CEITEC

Central European Institute of Technology

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Creating Three-Dimensional Computer Models Using Robotic Manipulator and Laser Scanners

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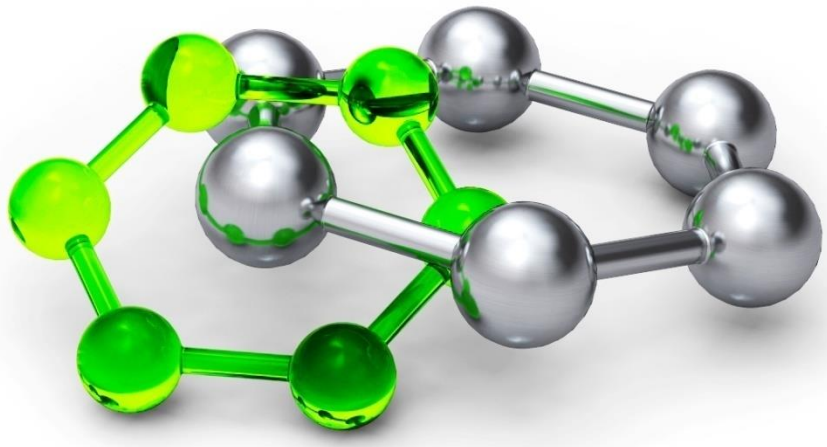
OP Research and Development for Innovation



Our Mission

- CEITEC: Centre of scientific excellence whose results will contribute to the **improvement of quality of life and human health**.
- our project – cooperation with ICRC
- **improvement** of both patient and medical doctor's life by
  - doctors – reduce of both acquisition and operational costs of device, its faster operation, easy using
  - patient – increase of comfort, shortening of wait times

Present State

Task: *After serious injuries or invasive surgeries there is necessary to monitor progress of recovery => comparing 3D models.*

Solution:

- 3D model made by Magnetic Resonance Imaging
- just outer surface is extracted from model

Present State

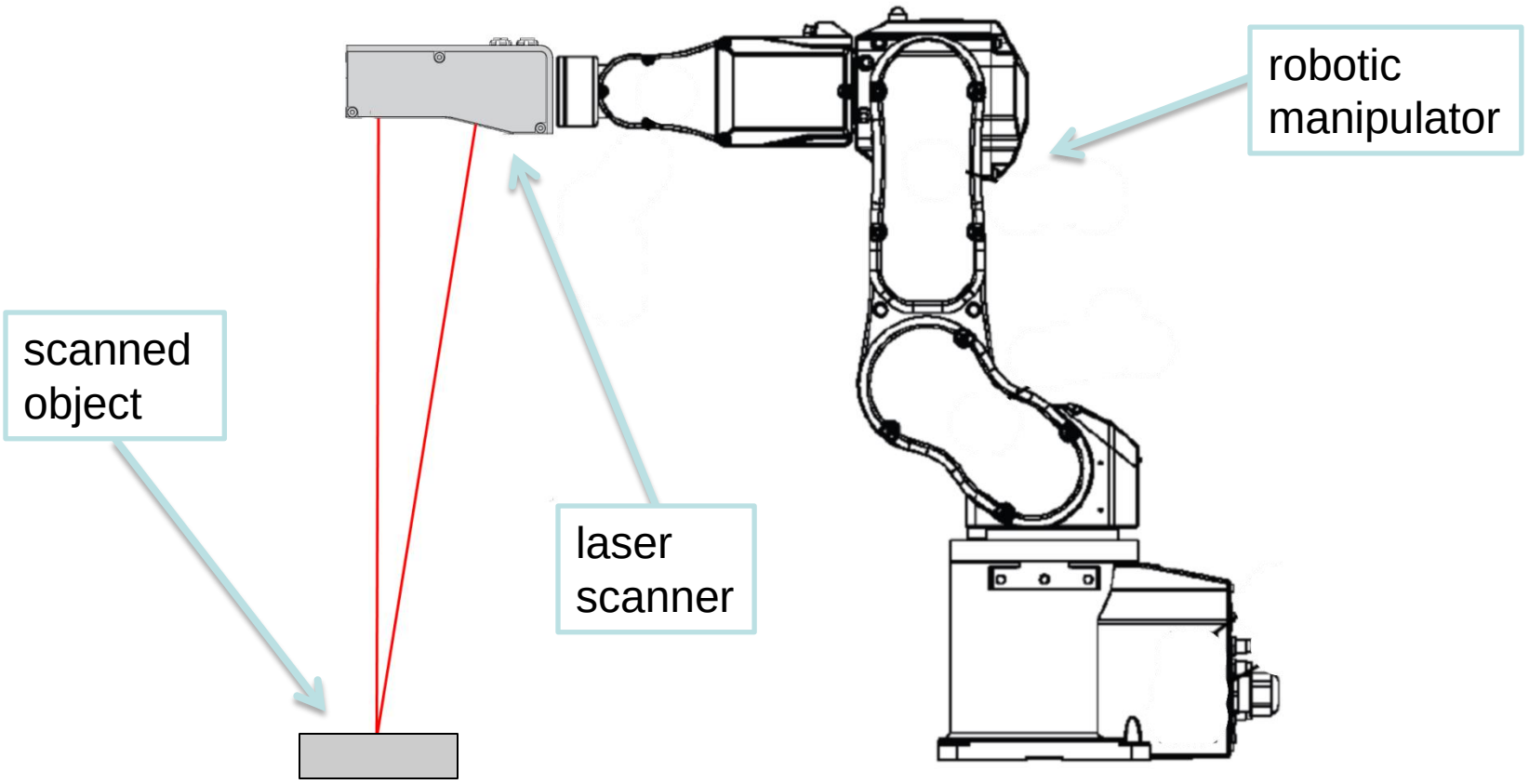
Task: *After serious injuries or invasive surgeries there is necessary to monitor progress of recovery => comparing 3D models.*

Solution:

- model made by Magnetic Resonance Imaging
- just outer surface is e

very expensive
long capturing time
blocking patients who need MRI

Our Solution



Advantages of our solution

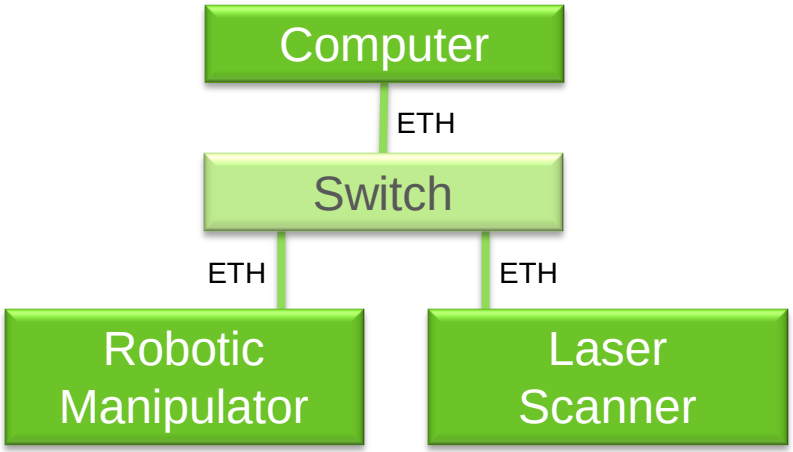
- much lower acquisition costs (20 mil. vs. cca 1 mil. CZK)
- much lower operation costs (7 000 vs. cca 2 CZK)
- faster model capturing (20-30 min. vs. cca 2 min.)
- we don’t block patients who need MRI

