

ROS-Based 3D On-Line Monitoring for LMD Robotized Cells

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Index

1. Motivation and Innovative Character.
2. Proposed Solution.
3. 3D Geometrical Monitoring.
4. Self-Calibration.
5. Experimental Results.
6. Conclusions and future work.

Motivation and Innovative Character



Laser Metal Deposition (LMD)

- Promising additive manufacturing technique.
 - Parts are built up layer by layer directly from a 3D CAD model.
- For repair and direct fabrication of pieces.
- Near-net-shape (close to the final shape).
- Manufacturing of large metallic parts.
 - The material is directly deposited on the previous surface.

LMD Issues

- Thermal heating accumulation produces geometrical distortions.
- Distortions rise in poor dimensional accuracy and defects.
- Traditional off-line process (with constant parameters) becomes unsuccessful.

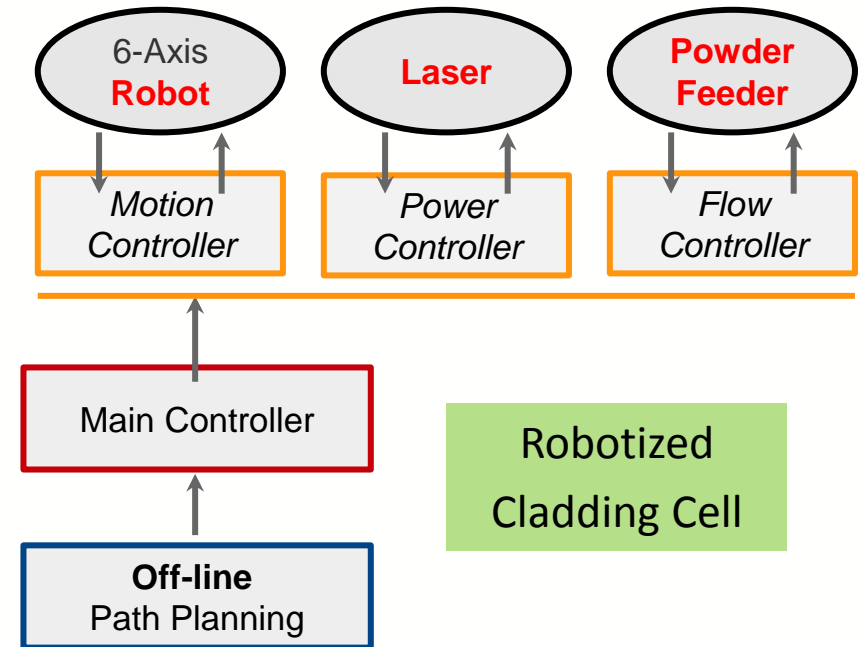
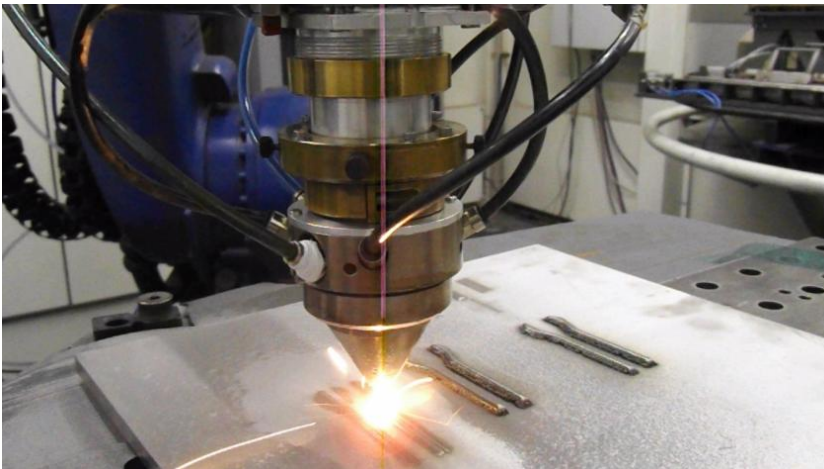


Motivation

- There are a lot of industrial robotized laser cells.
- Empower robotized laser cells for effective AM.

Innovation

- Retrofit current industrial facilities.
- Apply state of the art robotic software solutions.

