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

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TAMS

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   State of research
   Concept

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Application example
Application example
3-Dimensional magnetic flux sensor

2D circuit on FDM surface

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

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Requirements
- Conductive material / extruder
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- Editor "Object ↔ Schematic"
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Basic Concept

Introduction - Concept

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

Slicer (Slic3r, Curaengine)

- .stl file +
  - Layers
  - Lines
  - Part-boxes
  - (landing patterns)
  - (part informations)

Mashup Editor

- .sch file

Static Controller (e.g. octoprint, printrun, ...)

- Gcode file +
  - Print layer
  - Print circuit
  - Place component

- enhanced gcode?
- single gcode instructions

Interactive Controller (openCV, pathplanner)

Printer (Hardware)

New components:
- syringe extruder
- vacuum pump

Camera setup

Printer (Hardware)
Basic Concept

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  - Layers
  - Lines
  - Part-boxes
  - (landing patterns)
  - (part informations)

- .gcode file +
  - Print layer
  - Print circuit
  - Place component

- .sch file

- Enhanced gcode?

- Object file

- Printer (Hardware)
  - New components:
    - syringe extruder
    - vacuum pump
  - Camera setup

- Mashup Editor
  - Slicer
    (Slic3r, Curaengine)
  - (Layers
    - Lines
    - Part-boxes
    - (landing patterns)
    - (part informations)

- Interactive Controller
  (openCV, pathplanner)

- Static Controller
  (e.g. octoprint, printrun, ...)
  - gcode

- Printer (Firmware)
  - single gcode instructions
Hardware setup

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

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Camera setup

Printer (Hardware)
- New components:
  - syringe extruder
  - vacuum pump
- Camera setup
Gcode extension

```gcode
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

•
•
•
command 21
command 20
command 19
command 18

C11
C12
C13
C14
C15
C16

OK C12

C17

C11
Printer

C16 C15 C14 C13 C12
Host extension I

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

OctoPrint Einstellungen

**Tray**

**Tray position**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>114,3 mm</td>
</tr>
<tr>
<td>Y</td>
<td>357,7 mm</td>
</tr>
<tr>
<td>Z</td>
<td>-0,6 mm</td>
</tr>
</tbody>
</table>

**Tray dimension**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rows</td>
<td>4</td>
</tr>
<tr>
<td>Columns</td>
<td>7</td>
</tr>
<tr>
<td>Box size</td>
<td>15 mm</td>
</tr>
<tr>
<td>Rim size</td>
<td>1 mm</td>
</tr>
</tbody>
</table>
Pick ’n place
Pick 'n place
Ba-Thesis
Intermediate results I

[Images of 3D-printed objects showing integration of conductive materials and SMD-components into FDM printing process]
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

![Graph showing the change in resistance (R) over time (t) for different conditions. The graph compares 10 cm open room temp, 10 cm open 60 deg, 10 cm covered room temp, and 10 cm covered 60 deg conditions. The x-axis represents time in minutes, and the y-axis represents resistance in Ohms.]
Evaluation

Critical measures

▶ Channel width
▶ Conductivity
▶ Reliability
▶ Costs

Ongoing...
Basic Concept

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

University of Hamburg
MIN Faculty
Department of Informatics

Enhanced gcode?
.stl file +
- Layers
- Lines
- Part-boxes
- (landing patterns)
- (part informations)

Slicer
(Slic3r, Curaengine)

.gcode file +
- Print layer
- Print circuit
- Place component

Mashup Editor

Circuit schematic

Static Controller
(e.g. octoprint, printrun, ...)

gcode

enhanced gcode?

single gcode instructions

Interactive Controller
(openCV, pathplanner)

Printer (Hardware)

New components:
- syringe extruder
- vacuum pump

Camera setup

Printer (Firmware)
challenges

Integration into slicing process

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

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Integration into slicing process

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

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

Thank you for your attention!