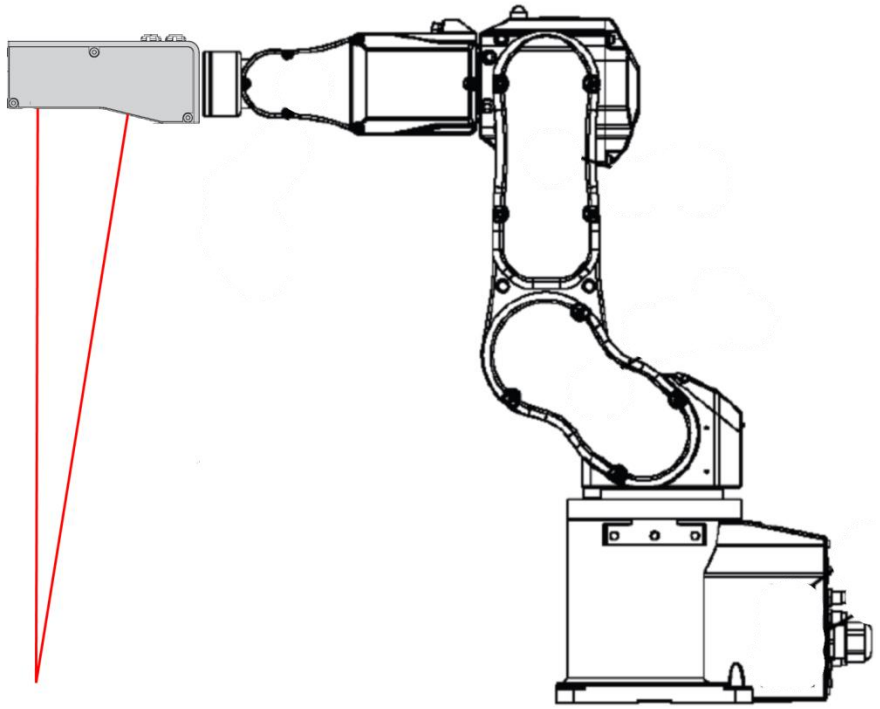
Extra:

- flexibility – both tiny and large structures
- other usings: ergonomic rehabilitation tools, historical objects archiving, 3D cloning, ...

Scanning System Architecture

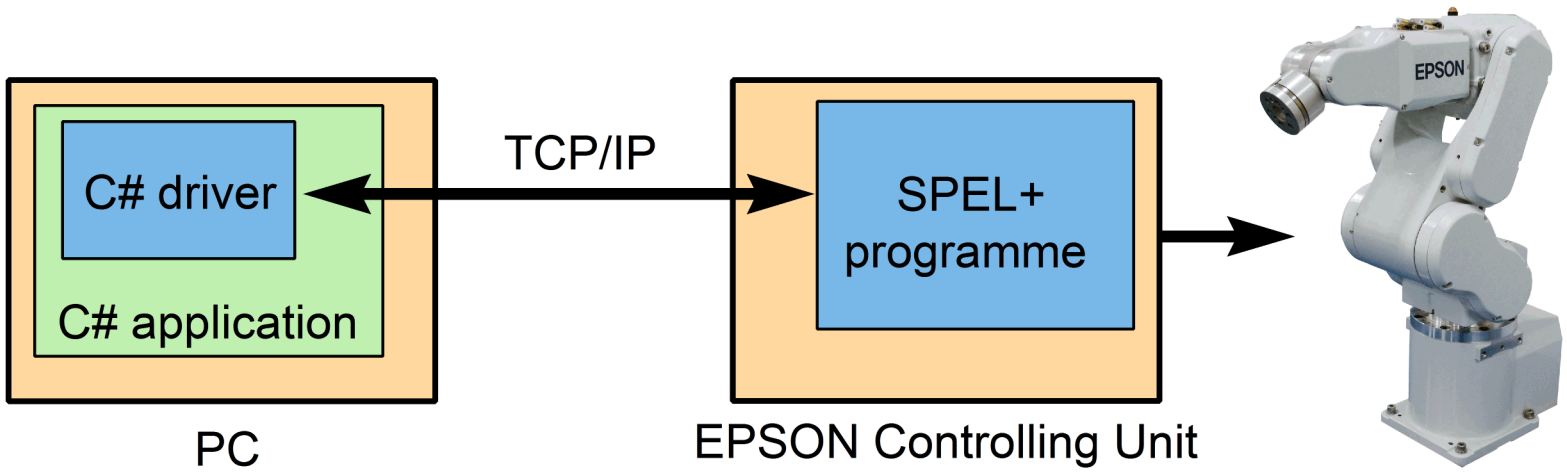
- robot + laser scanner (exchangeable)
- devices connected using Ethernet
- C# drivers for devices