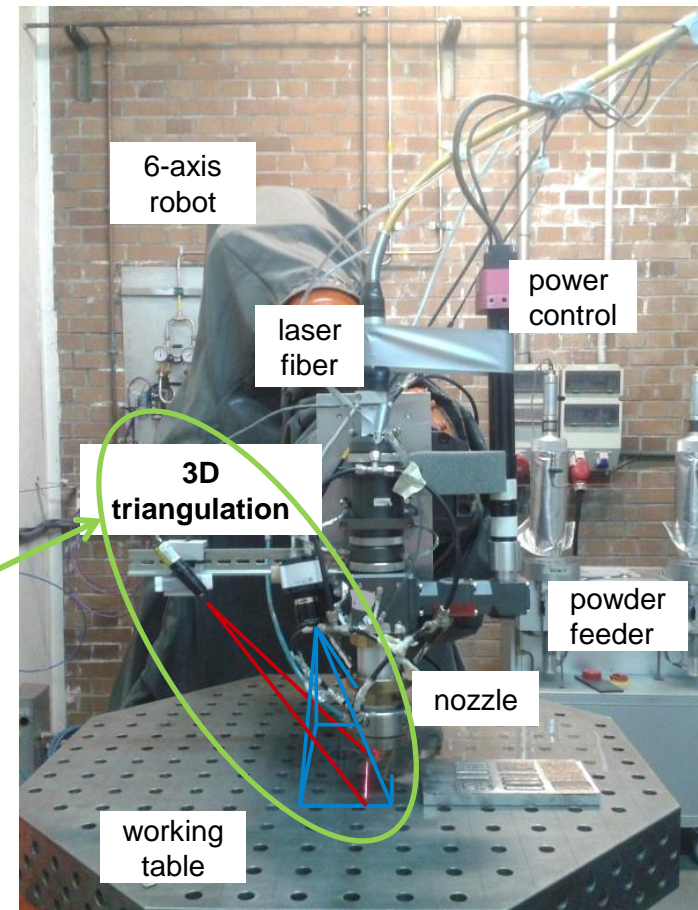
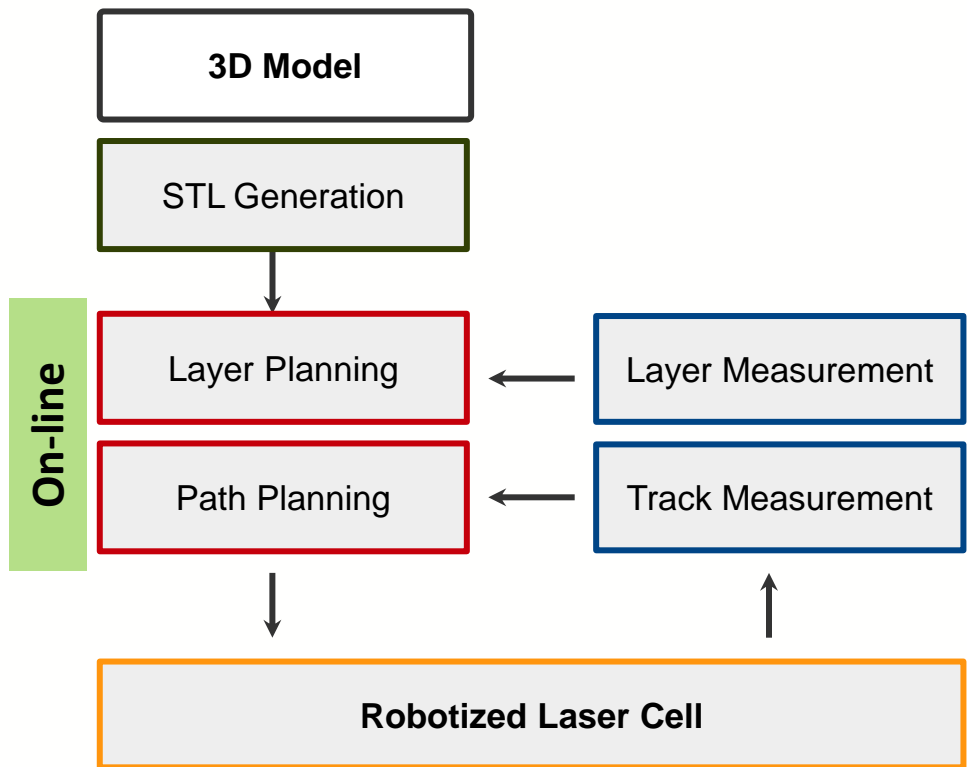


Proposed Solution



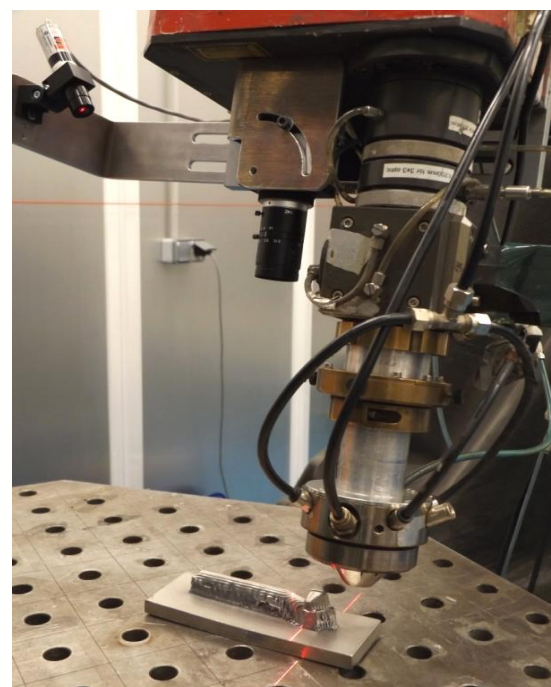
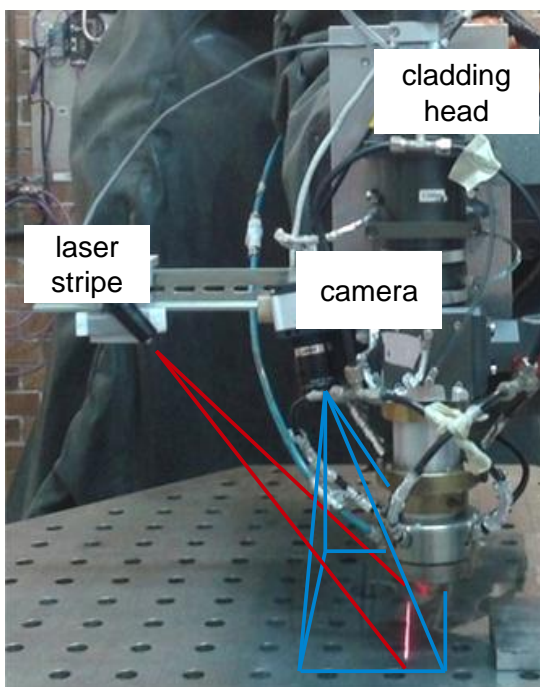
LMD geometrical control

- On-line geometrical monitoring.
- Adaptive path planning.



