



# Integration of conductive materials and SMD-components into FDM printing process

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University of Hamburg  
TAMS

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## 1. Introduction

- State of research
- Concept

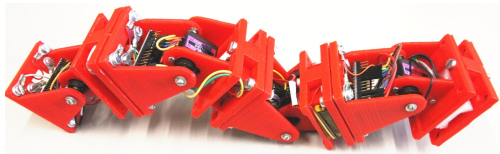
## 2. Progress

- Hardware setup
- Control software
- Material tests

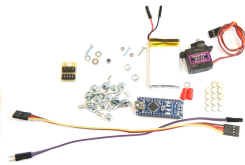
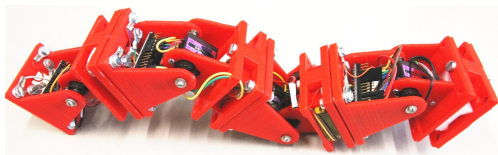
## 3. Next Steps



# Application example

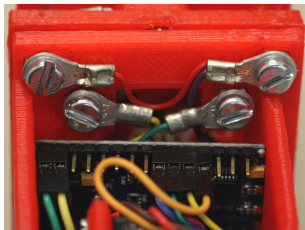
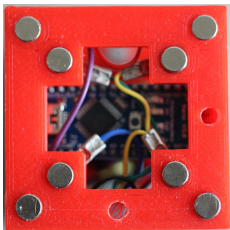
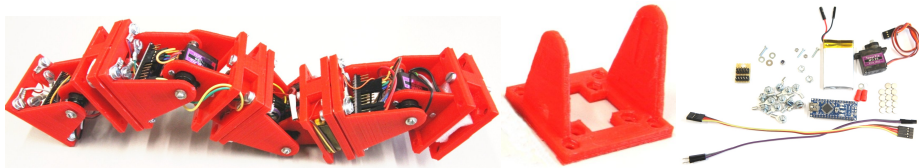


# Application example

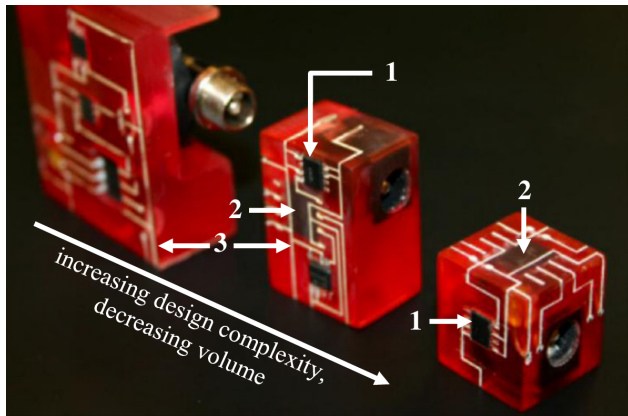




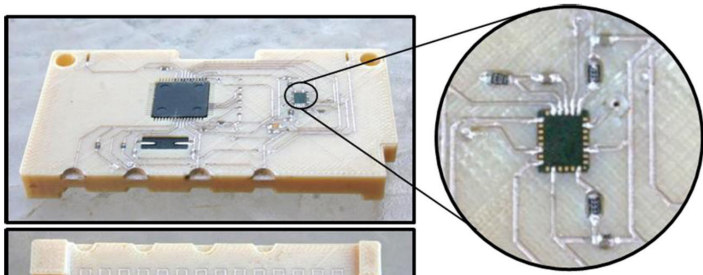
# Application example



## 3-Dimensional magnetic flux sensor



## 2D circuit on FDM surface



D. Espalin et. al *3D Printing multifunctionality: structures with electronics*. Int J Adv Manuf Technol, 2014



# Basic Concept

## Idea

- ▶ Printing "wires" with second, conductive material
- ▶ Embedding SMD-Components on printed wires

## Requirements

- ▶ Conductive material / extruder
- ▶ Pick 'n place hardware
- ▶ Editor "Object ↔ Schematic"
- ▶ Extended slicing software





