PrintTalk
A Constraint-Based Imperative DSL for 3D Printing

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Modelling Techniques

- Direct Modelling
- Parametric Modelling
Modelling Techniques

- Direct Modelling
- **Parametric Modelling**

  ✓ Suitable for Programmatic 3D Design

  ✓ Parts of a Composite 3D Design can be **Assembled**, **Adapted** and **Reused** in a Systematic Way

```
A CSG Tree

difference(){
  intersection(){
    cube(100, center=true);
    sphere(60);
  };
  rotate([90, 0, 0]){ 
    cylinder(h=100, r=40, center=true);
  };
};
```

Parametric Modelling in OpenSCAD
Problem

Existing Parametric Modelling Languages do not support Constraints

• Hard to Express certain Aspects of 3D Models without Constraints

• Examples:
  • “Shape A should be on top of Shape B”
  • “Shape A should be Equidistant from Shapes B and C”
PrintTalk

Main Components:

• **Gadgets** for Reuse and Parameterisation and Composition

• **Constraints** and **Constraint Variables** for Improving Reusability

• **Topologies** for Automation

(gadget: <name>
  (<parameters>)
  (<constraint-vars>)
  (script: <scripts>)
  (constraints: <constraints>))

PrintTalk Topologies
Example Program
Cube with a Hole

```printTalk
(gadget:
  cube-hole
  (x y z cube-size)
  (cyl-dia)
  (script:
    (cylinder x y z cyl-dia cube-size)))
(constraints:
  (constraint:<! cyl-dia cube-size)))
(print: (cube-hole 0 0 0 10) "cube-hole.stl")
```
Combining Gadgets
Implementing PrintTalk

The PrintTalk Toolchain:

- **PrintTalk Program** → **Racket Parser** → **S-expressions** → **Racket Expander + Evaluator** → **SMT script** → **Z3** → **Values** → **OpenSCAD script** → **OpenSCAD** → **3D Printing Object**

- **G-code** (from Slicer)
- **STL file** (from OpenSCAD)

- **Racket**
Evaluating PrintTalk

**Design Science:** Compare PrintTalk to alternative Languages for designing the same Object.

- OpenSCAD vs. PrintTalk without Constraints
  - ✓ Similar Complexity

- OpenSCAD vs. PrintTalk with Constraints
  - ✓ Most Suitable Paradigm can be selected for each Problem
  - ✓ Not all Calculations must be performed explicitly
  - ✓ Increased Reusability of Gadgets that contain Constraint Variables
Future Work

• Maturity of the Prototype
• Constraint Solver
• Third-party software (OpenSCAD)
• User-Defined Topologies
• Error Handling
• Static Analysis
Conclusion
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