3D scanning setup

- Industrial CMOS camera.
- Industrial RED laser stripe.
- Fixture to attach the components to the laser cladding head.



3D Geometrical Monitoring

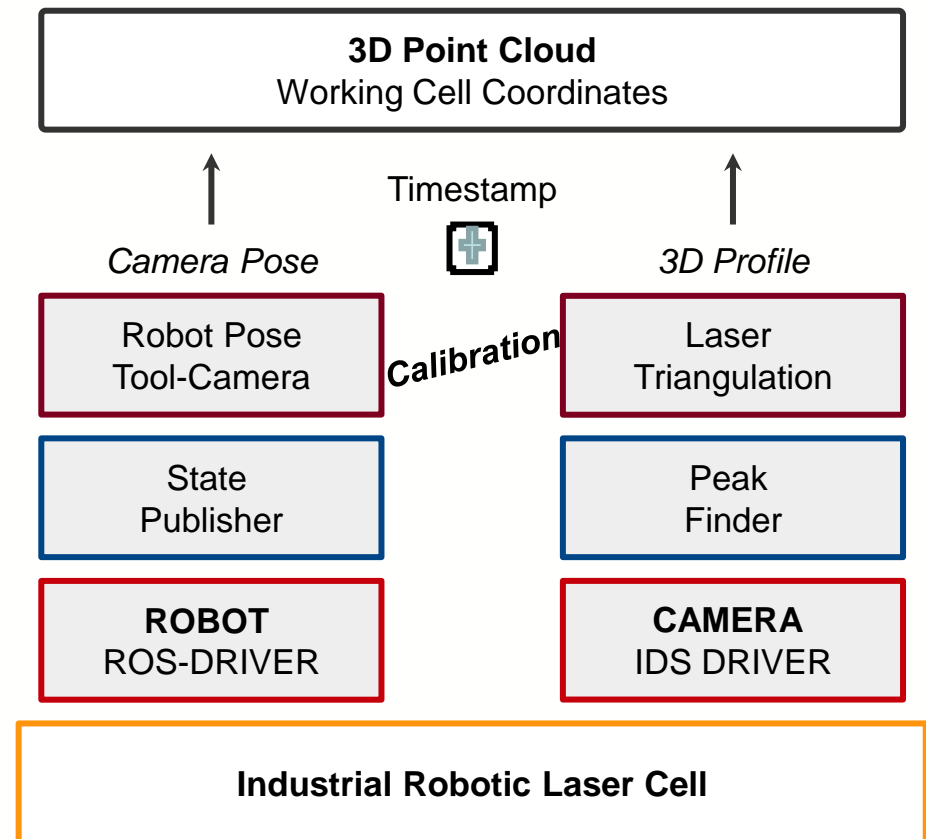


3D Geometrical Monitoring

- 3D point cloud (geometric information)
 - On-line generation.
 - In robot coordinates.
 - Independently of the speed.
 - No movement restrictions.
 - Free orientation.

Monitoring main tasks

- Laser Stripe Detection
- Laser Triangulation
- Transformation to robot coordinates



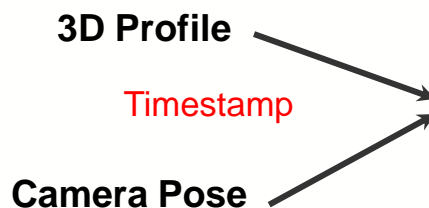
3D profile calculation

- Center Of Gravity method as peak finder.
- Point correspondence for 2D-to-3D mapping solution.

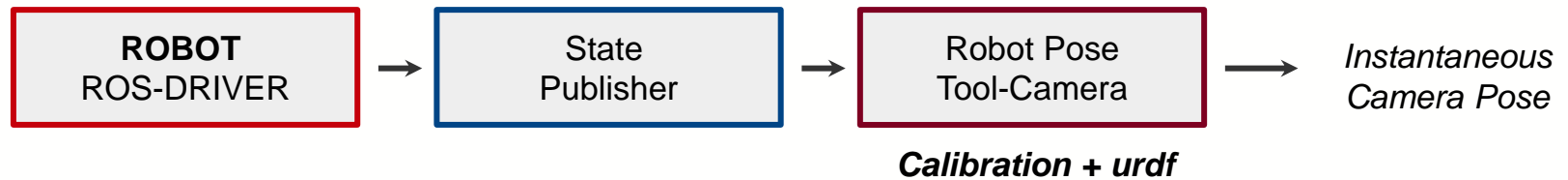


Point cloud reconstruction

- ROS-based
 - Tf library (interpolation)