# Basic Concept

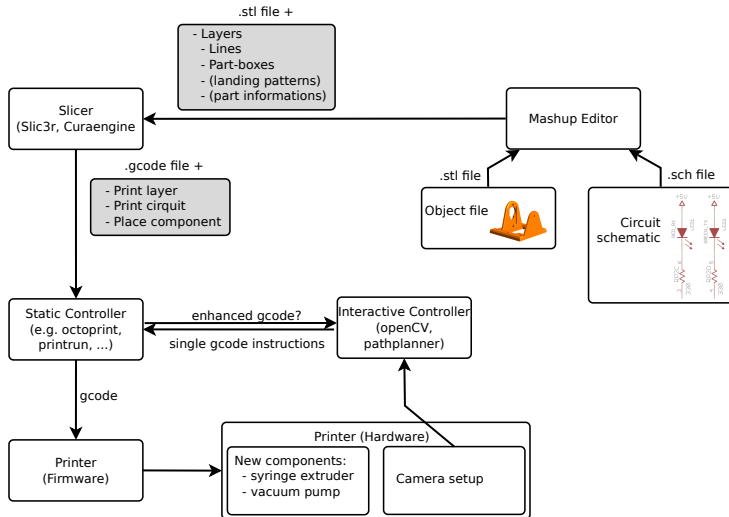
## Idea

- ▶ Printing "wires" with second, conductive material
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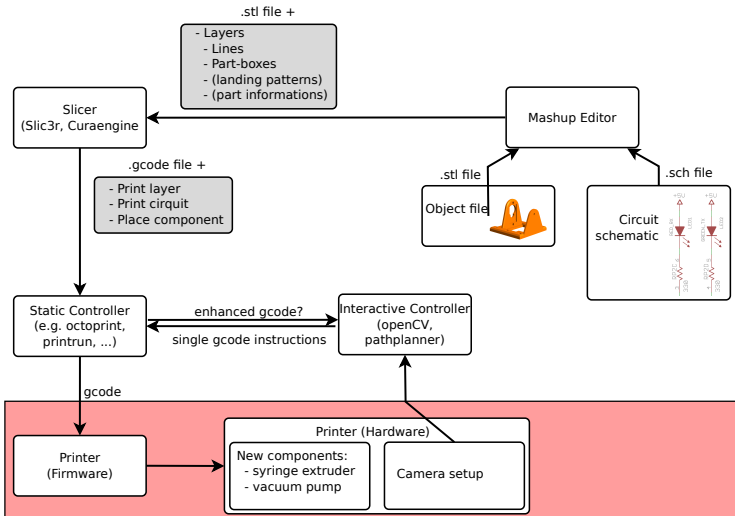
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- ▶ Editor "Object ↔ Schematic"
- ▶ Extended slicing software

# Basic Concept

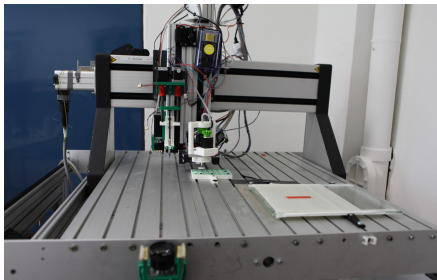


# Basic Concept



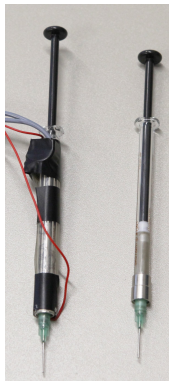
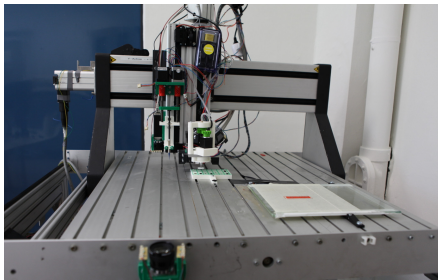
## Hardware setup

- ▶ Milling cutter as printing platform
- ▶ Syringe Extruder
- ▶ Vacuum pipette / cameras
- ▶ Object tray
- ▶ Migration to professional platform



