Sketch Input of Engineering Solid Models

1. Introduction and Taxonomy

Pedro Company
Peter Varley
Introduction

Sketches are drawings which are intended as preliminary explorations, not as finished works.

Sketches are an important kind of graphic.
We are interested in sketches as they assist product designers during the creative stages of product design.
Introduction

We know that people understand sketches!

If I draw this:

Most of you, if not all, perceive this:
We know that people understand sketches!

If I draw this:

Most of you, if not all, perceive this:

If I draw this:

Those of you who have been trained, perceive this:
Introduction

Computers are **blind** to engineering sketches!

*New computer tools are required!*
Introduction

Computers are **blind** to engineering sketches!

**New computer tools** are required!

⚠️ Computer-Aided Design (CAD) tools cannot solve the problem!

...because CAD applications are unable to work with:

- confused
- poorly structured
- incomplete ideas
Why not CAD?

CAD is a useful tool for detailed design:

**DESIGN-BY-DRAWINGS**
has been the major design approach since the end of the 17th century

Later, it was assisted by the computer (CAD 2D or CADD)

Finally, it is performed by the computer (CAD 3D)

Current paradigm is
**DESIGN BY "VIRTUAL" MODELS**
Why not CAD?

But, neither CAD 2D nor CAD 3D is helpful for **conceptual** design...

...as both require a **fully defined prior mental model**

- CAD 2D = Design by drawing
- CAD 3D = Design by models

The detailed geometry must be in their minds before they start producing the drawing/model!
Why not CAD?

The designer is asked to provide actions to be executed by the CAD application.

well defined sequential tasks!
Why not CAD?

The designer is asked to provide **actions** to be executed by the CAD application.

And this is not a good strategy while the designer is trying to fix **visions**.

The TOOL is conditioning the TASK!

well defined sequential tasks!

poorly-defined, non-sequential ideas!
But computers are *blind* to engineering sketches!

New computer tools are required!

The scientific area aimed at solving this problem is known as:

**SBIM**

Sketch-Based Interfaces and Modelling
We consider SBIM to be divided into three main spheres of work and several different sectors:

- **Sketch Understanding**
  - Input & Interaction
  - Document image processing
  - Editing & Beautification
  - On-line
    - Batch
  - Segmentation
  - Textual processing
  - Graphics processing
  - Automatic
    - Interactive
      - Primitives
      - Regularities
      - Symbols
      - Menu-driven
        - Gesture-based

- **3D Modelling**
  - Interactive
  - Template Matching
  - 3D Reconstruction
    - Textual interpretation
    - Graphics interpretation
    - Global interpretation
    - Single view
    - Multiple views
    - Menu-driven
      - Gesture-based

- **Knowledge-based interpretation**

(More details in Annex 1)
We are currently interested in one particular sector:

Sketch Input of Engineering Solid Models

We name it as Sketch-Based Modelling
SBM tools have been developed to some extent.

But, DESIGNERS do not yet use Sketch-Based Modelling (SBM) tools!
What we now know as **Sketch-Based Modelling**…

…comes from what was formerly known as **Geometrical Reconstruction**
The former goal of geometrical reconstruction was extracting information from old engineering blueprints.

In other words, “archaeological” recovery of old know-how.
Background

But the task proved difficult...

...because the vectorisation stage is complex...

"Scanning's pretty fast, but then converting every little raster dot into a vector dot takes forever."

www.penwill.com
But the task proved difficult…

...because the vectorisation stage is complex...

…and because engineering drawings convey:

- 3D information represented through complex views
  - main orthographic views, particular views, cuts, etc.

- annotations
  - dimensions, tolerances, etc.

---

Background

The short term problem was solved through brute force:

Translation services were offered!

Although this goal is still alive in architecture:

The main **goal** of the reconstruction community changed in the 1990s. Nowadays, most of the systems are oriented toward **conceptual design** via **sketch-based modelling**.

Background

- Sketching
- 2D Reconstruction (or Beautification)
- 3D Reconstruction
- Pictorial view
- Top view
- Side view
- Front view

using sketches generated by the user as input data
Background

The goal has changed over time:

2D + paper $\iff$ 2D + computer

2D + paper $\iff$ 3D + computer

Conceptual design $\iff$ 3D + computer

VECTORISATION

RECONSTRUCTION

SBM
There is no general approach which solves all the SBM problems.

Some critical features produce different bottlenecks.

States of the art are different for every critical feature.