ROS-Industrial components



ROS-Driver (ABB Rapid)

```

ROS_stateServer.mod x
35 LOCAL VAR socketdev client_socket;
36
37 PROC main()
38
39
40 TWrite "StateServer: Waiting for connection.";
41 ROS_init_socket_server_socket, server_port;
42 ROS_wait_for_client_server_socket, client_socket;
43
44 WHILE (TRUE) DO
45     send_joints;
46     WaitTime update_rate;
47 ENDWHILE
48
49 ERROR (ERR_SOCKET_TIMEOUT, ERR_SOCKET_CLOSED)
50 IF (ERRNO-ERR_SOCKET_TIMEOUT) OR (ERRNO-ERR_SOCKET_CLOSED) THEN
51     SkipWarn; ! TBD: include this error data in the message logged below?
52     ErrWrite W, "ROS StateServer disconnect", "Connection lost. Waiting for n
53     ExitCycle; ! restart program
54 ELSE
55     TRYNEXT;
56 UNDO
57 ENDPROC
58
59 LOCAL PROC send_joints()
60     VAR ROS_msg_joint_data message;
61     VAR jointtarget joints;
62     ! get current joint position (degrees)
63     joints := CJointT();
64
65     ! create message
66     message.header := [ROS_MSG_TYPE_JOINT, ROS_COM_TYPE_TOPIC, ROS_REPLY_TYPE_INVAL
67     message.sequence_id := 0;
68     message.joints := joints.robax;
69
70     ! send message to client
71     ROS_send_msg_joint_data client_socket, message;
72
73 ERROR
74 RAISE; ! raise errors to calling code
75 ENDPROC
76
77
78 ENDMODULE
    
```

```

abb_workcell.xacro x
1 <?xml version="1.0" ?>
2 <robot name="abb_workcell" xmlns:xacro="http://ros.org/wiki/xacro">
3
4     <property name="pi" value="3.141592654" />
5
6     <xacro:property name="tcp_frame">
7         <!-- origin xyz="0.3 0 0.12" rpy="0 -1.5708 0"/-->
8         <origin xyz="0.530 0.047 0.127" rpy="0 -1.5708 0" />
9     </xacro:property>
10
11     <xacro:property name="workobject_frame">
12         <origin xyz="1.655 -0.087 0.932" rpy="0 0 0" />
13     </xacro:property>
14
15     <xacro:property name="camera_frame">
16         <origin xyz="0.2879 -0.0399 0.1267" rpy="1.55420 0.00225 1.59185" />
17     </xacro:property>
18
19     <link name="world" />
20
21     <!-- Robot -->
22     <xacro:include filename="$(find abb_irb4400_support)/urdf/irb4400_macro.xacro"/>
23     <xacro:abb_irb4400 prefix="" />
24
25     <joint name="world-irb4400" type="fixed">
26         <parent link="world"/>
27         <child link="base_link"/>
28         <origin xyz="0 0 0.067" rpy="0 0 0" />
29     </joint>
30
31     <xacro:include filename="$(find etna_workcell)/urdf/irbp_a250.xacro"/>
32
33     <joint name="world-irbp_a250/base_link" type="fixed">
34         <parent link="world"/>
35         <child link="irbp_a250/base_link"/>
36         <origin xyz="1.755 0.014 0" rpy="0 0 -${pi/2}" />
37     </joint>
38
39     <link name="table0">
40         <visual>
41             <geometry>
42                 <mesh filename="package://etna_workcell/meshes/table/table.stl"/>
43             </geometry>
44             <material name="gray">
45                 <color rgba="0.4 0.4 0.4 0.4" />
46             </material>
47         </visual>
48     </link>
    
```

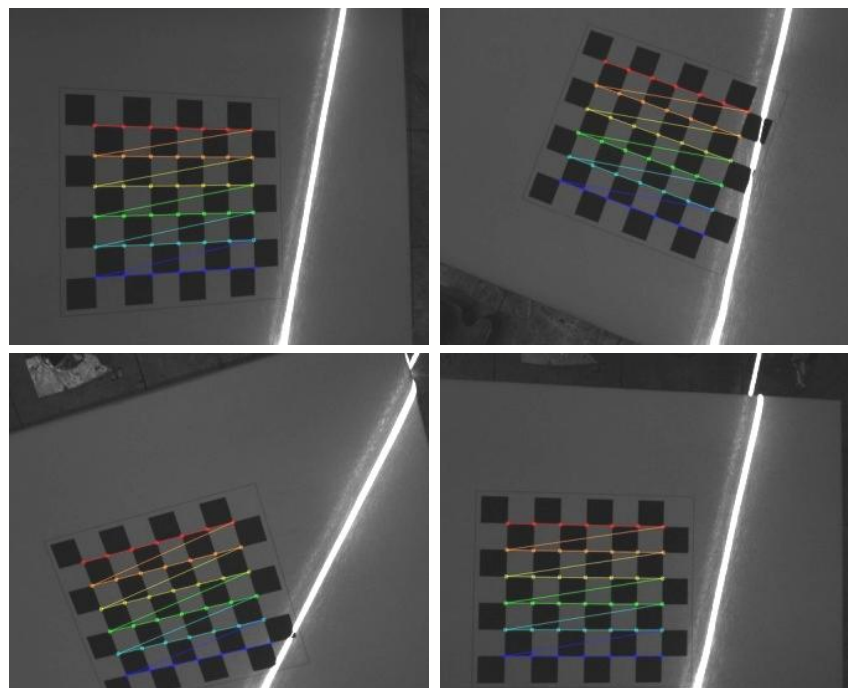
Geometrical Description of the Cell (urdf)

Self-Calibration



Calibration steps

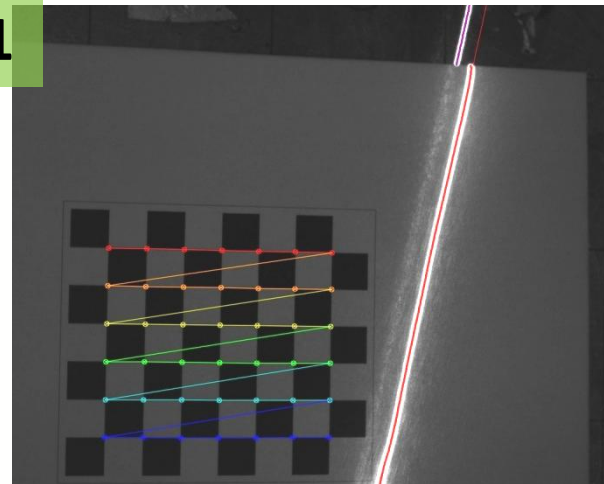
- Camera calibration (OpenCV method)
- Laser stripe calibration
- Hand-eye calibration (Classical method Tsai-Lenz)



