

## Implementation verification of picking system for industrial robot using ROS and MATLAB®

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Environmental & Social Systems Div.  
YASKAWA ELECTRIC CORPORATION

© 2019 YASKAWA Electric Corporation



Source : <https://jp.mathworks.com/products/simulink.html>



Source : <http://wiki.ros.org> Source: <http://gazebosim.org/>

MATLAB : Trademark of The MathWorks, Inc.

# Speaker Introduction

## My job

- Controller development for plants
- Especially on HMI for operators
- Specializes in software development



## My authored book on ROS

- **M.Morita** et al., "ROS Robot Programming for practical robotics development", Morikita Publishing Co., Ltd., 2018.
- I mainly wrote application sections such as **OpenCV**, **PCL**, **Pluginlib**, **rostopic**, **industrial\_ci** and so on...



Source : <https://opencv.org/>



Source : <http://pointclouds.org/>



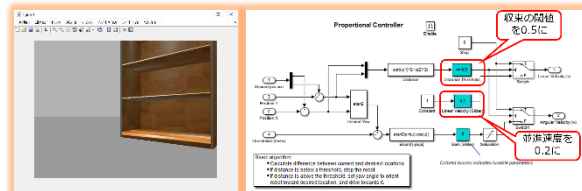
Travis CI

Source : <https://travis-ci.org/>

- Also wrote **MATLAB integration**



MATLAB  
Simulink



1st prize seller on Amazon JP (Robotics category)

Source : <https://images-na.ssl-images-amazon.com/images/I/51joyPVM8tL.jpg>

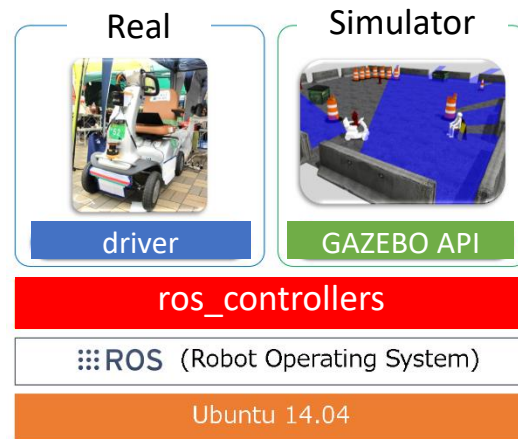
# ROS commmits experiences and contributions (Hobby)

## Autonomous drive

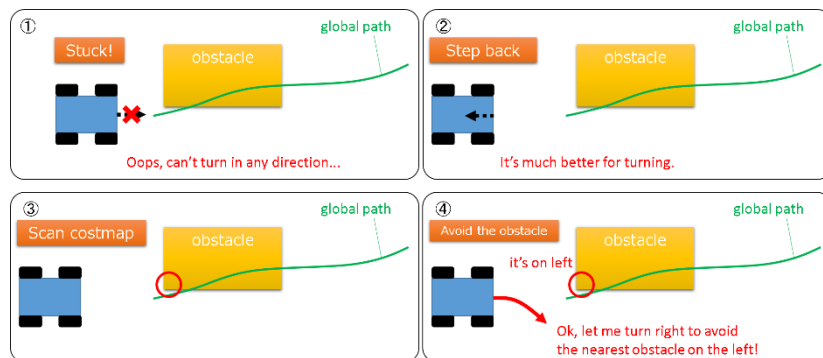
### ● ackermann\_steering\_controller

First author

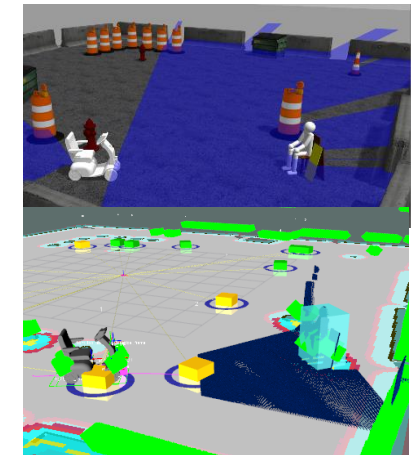
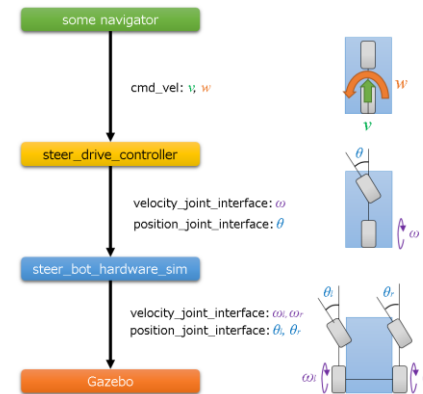
Sent PR to  
ros\_controllers repo  
& already merged!