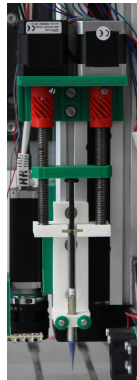
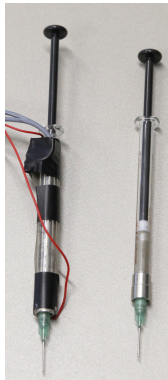
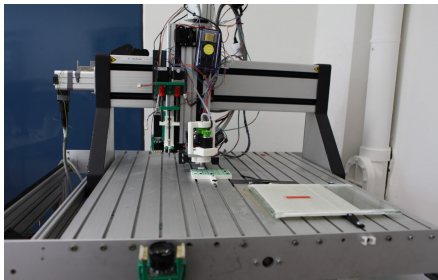
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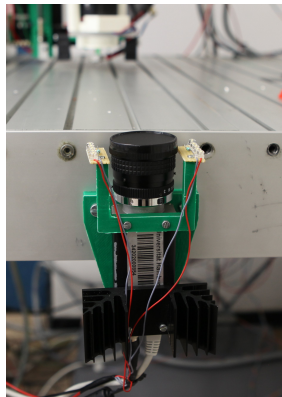
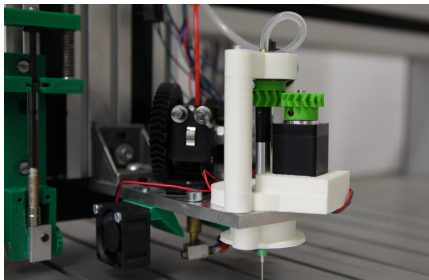
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## Hardware setup

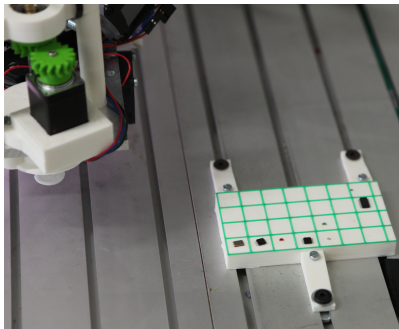
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- ▶ Object tray
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# Hardware setup

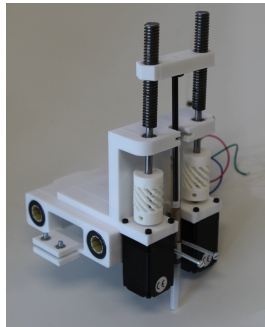
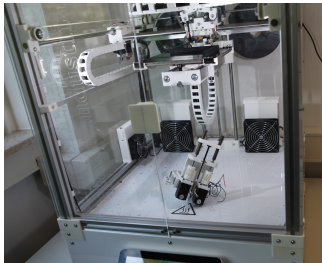
- ▶ Milling cutter as printing platform
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- ▶ Object tray
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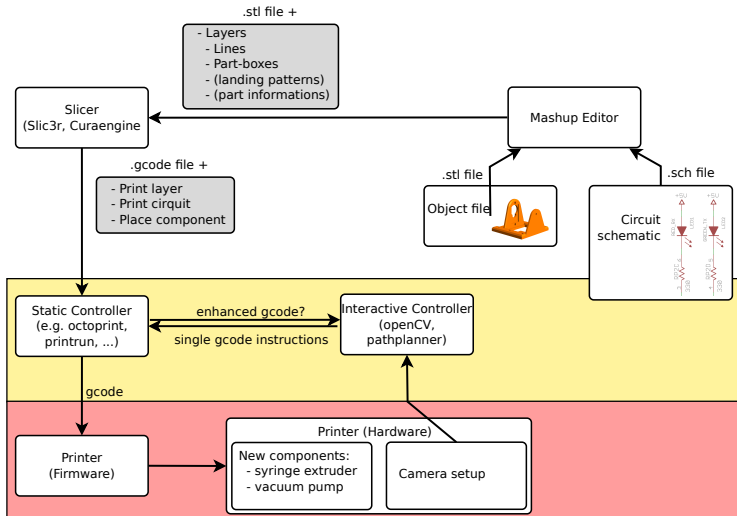