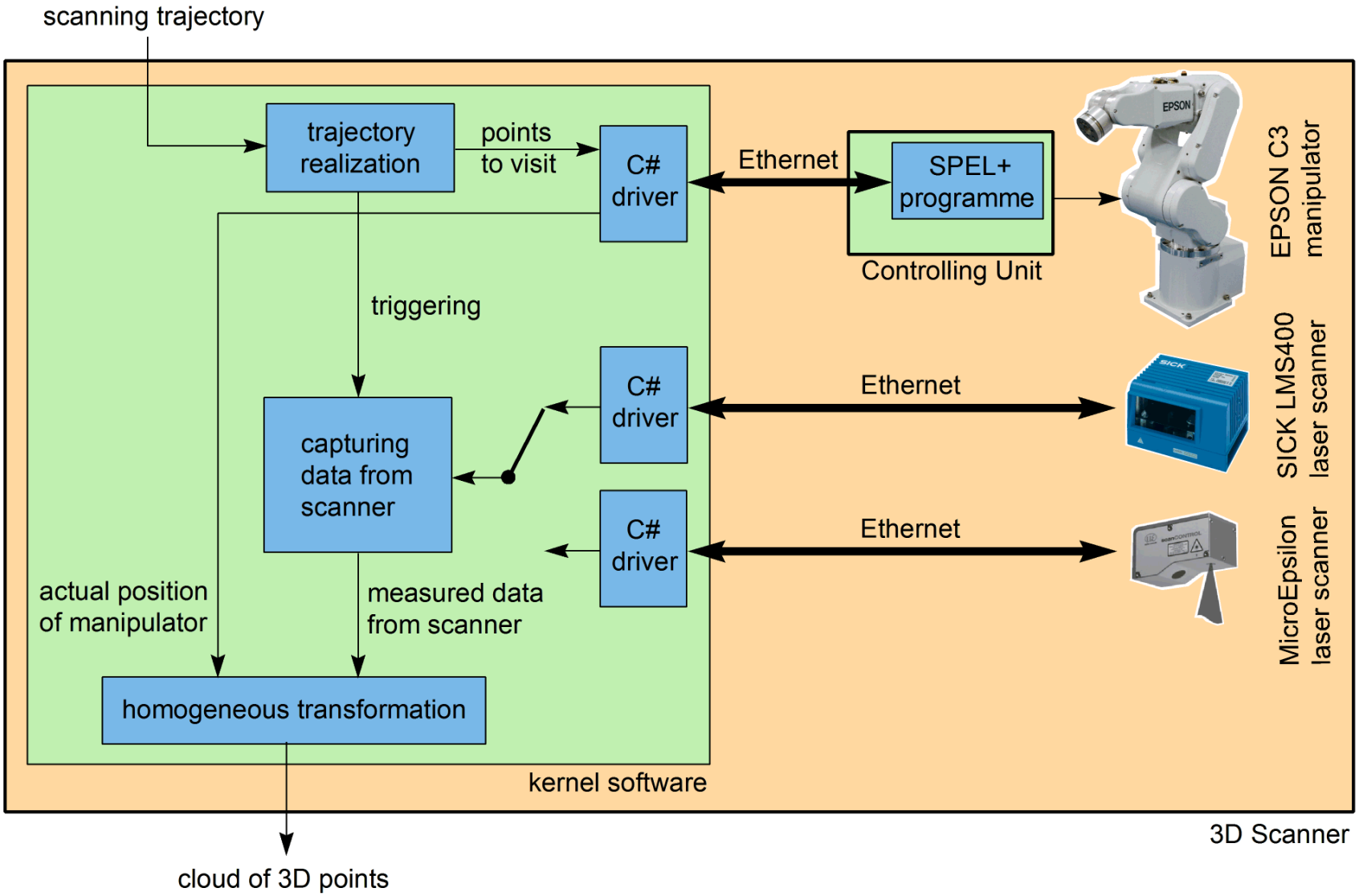


Robotic Manipulator Driver

- robot ordinarily executes predefined program
- real-time response required

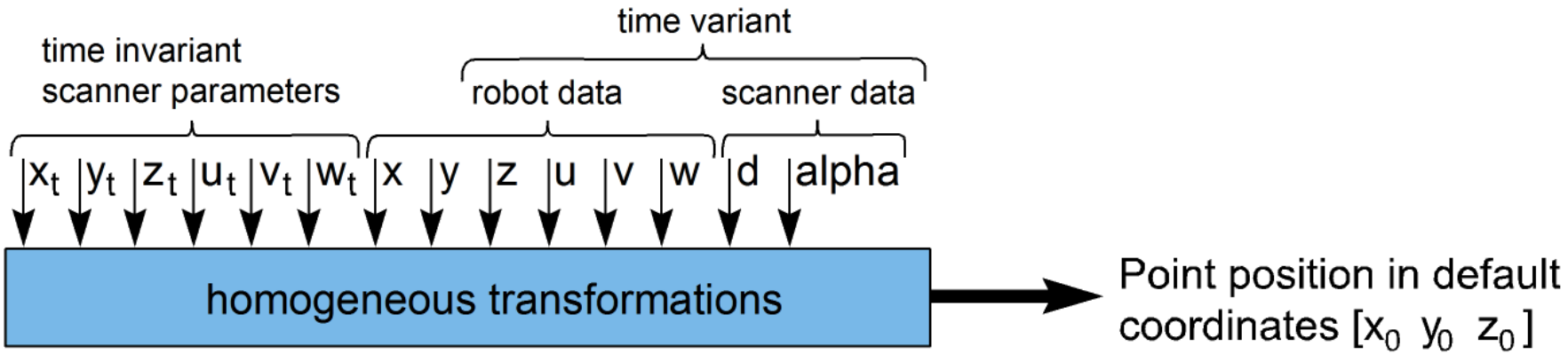


Operating Principle

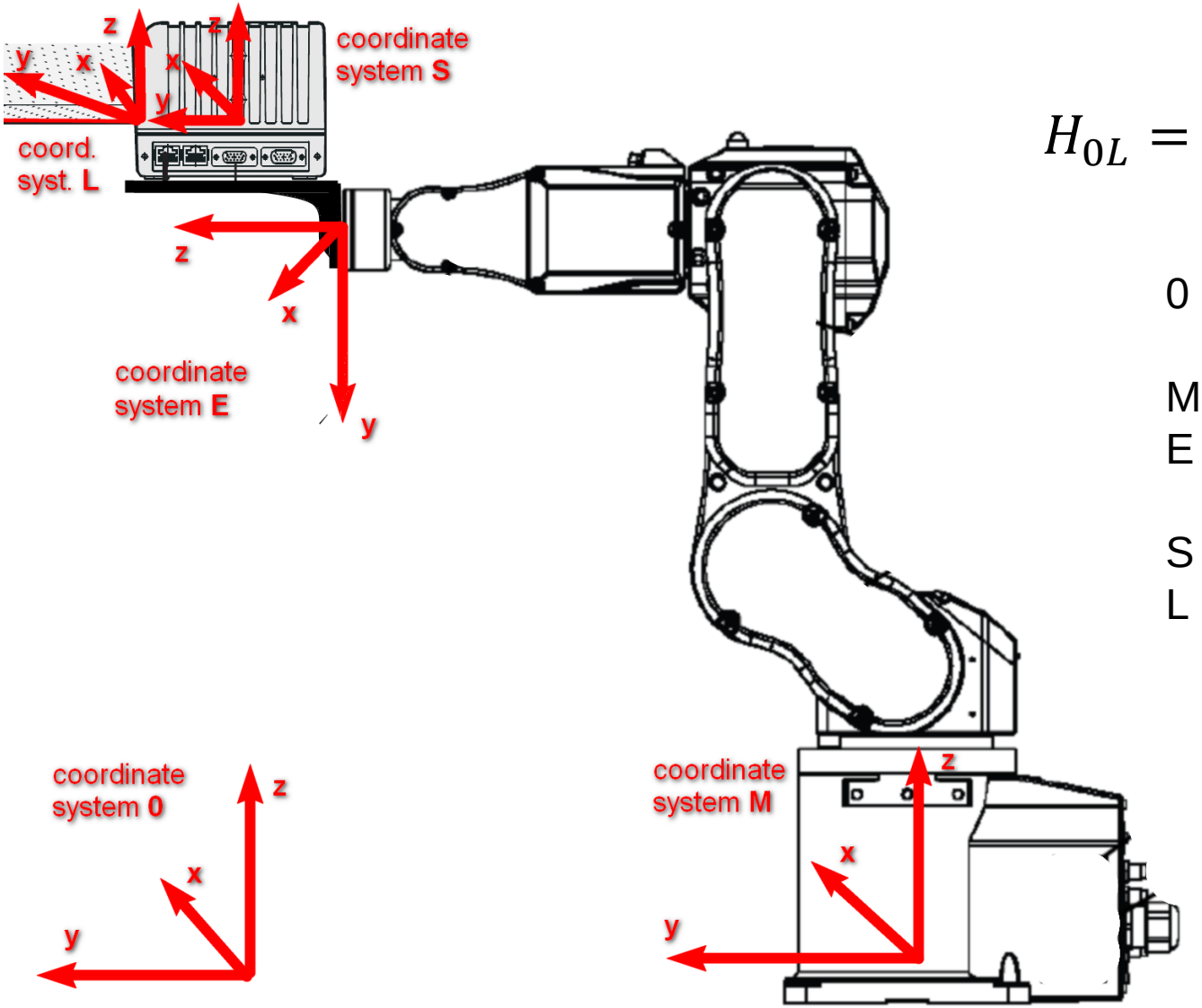


Homogeneous Transformations

- computes position of measured point in default coordinate system



Homogeneous Transformations

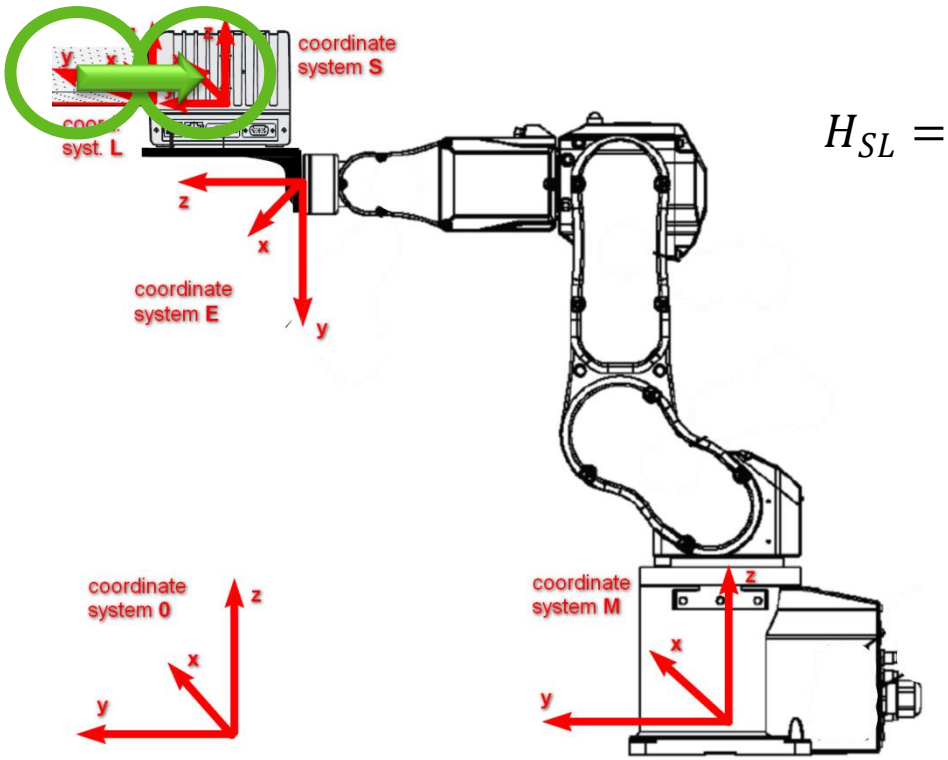


$$H_{0L} = H_{0M} H_{ME} H_{ES} H_{SL}$$

0 ... default coordinate system
M ... manipulator
E ... manipulators' end-point
S ... laser scanner
L ... laser range-finder

Homogeneous Transformations

- H_{SL}: rotation along Z axis by angle α

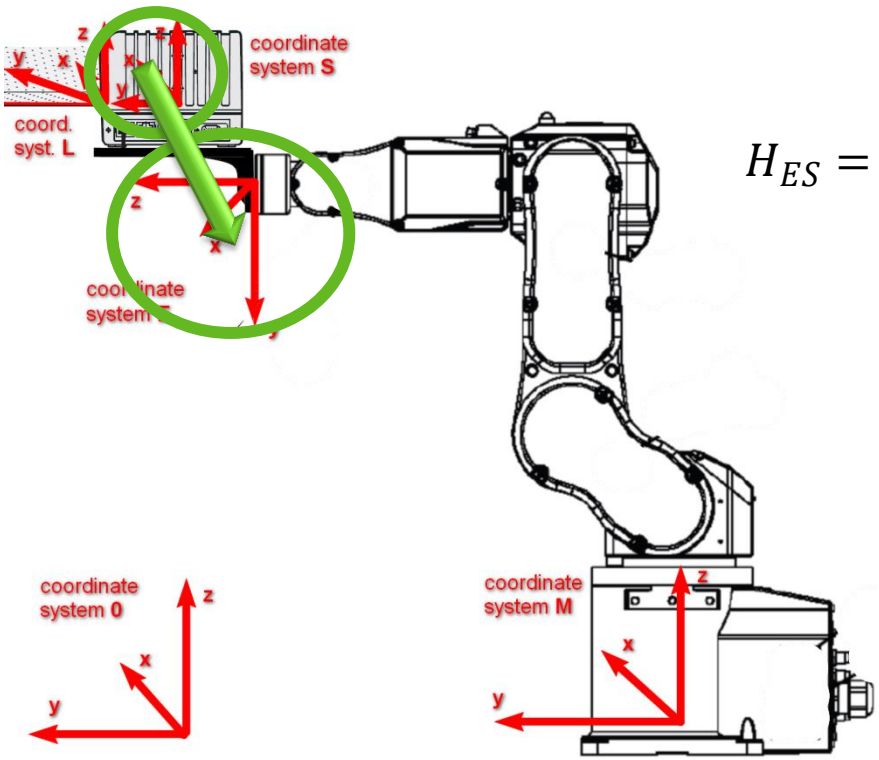


$$H_{SL} = \begin{bmatrix} \cos(180-\alpha) & -\sin(180-\alpha) & 0 & 0 \\ \sin(180-\alpha) & \cos(180-\alpha) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