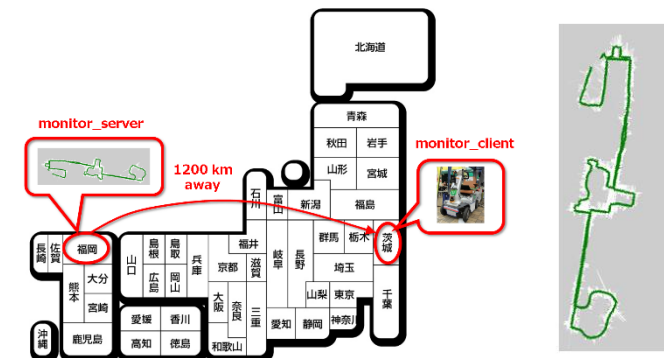
### ● stepback\_and\_rotate\_recovery (plugin)



### ● steer\_bot\_hardware\_sim (plugin)



### ● Remote monitoring with integrating ROS & OpenVPN



# ROS industrial robot apps through my Ph.d program

## Easy to use industrial robots



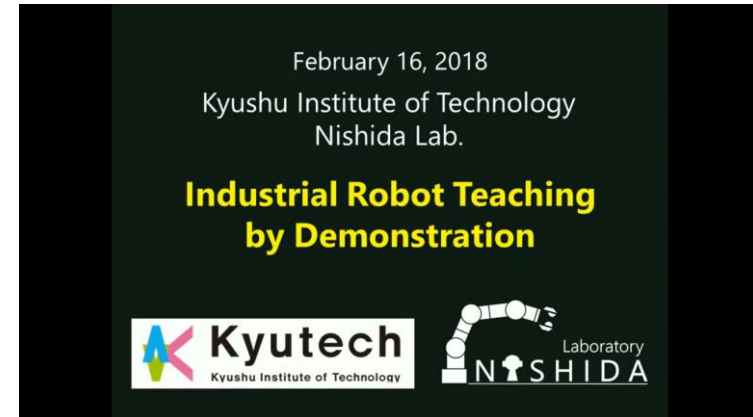
- Construction of industrial robot (teach-less) interactive UI with Pepper (voice+tablet)



- Industrial robot operation from a remote place (teach-less)