## Hardware setup

- ▶ Milling cutter as printing platform
- ▶ Syringe Extruder
- ▶ Vacuum pipette / cameras
- ▶ Object tray
- ▶ Migration to professional platform



# Basic Concept



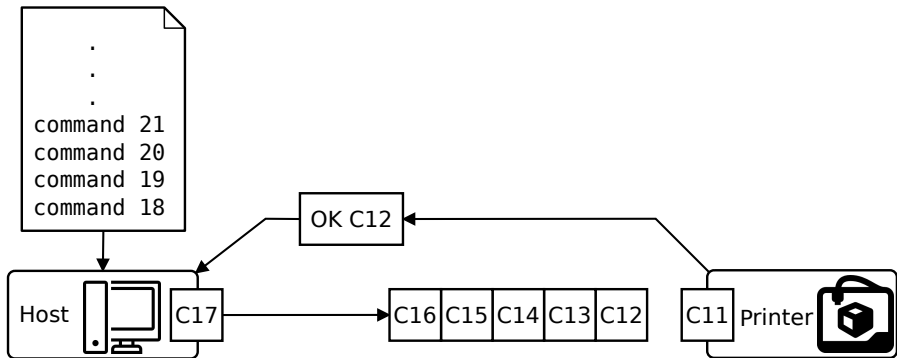


## Gcode extension

```

1  G28
2  G1 X10 Y35 Z10.48 F3000
3  M361 P4
4
5  ;<part id="1" name="LED_1206">
6  ; <position box="4" />
7  ; <size height="1.05" />
8  ; <shape>
9  ;   <point x="value" y="value" />
10 ;   <point x="value2" y="value2" />
11 ; </shape>
12 ; <pads>
13 ;   <pad x1="-0.4" y1="-0.8" x2="0.1" y2="0.3" />
14 ;   <pad x1="-1.4" y1="-0.8" x2="-0.9" y2="0.3" />
15 ; </pads>
16 ; <destination x="104.938" y="27.987" z="8.000" orientation
    = "90" />
17 ;</part>
    
```

# Buffered control loop



# Host extension I

localhost:5000

vala symbol X11 could not b → ☆ 📁 ⬇️ 🔴 X Lo

**Verbindung**

**Status**

Druckerstatus: **Drucke**  
 Datei: **testfile\_short.gcode**  
 Zeitrafer: -  
 Ungefähre Druckdauer: **00:00:51**  
 Druckdauer: **00:00:01**  
 Verbleibende Druckdauer: **ein paar Sekunden**  
 Gedruckt: **53.0bytes / 1.5KB**

**Drucken** **Pause** **Abbruch**

**Dateien**

Suchen...

Größe: 2.5KB

**linear\_object\_pnp.gcode**  
Hochgeladen: vor 11 Tagen  
Größe: 36.3KB

**stick\_attiny\_pnp.gcode**  
Hochgeladen: vor 11 Tagen  
Größe: 85.3KB

**stick\_attiny\_pnp\_only.gcode**  
Hochgeladen: vor 11 Tagen

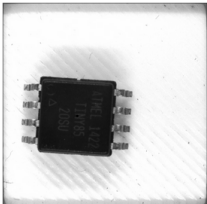
Temperatur Kontrolle GCode Viewer Terminal **OctoPNP**

**State**

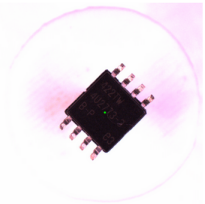
PNP State: **Loaded file with 4 SMD parts**  
 Current operation: **pick part nr 4**  
 DEBUG: a

**Camera images**

**Head camera**



**Bed camera**





# Host extension II

localhost:5000

vava symbol X11 could not b

Lokal | aus

## OctoPrint Einstellungen

### DRUCKER

[Serielle Verbindung](#)
[Druckerprofile](#)
[Temperaturen](#)
[Terminal Filters](#)

### FUNKTIONEN

[Funktionen](#)
[Webcam](#)
[API](#)