α ... rotation of laser sweeping mechanism from –x axis

Homogeneous Transformations

- H_{ES}: translation and RPY rotation in 6DOF describing mounting of laser scanner on robot



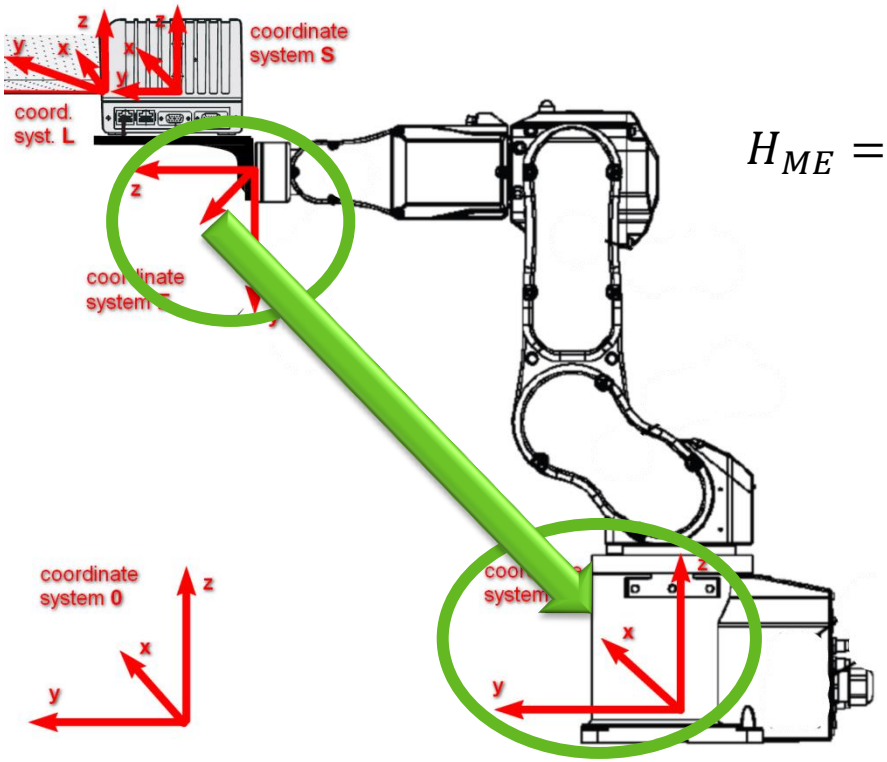
$$H_{ES} = \begin{bmatrix} c_u c_v & c_u s_v s_w - c_w s_u & s_u s_w + c_u c_w s_v & x_t \\ c_v s_u & c_u c_w + s_u s_v s_w & c_w s_u s_v - c_u s_w & y_t \\ -s_v & c_v s_w & c_v c_w & z_t \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

x_t, y_t, z_t ... translations
ut ... roll rotation
v_t ... pitch rotation
w_t ... yaw rotation

c_x ... cos (x_t)
s_x ... sin (x_t)

Homogeneous Transformations

- H_{ME}: translation and RPY rotation in 6DOF describing position of robot's end-point