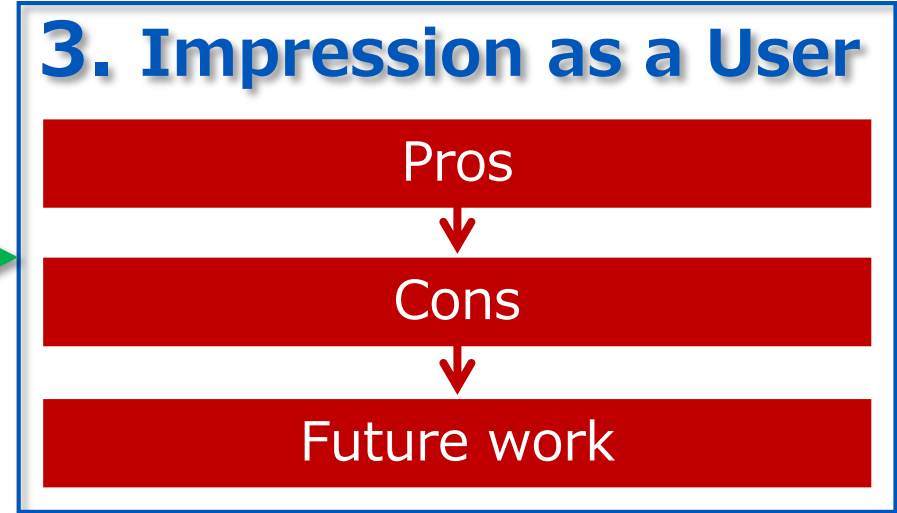
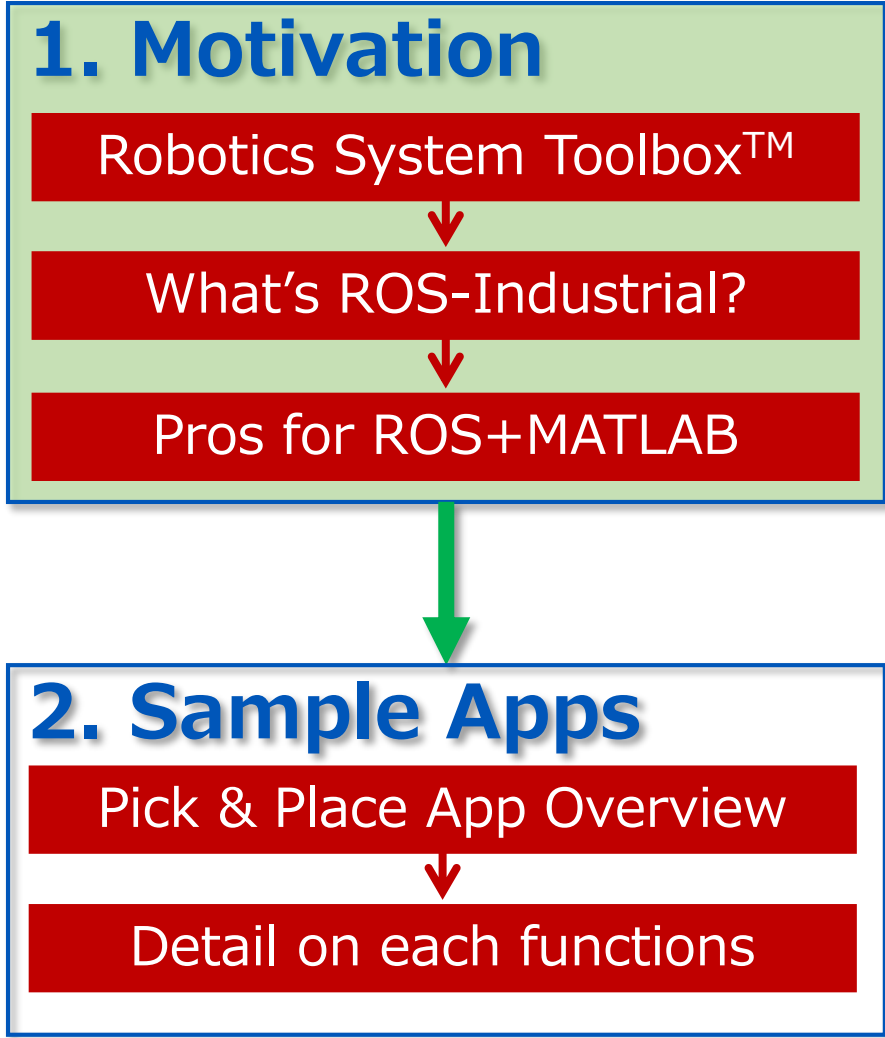
- Industrial robot operation from demonstration



- Improving the layout of industrial robots using 5G network



# Outline



# Motivation




**YASKAWA**

- Unique technologies with advantages
- Limited resources for new technology introduction and verification

**In-house tech.**

Expanding advanced functions and quality that are lacking with OSS alone



MATLAB/Simulink

- Secure quality that could be difficult to be provided by only installing OSS
- Advanced technology utilization not provided by ROS alone

**Commercial Tool**

Open Innovation



**ROS**

- Easy combination of advanced technologies
- Unevenness of the available functions



**OSS**

**Possibility of innovation through integration of**

**In-house tech.** × **OSS** × **Commercial Tool**

I introduce the combination verification of **OSS** × **Commercial Tool**

# High potential of Robotics System Toolbox



Source : <https://www.mathworks.com/products/matlab.html>

## Various Toolboxes



### Data Analytics

Demonstrates how to use MATLAB for large-scale data, machine learning, and analysis in an enterprise environment.



### Wireless communication

See how MATLAB can help you develop algorithms and perform wireless system simulations.