### OCTOPRINT

[Verzeichnisse](#)
[Aussehen](#)
[Logs](#)

### PLUGINS

[CuraEngine](#)
[OctoPNP](#)

### Tray

#### Tray position

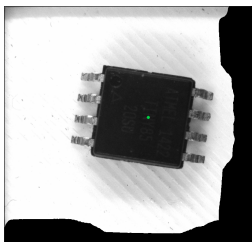
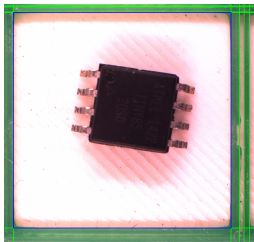
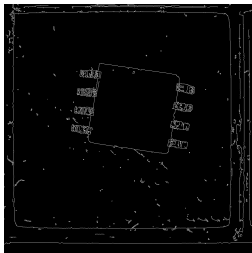
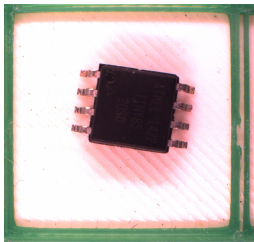
X	<input type="text" value="114,3"/>	mm
Y	<input type="text" value="357,7"/>	mm
Z	<input type="text" value="-0,6"/>	mm

#### Tray dimension

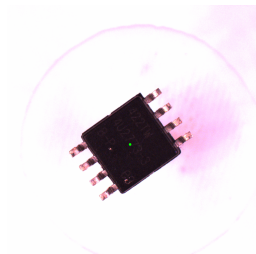
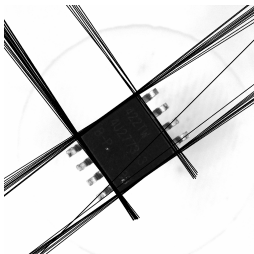
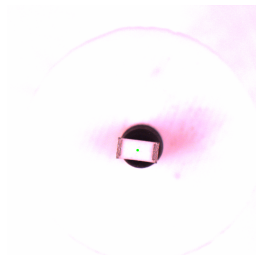
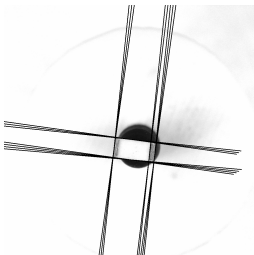
Rows	<input type="text" value="4"/>
Columns	<input type="text" value="7"/>
Box size	<input type="text" value="15"/> mm
Rim size	<input type="text" value="1"/> mm

### Cameras

# Pick 'n place

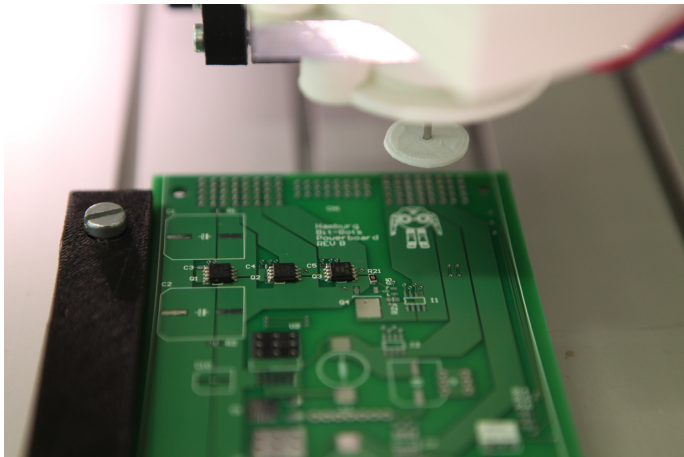


# Pick 'n place





# Ba-Thesis

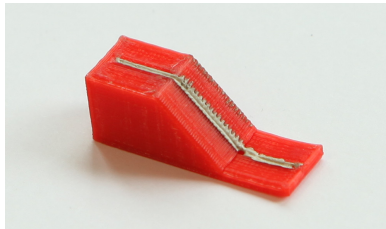
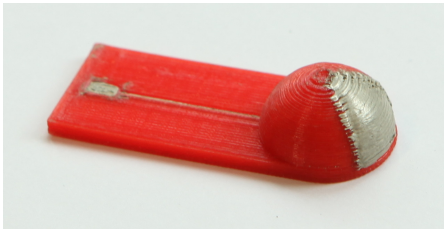