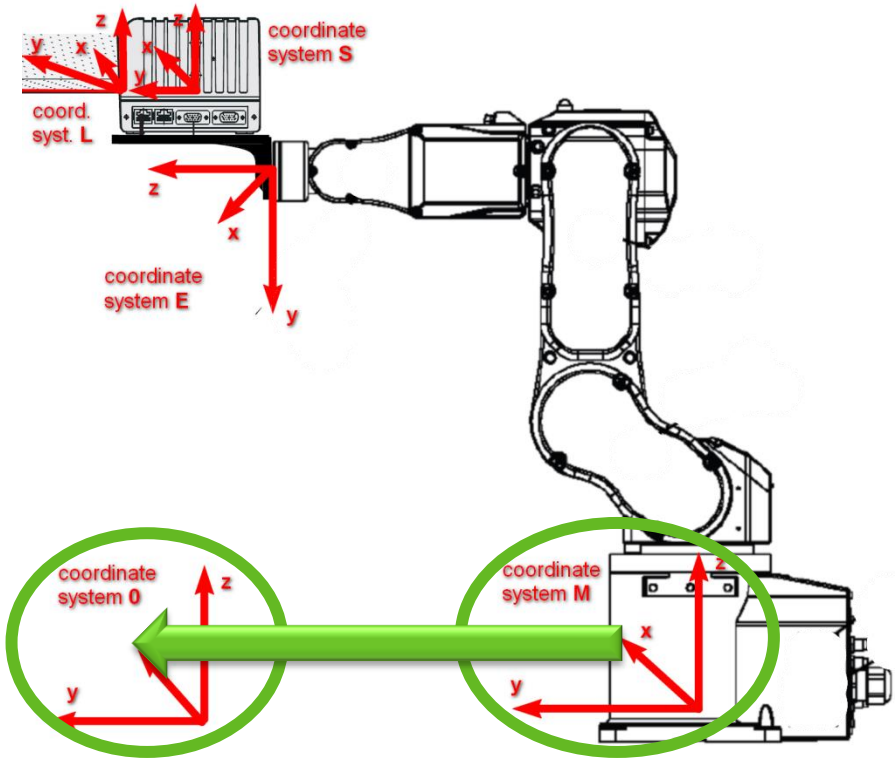
$$H_{ME} = \begin{bmatrix} c_u c_v & c_u s_v s_w - c_w s_u & s_u s_w + c_u c_w s_v & x \\ c_v s_u & c_u c_w + s_u s_v s_w & c_w s_u s_v - c_u s_w & y \\ -s_v & c_v s_w & c_v c_w & z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

x, y, z ... translations
u ... roll rotation
v ... pitch rotation
w ... yaw rotation

c_x ... cos (x)
s_x ... sin (x)

Homogeneous Transformations

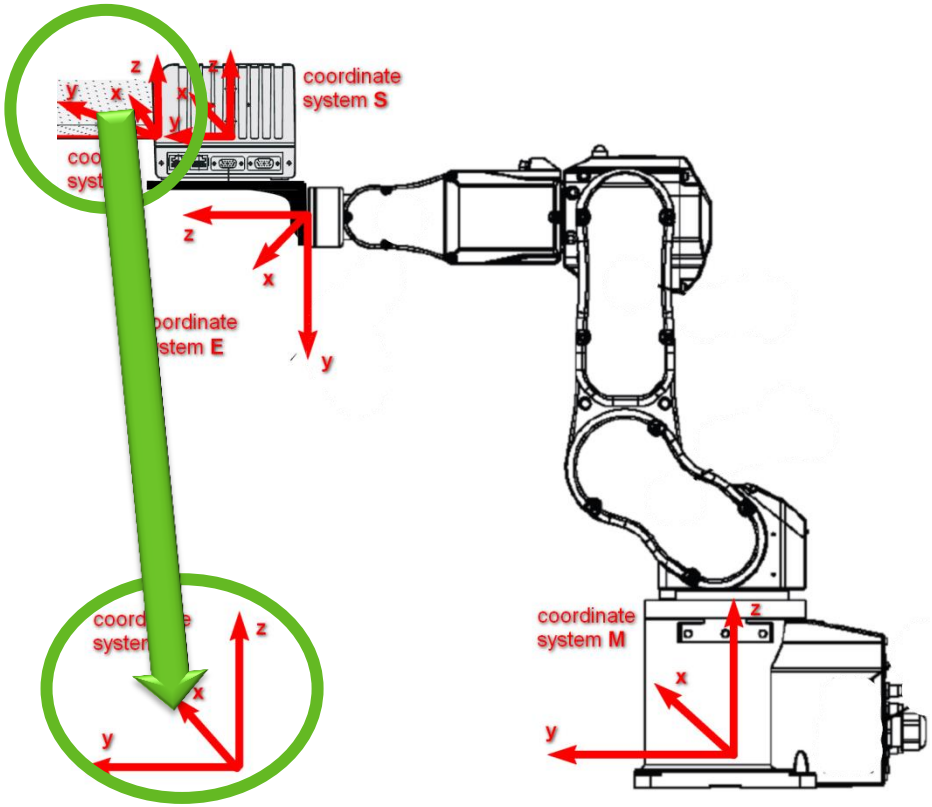
- H_{0M}: translation and RPY rotation in 6DOF describing position of robot in default system



Default system 0 is usually same as robotic manipulator's system M.

