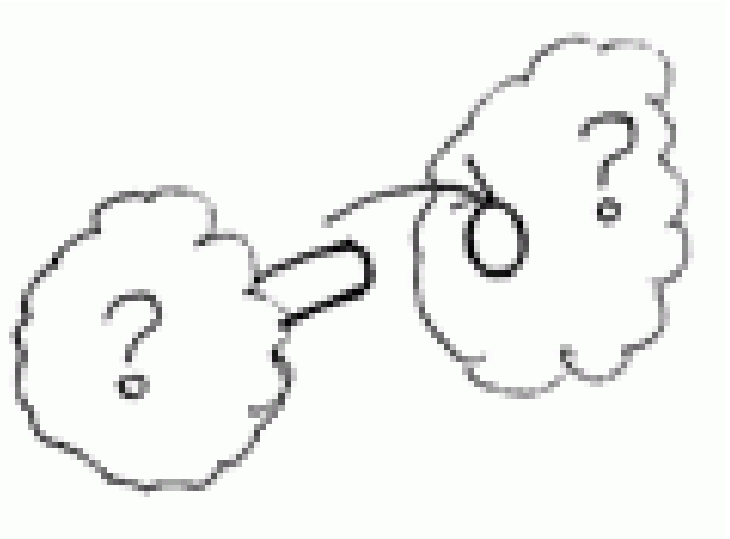
The designer needs to be free to choose the order in which things are created

Things which express design intent come first

Decorative detail can be left until last

In the example, the designer wants two (as yet undefined) objects to fit together

The fitting-together is the intent, so it should be the first thing to be defined



Freedom: Workflow

CAD is a useful tool for detailed design

But, neither CAD 2D nor CAD 3D is helpful for conceptual design
- both require a fully defined prior mental model

The designer provides *actions* to be executed by the CAD application
- *actions* are well defined sequential tasks

And this is not a good strategy while the designer is trying to realise *visions*
- *visions* are poorly-defined, non-sequential ideas

We want workflow which corresponds to real design workflow
- realising *visions*, not listing sequential *actions*

Freedom: Workflow

Ideal workflow:

Designer has idea

Designer sketches idea

Computer understands idea

Designer fills in details

Real-life workflow:

Designer has idea

Designer starts CAD package

Designer starts drawing

Computer demands concrete data (e.g. dimensions)

Designer enters concrete data

Designer continues drawing

Computer demands more concrete data

Designer enters more concrete data

Designer continues drawing

Designer forgets original idea …

Workflow: Do Not Disturb

Designers want to think about ideas, not about the tools they use
– Tools should be non-intrusive
– the designer should not have to think about them

Example: Mode switching

Pencil and paper: non-intrusive, just change the drawing angle or pressure

Single-key keyboard shortcut – fairly non-intrusive
- (normally, but beware language changes)

Multi-key keyboard shortcuts – fairly intrusive
- Not easy to remember them all

Selection from menus and submenus
-Very intrusive
- Moving outside the active area derails the designer’s train of thought

Conclusions

CAD tools offer engineering designers most of the functionality they need

CAD tools do not offer engineering designers:

Understanding
particularly understanding of annotations and design intent

Freedom
particularly freedom to order workflow

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