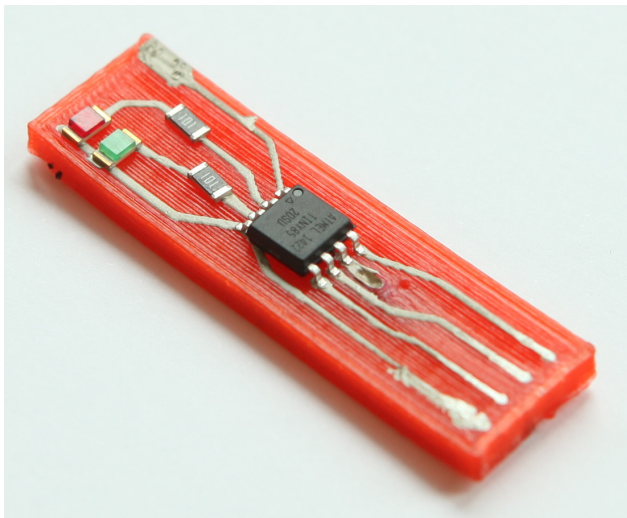
# Video



# Intermediate results I

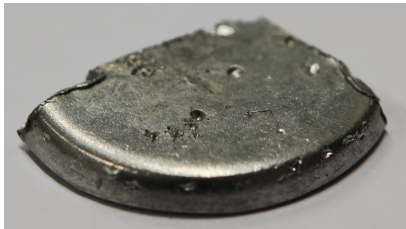


## Intermediate results II



# Conductive materials

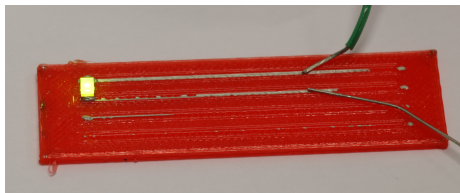
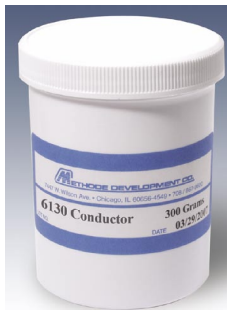
- ▶ Field's metal
- ▶ Silver filled polymer