Deep Learning



Computer Vision



Signal Processing



Econometrics and Risk Management



Robotics



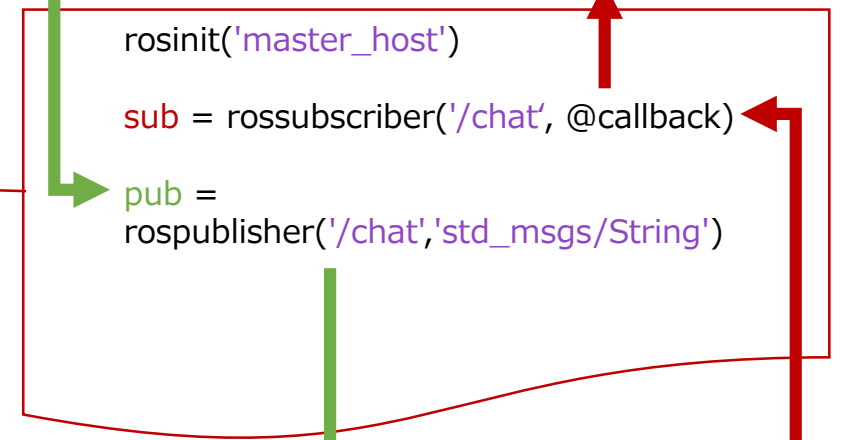
Control System



```
roscpp('master_host')
```

```
sub = rossubscriber('/chat', @callback)
```

```
pub = rospublisher('/chat','std_msgs/String')
```



Source : <http://news.mit.edu/2015/mit-team-places-sixth-darpa-robotics-challenge-0608>  
 Source : <https://www.tudelft.nl/en/2016/tu-delft/team-delft-wins-amazon-picking-challenge/>  
 Source : <https://youtu.be/1Zpw2288VMQ>  
 Source : <https://projects.preferred.jp/tidying-up-robot/>



# Difficulty of adopting ROS at the manufacturer 1) Technical Issue



Source : <http://news.mit.edu/2015/mit-team-places-sixth-darpa-robotics-challenge-0608>  
Source : <https://www.tudelft.nl/en/2016/tu-delft/team-delft-wins-amazon-picking-challenge/>  
Source : <https://youtu.be/1Zpw2288VMQ>  
Source : <https://projects.preferred.jp/tidying-up-robot/>



Technical issue:

- It is difficult to employ engineers who can handle the latest OSS libraries and various programming languages

Source : <https://www.preferred-networks.jp/ja/pfn-logo>  
Source : <https://www.tensorflow.org/>  
Source : [https://www.irasutoya.com/2016/04/blog-post\\_78.html](https://www.irasutoya.com/2016/04/blog-post_78.html)

Customers to deliver value to

But not easy...



Source : <https://pictarts.com/01-illustration/00011-free-art.html>



# Difficulty of adopting ROS at the manufacturer 2) Strategic Issue



Source : <http://news.mit.edu/2015/mit-team-places-sixth-darpa-robotics-challenge-0608>  
Source : <https://www.tudelft.nl/en/2016/tu-delft/team-delft-wins-amazon-picking-challenge/>  
Source : <https://youtu.be/1Zpw2288VMQ>  
Source : <https://projects.preferred.jp/tidying-up-robot/>



Strategic issue:

- Conflicts between the use of OSS and intellectual property protection.
- Less precedent usage of OSS in development especially among traditional makers.

Source : [https://www.irasutoya.com/2019/03/blog-post\\_877.html](https://www.irasutoya.com/2019/03/blog-post_877.html)

Customers  
to deliver value to

But not easy...

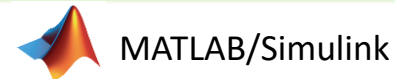


Source : <https://pictarts.com/01-illustration/00011-free-art.html>

# Difficulty of adopting ROS at the manufacturer 2) Strategic Issue



Source : <http://news.mit.edu/2015/mit-team-places-sixth-darpa-robotics-challenge-0608>  
Source : <https://www.tudelft.nl/en/2016/tu-delft/team-delft-wins-amazon-picking-challenge/>  
Source : <https://youtu.be/1Zpw2288VMQ>  
Source : <https://projects.preferred.jp/tidying-up-robot/>



- Software installation experience: more than **100,000** companies, governments, universities
- Customer base: More than **185** countries
- MATLAB Users: Over **4 Million** Worldwide
- MATLAB Central File Exchange Downloads: Over **3 Million** Files
- Number of contributors to the MATLAB Central app: more than **525,000** worldwide
- Number of third-party solutions created with MATLAB / Simulink: **500+**
- MATLAB Number of Books: More than **2,000** in **27** languages