We propose a taxonomy of critical features!
The features we consider critical are:

1. Number of views
2. Types of surface
3. Variety of inputs
4. Design intent

(More details in Annex 3)

Two kinds of **VIEW** are distinguished for reconstruction approaches:

- **Multiple orthographic views**

- **Single pictorial view**

*(More details in Annex 4)*
Two kinds of **VIEW** are distinguished for reconstruction approaches:

- ✓ multiple orthographic views
- ✓ single pictorial view

(More details in Annex 4)
Two kinds of **VIEW** are distinguished for reconstruction approaches:

- **√ multiple orthographic views**
- **√ single pictorial view**

(More details in Annex 4)
Our classification distinguishes two kinds of SURFACE:

- algorithms which only accept **flat** surfaces

  They are generically known as polytopes

- algorithms which accept **curved** surfaces

(More details in Annex 5)
### Taxonomy

Our classification distinguishes two kinds of **SURFACE**:

- ✓ algorithms which only accept flat surfaces
  - They are generically known as polytopes
- ✓ algorithms which accept curved surfaces

Both have been studied, but planar surfaces are more developed.

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(More details in Annex 4)

Teddy: A Sketching Interface for 3D Freeform Design

Takeo Igarashi
Hidekiyo Tanaka
Satoshi Matsuoka

http://www-ui.is.s.u-tokyo.ac.jp/~takeo/teddy/teddy/teddy.html
INPUT comprises:

1. perfect line drawings
2. line drawings containing some “geometrical” mistakes
3. freehand sketches
All three input types have been studied, but…

…perfect line-drawings were the most frequent in the beginning …

…now (in single view approaches) we are evolving towards hand-drawn line-drawings
Use of **HIDDEN LINES** in the input drawing results in two different inputs:

- **wireframes** (transparent models)
  - methods where the input includes all lines in the drawings

- **natural** (opaque models)
  - methods which reconstruct from an input which only contains the visible edges

All lines must be drawn in the input, but generally there is no need to distinguish between visible and hidden lines.

The system generally infers the rear part of the model after reconstructing the front part.
Natural drawings have been less studied than wireframes.

The need to infer the rear of the object makes the reconstruction process more difficult.

**Taxonomy**

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**Design Intent** and CAD have been linked for many time

However, the definition of Design Intent is ambiguous

Back in 1989 Design Intent was associated with design constraints and the methods of manipulating design constraints during product design activities.


...it still continues to be for many people!
When CAD people use the word “design”, they usually mean “model”.

Modelling is just representing the design in some way.

Design intent equates to the phrase Design for Change.

This implies that you are modelling a concept that can be flexible through changes.

[http://www.dezignstuff.com/blog/?p=3612](http://www.dezignstuff.com/blog/?p=3612)
Something has been done in the SBM sector to cope with design intent understood as design-for-change. However, no practical approaches have yet considered the explicit capture of complex design intent from the input sketches!
Taxonomy

We understand design intent as a mix of:

- **Geometry**  
  ...as far as it is linked to the shape

- **Psychology**  
  ...as far as it is not always explicit in the sketches

- **Engineering**  
  ...as far as it is linked to the function
We understand design intent as a mix of:

- **Geometry**
- **Psychology**
- **Engineering**

When geometry dominates, design intent is mainly conveyed through geometrical features which have already been studied as “regularities”.

We understand design intent as a mix of:

- **Geometry**
- **Psychology**
- **Engineering**

Information not explicitly included is perceived through "perceptual cues" sometimes clues.

Fundamentals of perceptual cues have been studied:

We understand design intent as a mix of:

✓ Geometry
✓ Psychology
✓ Engineering

When function dominates, design intent is mainly conveyed through "engineering features"
Consequently, we can define **Design Intent** as:

The set of intentions in sketches conveyed though **cues**, which, when perceived, reveal **regularities** or **features** of the object.

Just a few of them have already been studied:

- Edge parallelism
- Face planarity
- ...
Example:

Early detection of symmetry in a 2D line-drawing and improvement of the reconstruction process by making use of symmetry.

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Summary

WIMP user interfaces are not appropriate for conceptual design stages

But SBM tools are not yet used
Summary

SBM tools look suitable, but need improvement.

Roughly speaking, there are two categories of problem:

✓ Problems where a reasonably good solution exists

✗ Open problems

...although some improvements are still required

Our taxonomy helps in finding critical features which must be studied further:

1. Number of views
2. Types of surface
3. Variety of inputs
4. Design intent
Next presentations

In the second presentation we shall describe the main stages in an SBM process

We shall describe in detail the most important algorithms for required by an SBM process when the inputs are wireframe drawings:

1. Finding faces for polyhedral shapes
2. Inflating polyhedral shapes
3. Rounds and fillets

Starts ** time **
Next presentations

In the third presentation we shall describe some algorithms required by an SBM process where the inputs are natural drawings:

1. Fleshing out frontal geometry
2. Deducing the back of the object
Next presentations

In the **fourth** presentation we shall briefly introduce some **long term open problems** in the sector of SBM tools:

1. Making virtual paper and pencil more usable than actual paper and pencil
2. Interpreting annotated engineering sketches
3. Creating assemblies from sketches