Material	32.5Bi 51In 16.5Sn
M.P.	~ 62°C
Costs	~ 425 €/kg
Sheet res.	-

## Conductive materials

- ▶ Field's metal
- ▶ Silver filled polymer

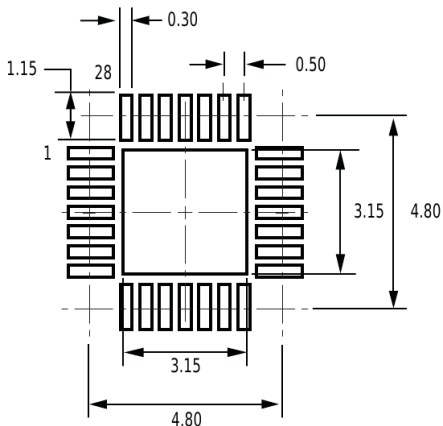


Material	#6130F
Curing	~ 20 min at 95°C
Costs	~ 2500 \$/kg
Sheet res.	0.04 Ω/□

# Evaluation

## Critical measures

- ▶ Channel width
- ▶ Conductivity
- ▶ Reliability
- ▶ Costs

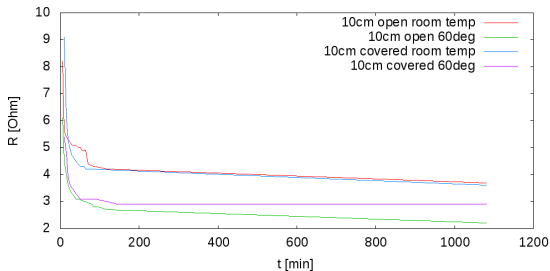




# Evaluation

## Critical measures

- ▶ Channel width
- ▶ Conductivity
- ▶ Reliability
- ▶ Costs





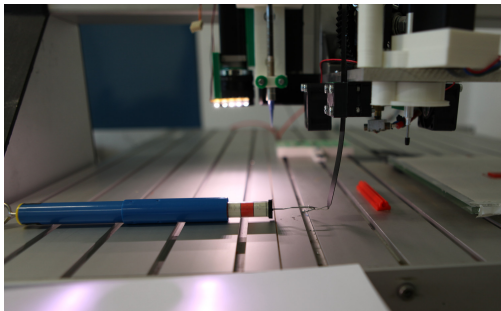


# Evaluation

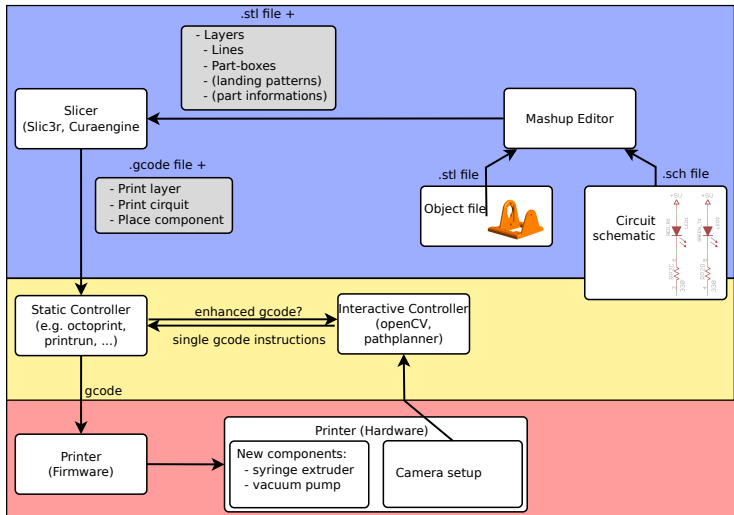
## Critical measures

- ▶ Channel width
- ▶ Conductivity
- ▶ Reliability
- ▶ Costs

Ongoing...



# Basic Concept

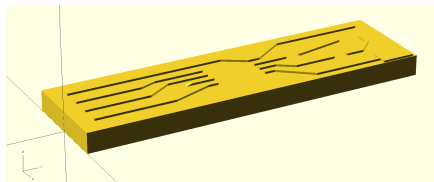




# challenges

## Integration into slicing process

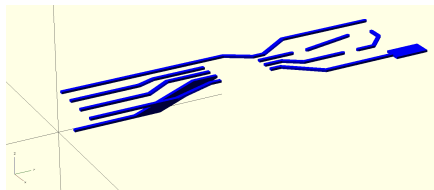
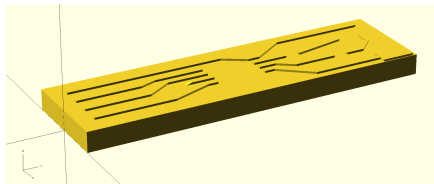
- ▶ Integration of circuit and SMD components into Slicing process
- ▶ 3D Routing and placing on or inside objects



# challenges

## Integration into slicing process

- ▶ Integration of circuit and SMD components into Slicing process
- ▶ 3D Routing and placing on or inside objects

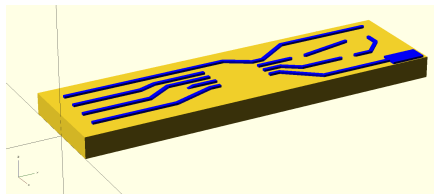




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## Integration into slicing process

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# challenges

## Integration into slicing process

- ▶ Integration of circuit and SMD components into Slicing process
- ▶ 3D Routing and placing on or inside objects

Ba-Thesis II



# Applications in robotics

- ▶ Integration / miniaturization
- ▶ Force- torque sensors
- ▶ Robot arm for part placement



# The end

# Thank you for your attention!