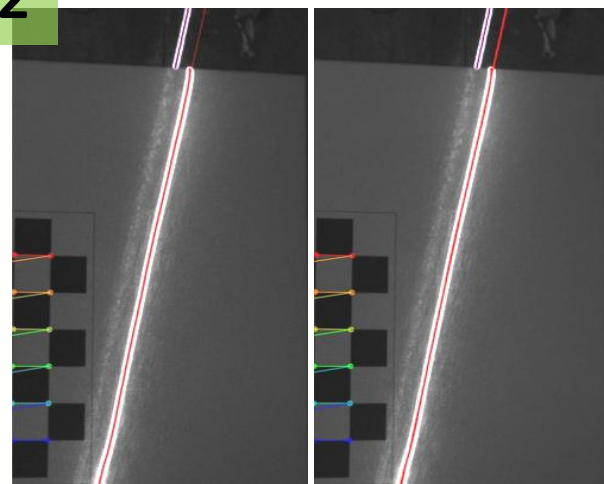
Laser stripe calibration steps

1. Checkerboard localization.
2. Laser stripe detection (RANSAC).
3. Laser plane estimation (RANSAC).
4. 2D-to-3D transformation matrix estimation.

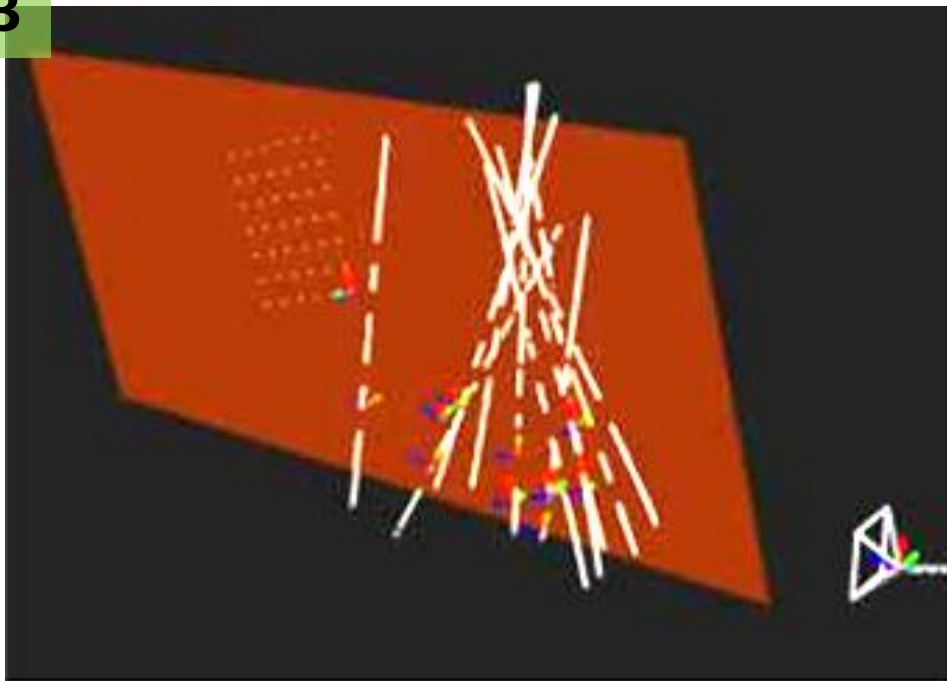
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2