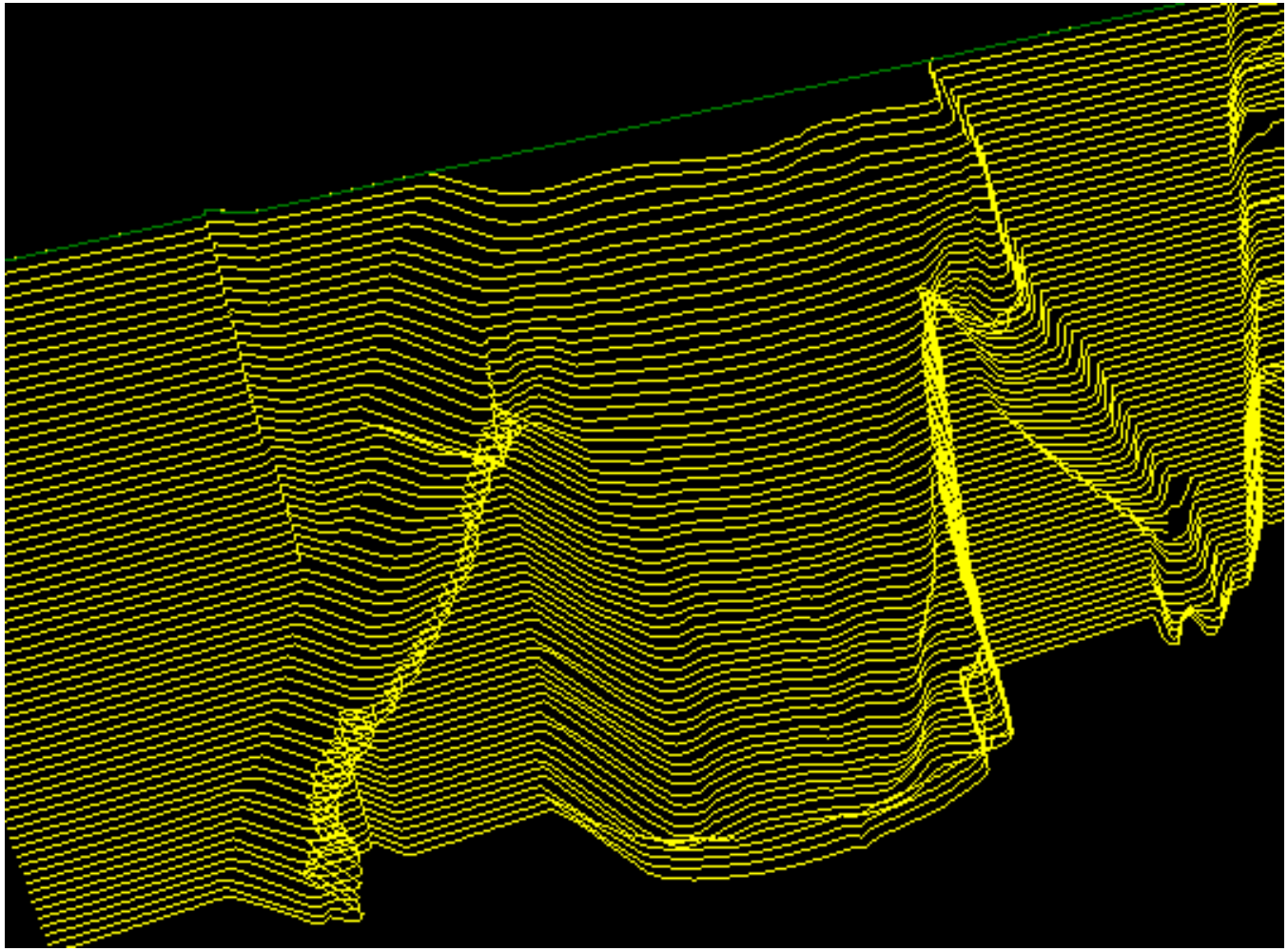
Homogeneous Transformations

- H_{0L}: combination of all particular matrices

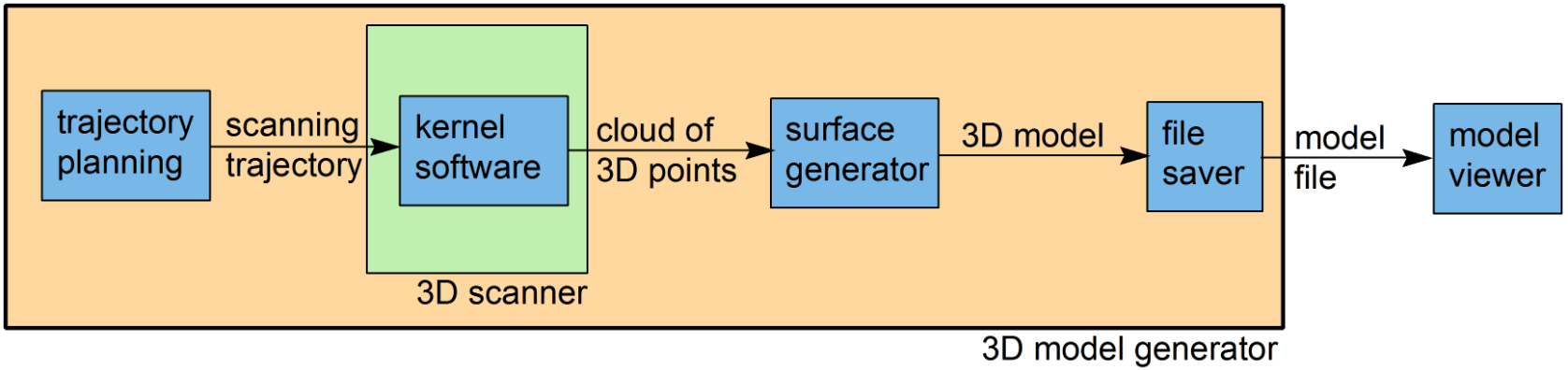


$$H_{0L} = H_{0M} H_{ME} H_{ES} H_{SL}$$

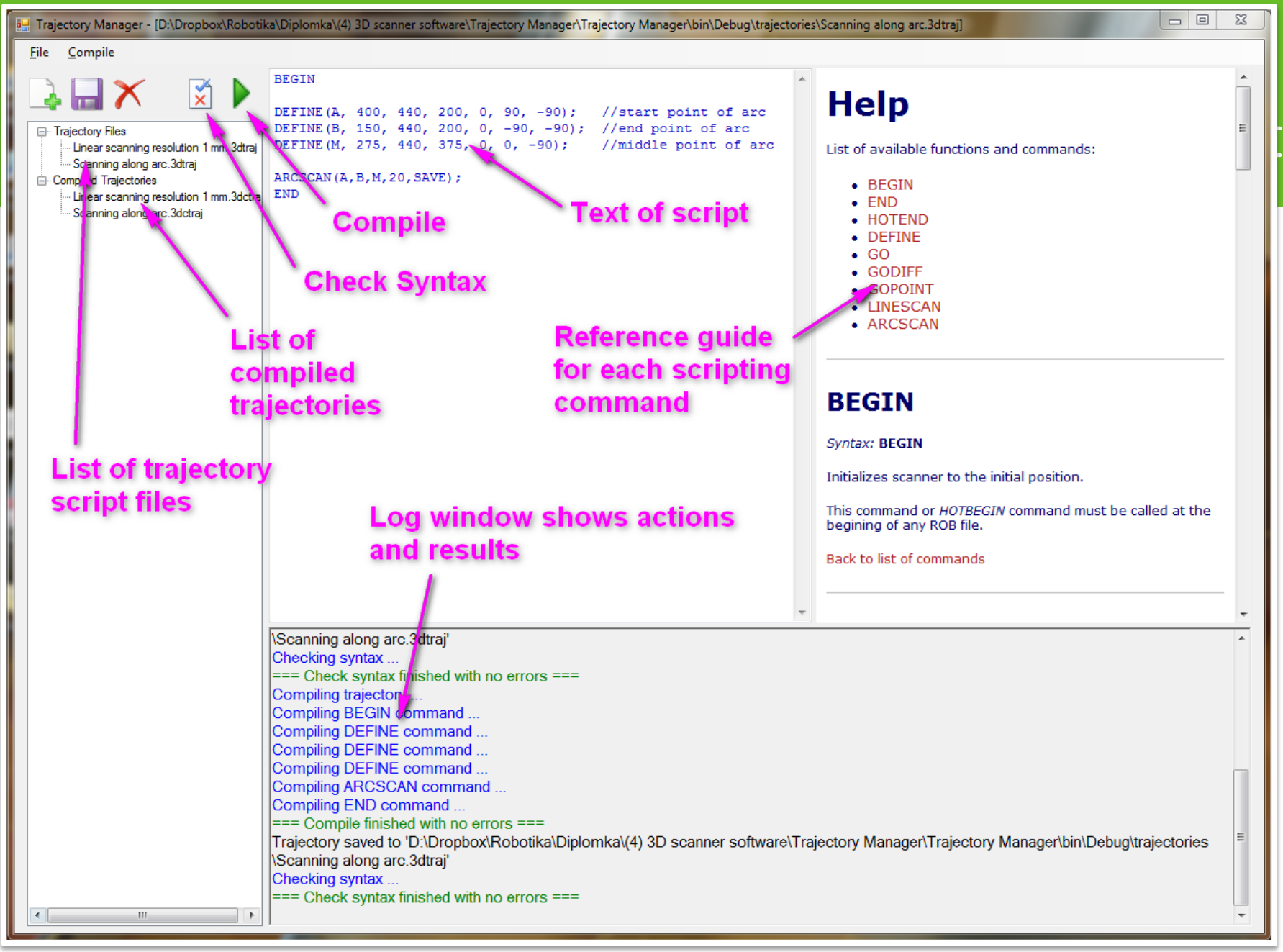
Example of Raw Point-Cloud



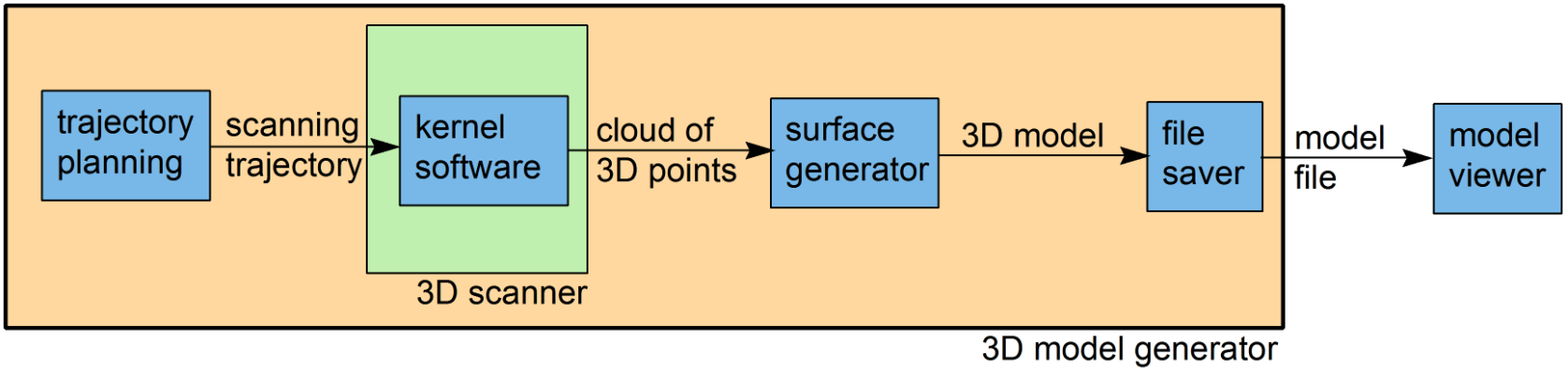
Higher Software Layer



- user friendly defining of scanning trajectory
- surface-covered 3D model generation from measured point-cloud
- saving and displaying of models