Customers  
to deliver value to



Source : <https://pictarts.com/01-illustration/00011-free-art.html>

# Difficulty of adopting ROS at the manufacturer 1) Solution



Source : <http://news.mit.edu/2015/mit-team-places-sixth-darpa-robotics-challenge-0608>  
Source : <https://www.tudelft.nl/en/2016/tu-delft/team-delft-wins-amazon-picking-challenge/>  
Source : <https://youtu.be/1Zpw2288VMQ>  
Source : <https://projects.preferred.jp/tidying-up-robot/>



Solution:

1. Many MATLAB engineers exist in manufacturers
2. MATLAB resources are also accumulated a lot there

Source : [https://www.irasutoya.com/2019/05/blog-post\\_67.html](https://www.irasutoya.com/2019/05/blog-post_67.html)

Technical issue:

- It is difficult to employ engineers who can handle the latest OSS libraries and various programming languages

Customers  
to deliver value to

Possible!



Source : <https://pictarts.com/01-illustration/00011-free-art.html>

# Difficulty of adopting ROS at the manufacturer 2) Solution



Source : <http://news.mit.edu/2015/mit-team-places-sixth-darpa-robotics-challenge-0608>  
Source : <https://www.tudelft.nl/en/2016/tu-delft/team-delft-wins-amazon-picking-challenge/>  
Source : <https://youtu.be/1Zpw2288VMQ>  
Source : <https://projects.preferred.jp/tidying-up-robot/>



**Solution:**  
1. Interfacing ROS thru MATLAB increases product reliability  
2. MATLAB-based product development is often experienced

Source : [https://www.irasutoya.com/2013/07/blog-post\\_5717.html](https://www.irasutoya.com/2013/07/blog-post_5717.html)

**Strategic issue:**

- Conflicts between the use of OSS and intellectual property protection.
- Less precedent usage of OSS in development especially among traditional makers.

Customers  
to deliver value to

**Possible!**



Source : <https://pictarts.com/01-illustration/00011-free-art.html>

**That's why I started to watch on MATLAB & ROS integration!**

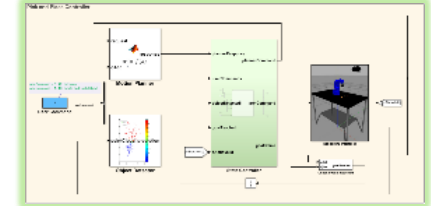
# Robotics System Toolbox

Windows : Trademark of Microsoft Corporation  
Linux : Trademark of Torvalds, Linus  
Simulink : Trademark of The MathWorks, Inc.