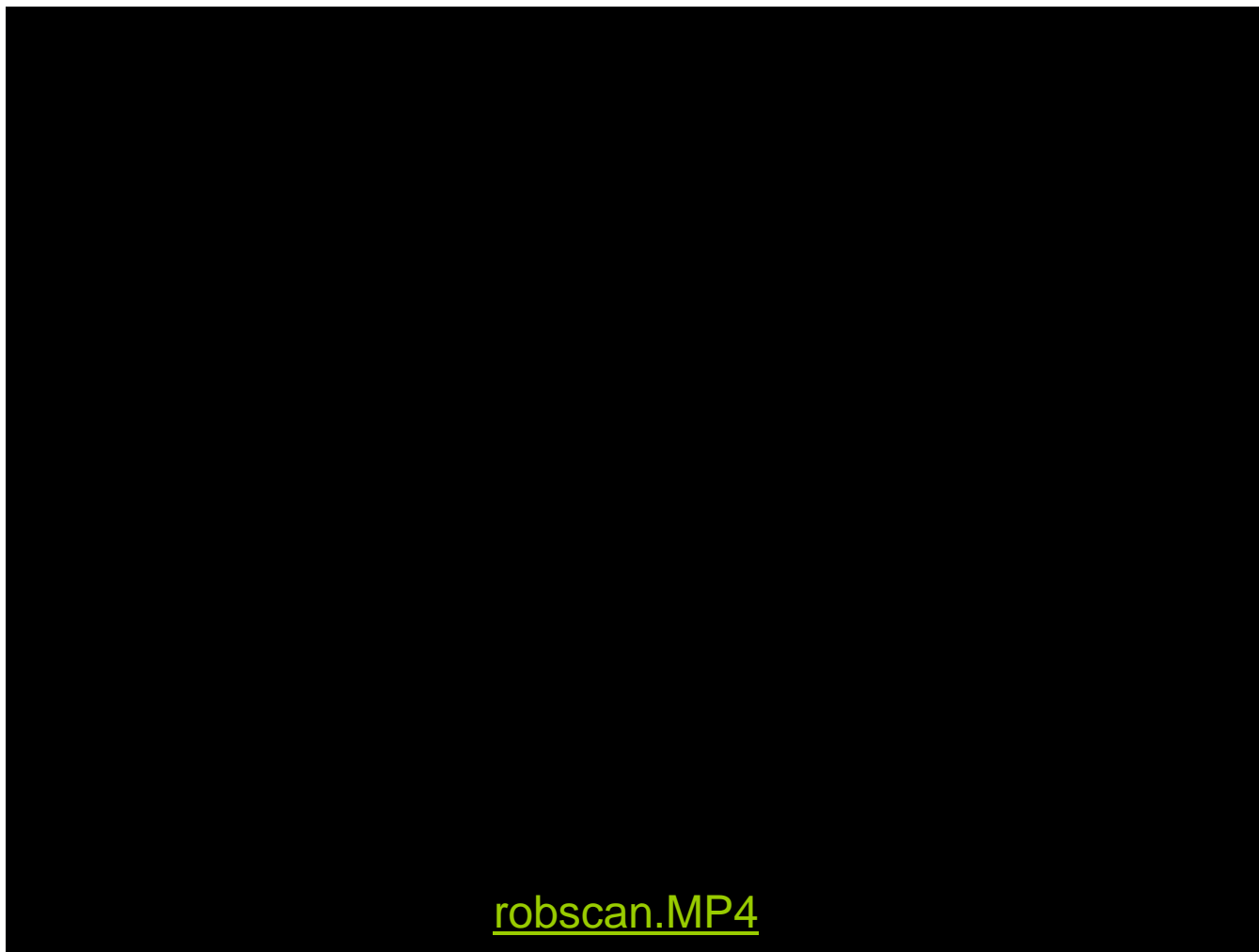
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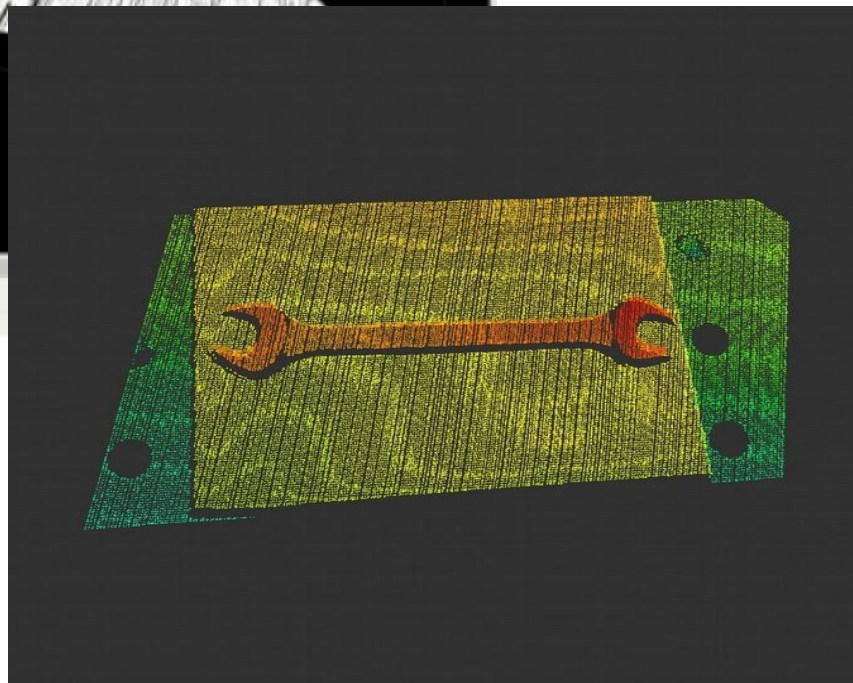
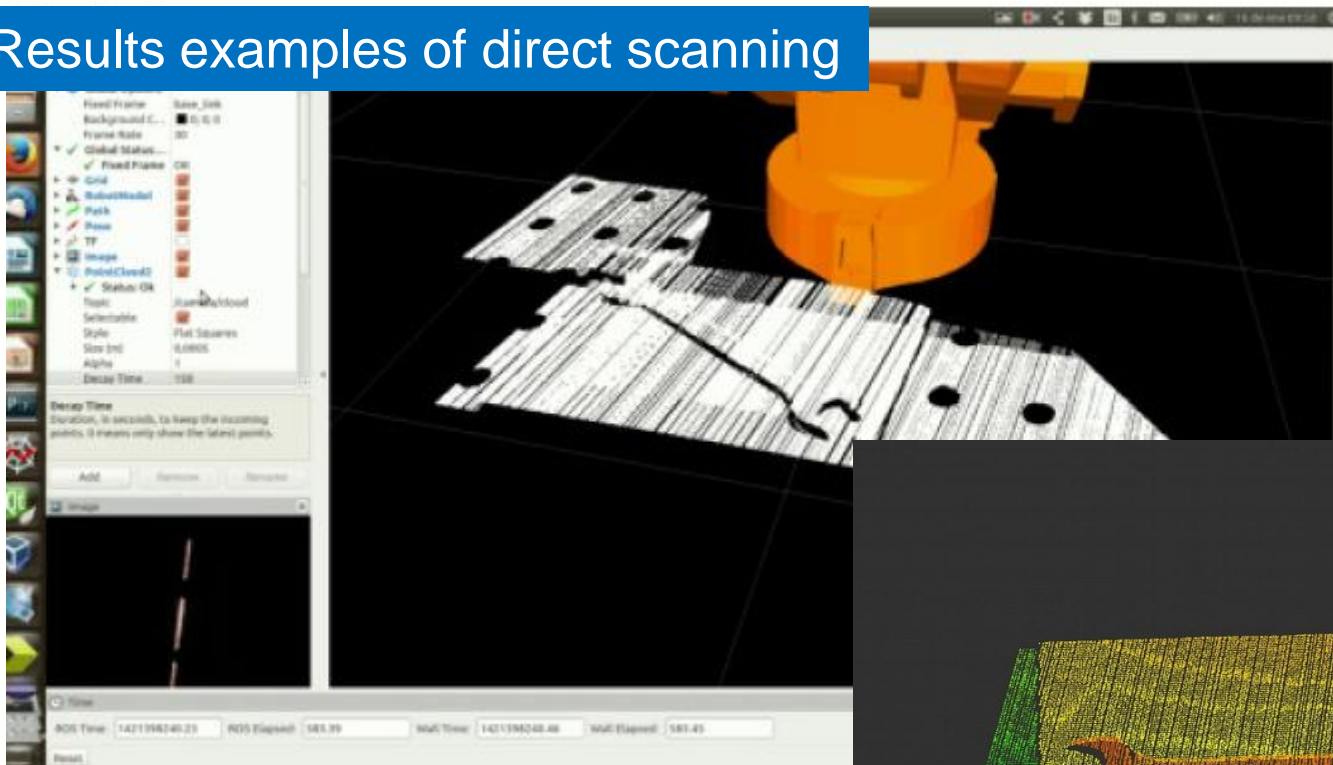
Experimental results