Trajectory Manager - [D:\Dropbox\Robotika\Diplomka\(4) 3D scanner software\Trajectory Manager\Trajectory Manager\bin\Debug\trajectories\Scanning along arc.3dtraj]
File
Compile
Trajectory Files
Linear scanning resolution 1 mm.3dtraj
Scanning along arc.3dtraj
Compiled Trajectories
Linear scanning resolution 1 mm.3dctraj
Scanning along arc.3dctraj
BEGIN
DEFINE(A, 400, 440, 200, 0, 90, -90); //start point of arc
DEFINE(B, 150, 440, 200, 0, -90, -90); //end point of arc
DEFINE(M, 275, 440, 375, 0, 0, -90); //middle point of arc
ARCSCAN(A,B,M,20,SAVE);
END
Help
List of available functions and commands:
BEGIN
END
HOTEND
DEFINE
GO
GODIFF
GOPOINT
LINESCAN
ARCSCAN
BEGIN
Syntax: BEGIN
Initializes scanner to the initial position.
This command or HOTBEGIN command must be called at the begining of any ROB file.
Back to list of commands
\Scanning along arc.3dtraj'
Checking syntax ...
=== Check syntax finished with no errors ===
Compiling BEGIN command ...
Compiling DEFINE command ...
Compiling DEFINE command ...
Compiling DEFINE command ...
Compiling ARCSCAN command ...
Compiling END command ...
=== Compile finished with no errors ===
Trajectory saved to 'D:\Dropbox\Robotika\Diplomka\(4) 3D scanner software\Trajectory Manager\Trajectory Manager\bin\Debug\trajectories
\Scanning along arc.3dtraj'
Checking syntax ...
=== Check syntax finished with no errors ===
Compile
Text of script
Check Syntax
List of compiled trajectories
Reference guide for each scripting command
List of trajectory script files
Log window shows actions and results

Higher Software Layer



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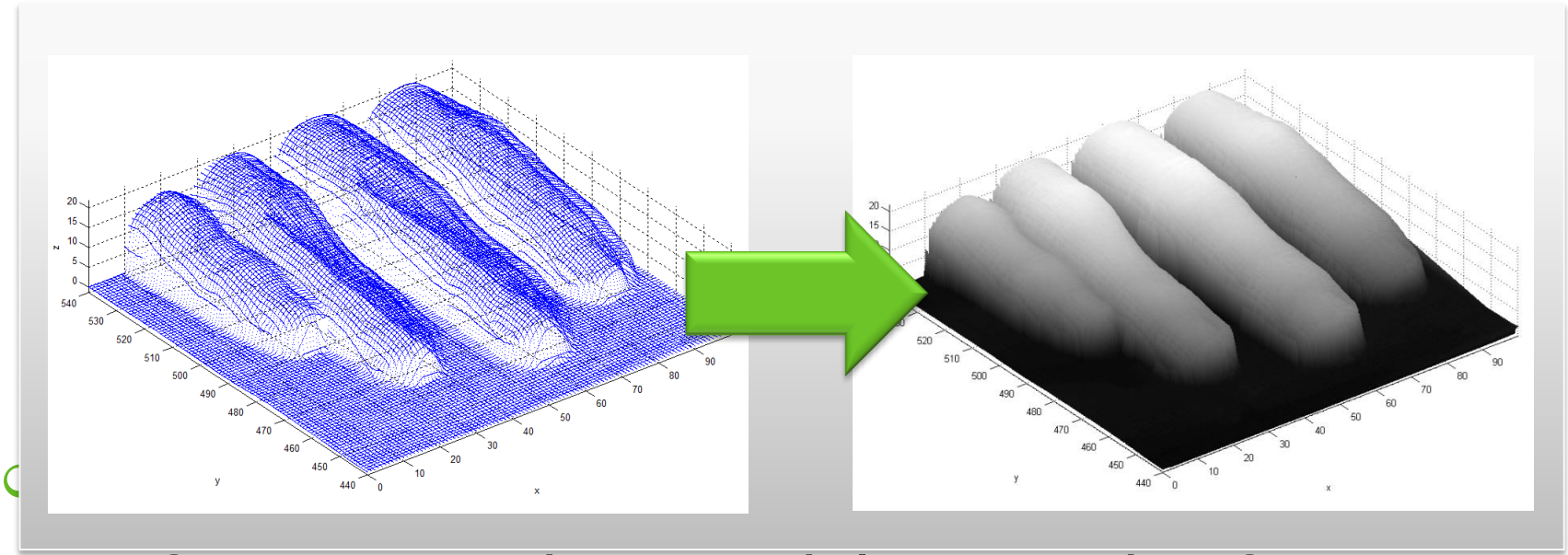

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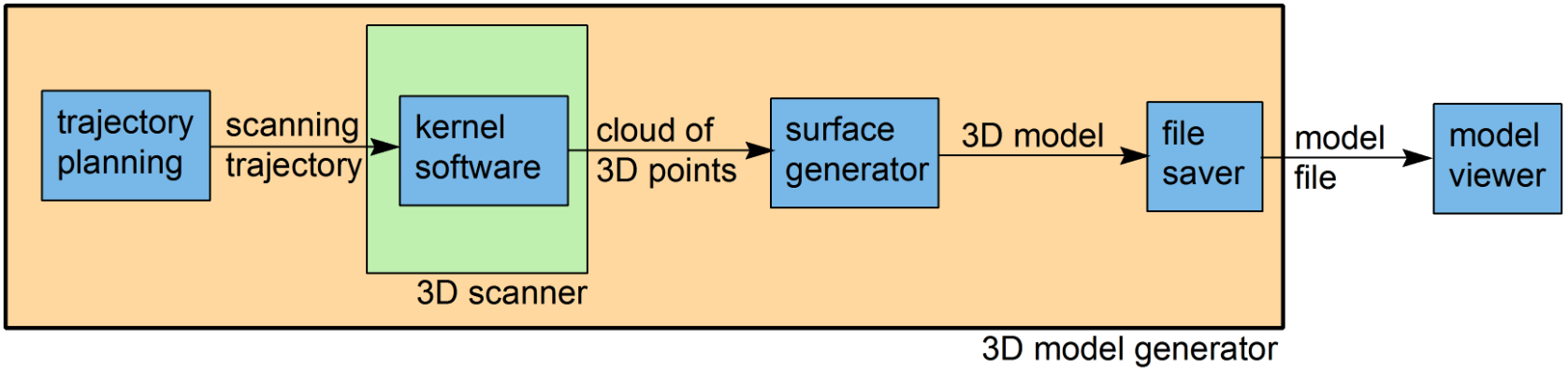