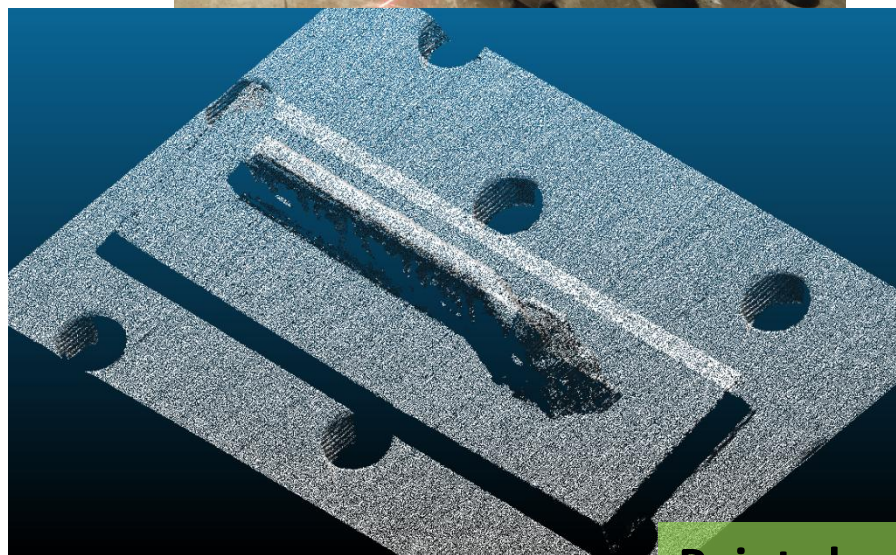
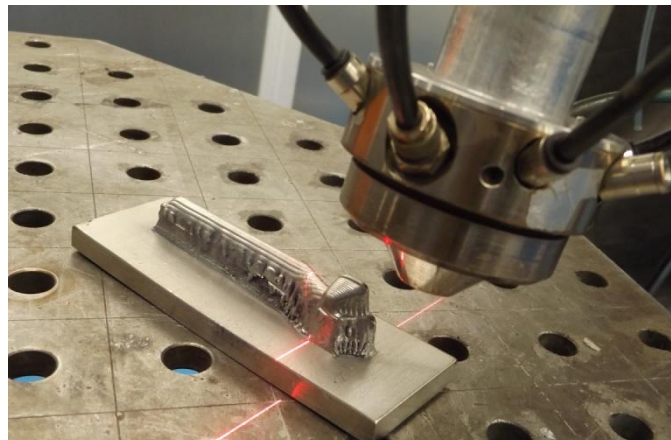
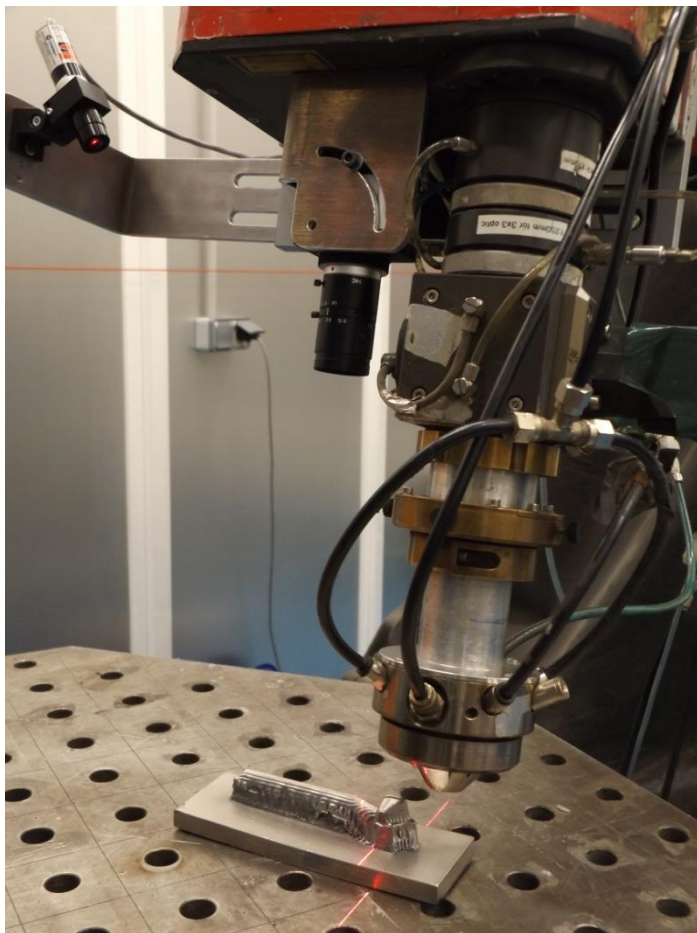
On-line scanning



Results examples of direct scanning



Processing results



Point cloud

Conclusions and Future Work

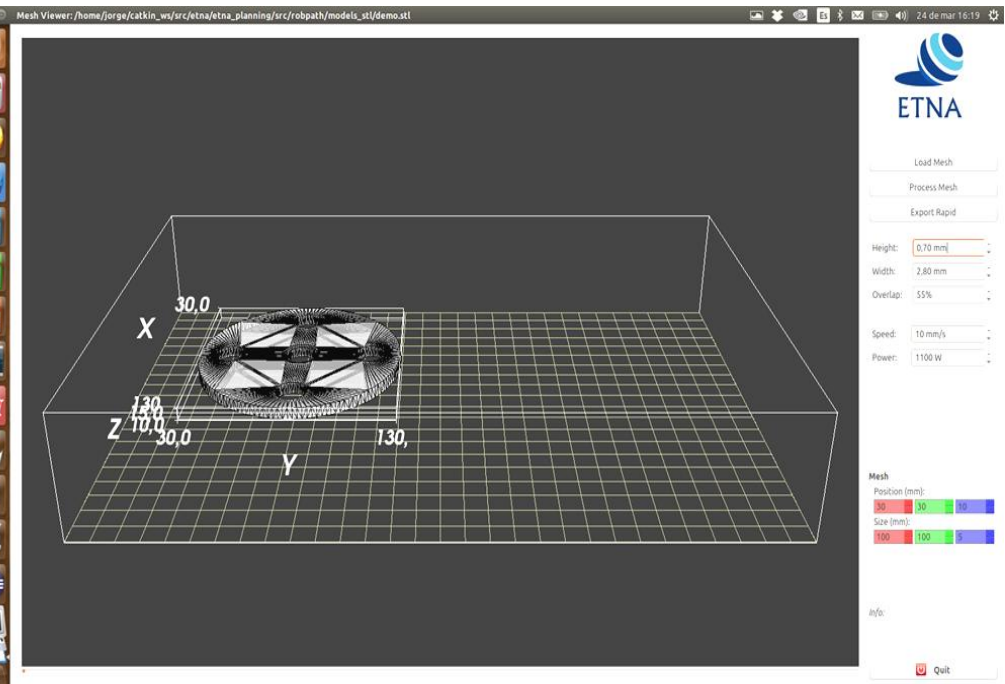
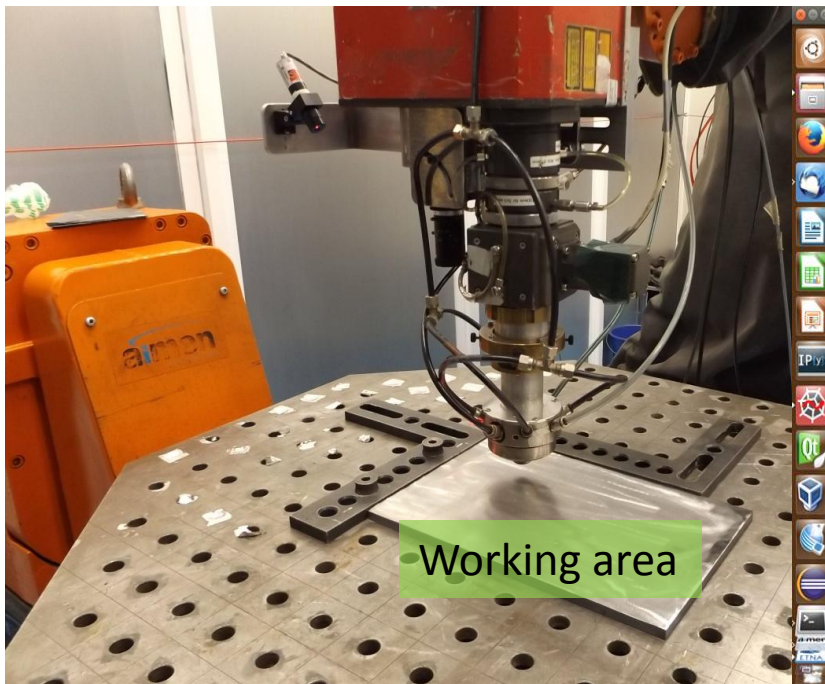


Future work

- Complete the layer measurement module.
- Develop the on-line path planning system.
- Enable a full automatic LMD robotized cell.

LASHARE Project

<http://www.lashare.eu/>



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Thank you for your attention

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