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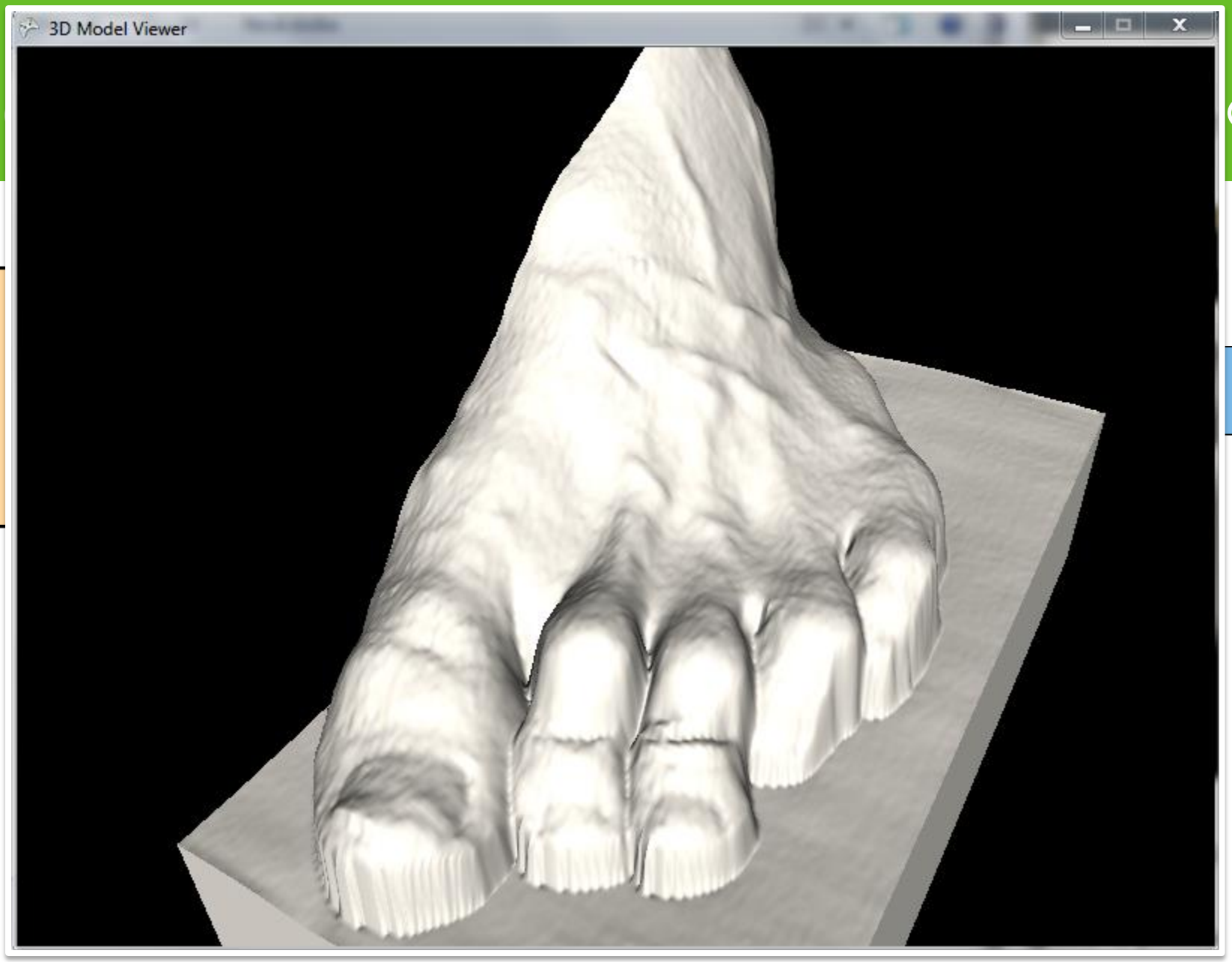
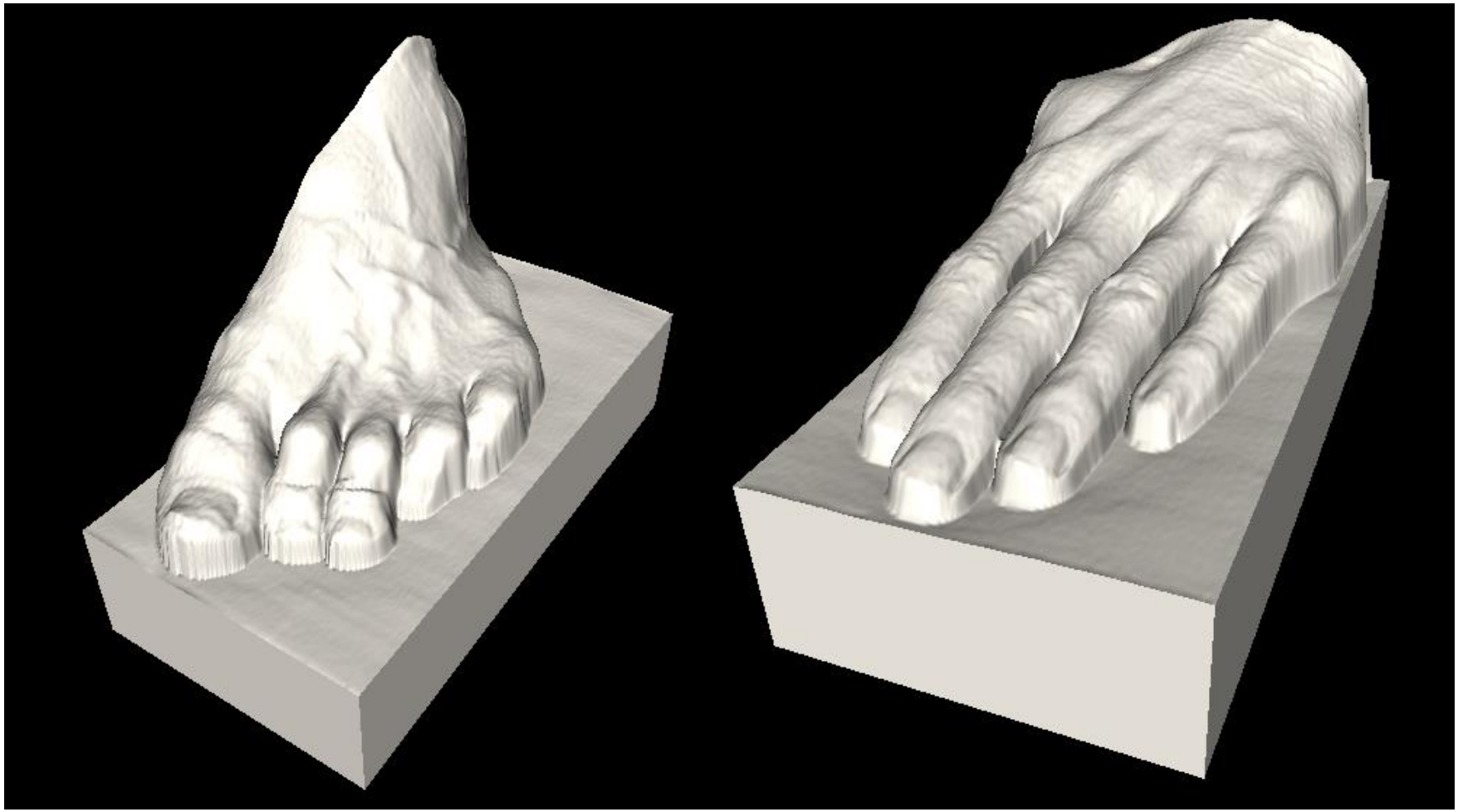

3D Model Viewer

Captured Model Examples



Summary

- standalone scanning system capturing 3D models
- output is shaded surface
- designed for hospital – brings savings
- very wide area of usability because of:
  - flexibility of movement because of 6DOF robot
  - changeable scanner – possibility of scanning both tiny and large structures

Future Work

- functions for automated design of ergonomic splints
- functions for comparing differences between several models (sequence of models analyze)
- data fusion with other medical devices – one model containing all available information about human body

Thank You for Your attention

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