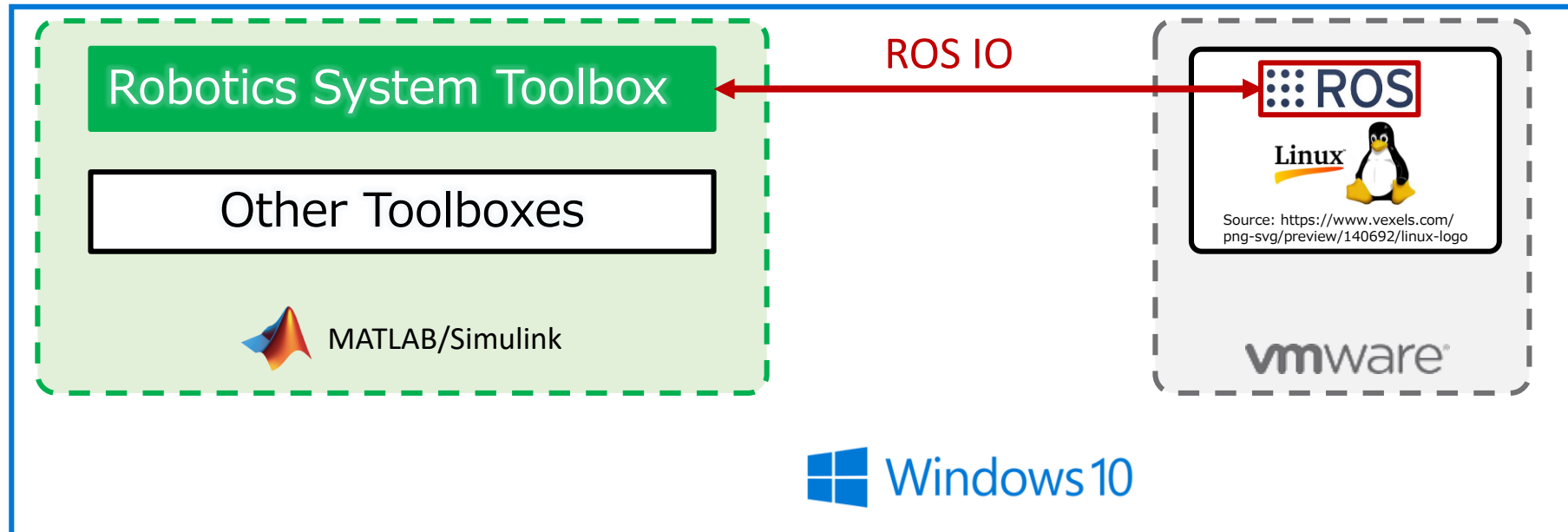
## Robotics System Toolbox



- Includes various algorithms and functions essential for robotics
- Added interface for linking MATLAB® / Simulink® and ROS



## Usage in the demo



# Development of ROS for industrial application

## ROS-Industrial (ROS-I)



Source:  
<https://rosindustrial.org/ric/current-members>

- Consortium to promote industrial application of ROS
- Over 60 global companies such as manufacturers, users and plants participate



Yaskawa  
U.S.A

# Motoman's repository of ROS-Industrial

Free published in GitHub repository 

- Driver, 3D CAD model, visualization tool correspondence, etc.

GP12/7/8



MH5/12/50



MotoMINI



SDA10F/10D



SIA5D/10D/20D



ROS-Industrial Motoman meta-package (<http://wiki.ros.org/motoman>)

motoman ros-industrial ros urdf moveit

Reference: GitHub

508 commits 8 branches 7 releases 24 contributors

Branch: kinetic-devel New pull request Create new file Upload files Find file Clone or download

shaun-edwards Merge pull request #253 from gavanderhoorn/cleanup\_manifests ... Latest commit 80c5299 on 13 Nov 2018

motoman	all: fix grouping of elements in manifests.	3 months ago
motoman_driver	driver: sort source list JTA node.	3 months ago
motoman_gp12_support	support: harmonise build scripts.	3 months ago
motoman_gp7_support	support: harmonise build scripts.	3 months ago
motoman_gp8_support	support: harmonise build scripts.	3 months ago
motoman_mh12_support	support: harmonise build scripts.	3 months ago
motoman_mh50_support	support: harmonise build scripts.	3 months ago
motoman_mh5_support	support: harmonise build scripts.	3 months ago
motoman_motomini_support	all: fix grouping of elements in manifests.	3 months ago
motoman_msgs	Order dependencies.	3 months ago
motoman_sda10f_moveit_config	Order dependencies.	3 months ago
motoman_sda10f_support	support: harmonise build scripts.	3 months ago
motoman_sia10d_support	support: harmonise build scripts.	3 months ago
motoman_sia10f_support	support: harmonise build scripts.	3 months ago
motoman_sia20d_moveit_config	Order dependencies.	3 months ago
motoman_sia20d_support	support: harmonise build scripts.	3 months ago
motoman_sia5d_support	support: harmonise build scripts.	3 months ago

Source: <https://github.com/ros-industrial/motoman>

# Pros of ROS implementation at the manufacturer

## ROS features



- Communication library → Focus on application development
- Development and operation tools → Graph, 3D Viewer, Simulator, Compiler
- High-performance library → Also functions at academic level
- Ecosystem → Easy to share and install apps



## Easy benchmarking

- Free access to advanced technologies available with ROS

## Easy combination verification

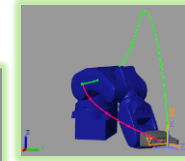
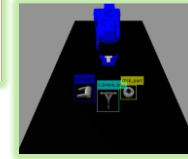
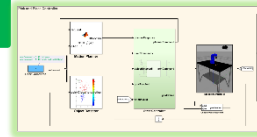
- Sensor / actuator compatible with ROS can be easily introduced
- Interworking can be expected with simple settings by using the ROS network

**Reduction of development man-hours Efficiency of advanced function benchmark etc.**



# Advantages of Introducing Robotics System Toolbox

## Robotics System Toolbox Features



- Maternal MATLAB is multi-platform
- Can interact with other toolboxes and scripts



## Easy combination verification with existing models

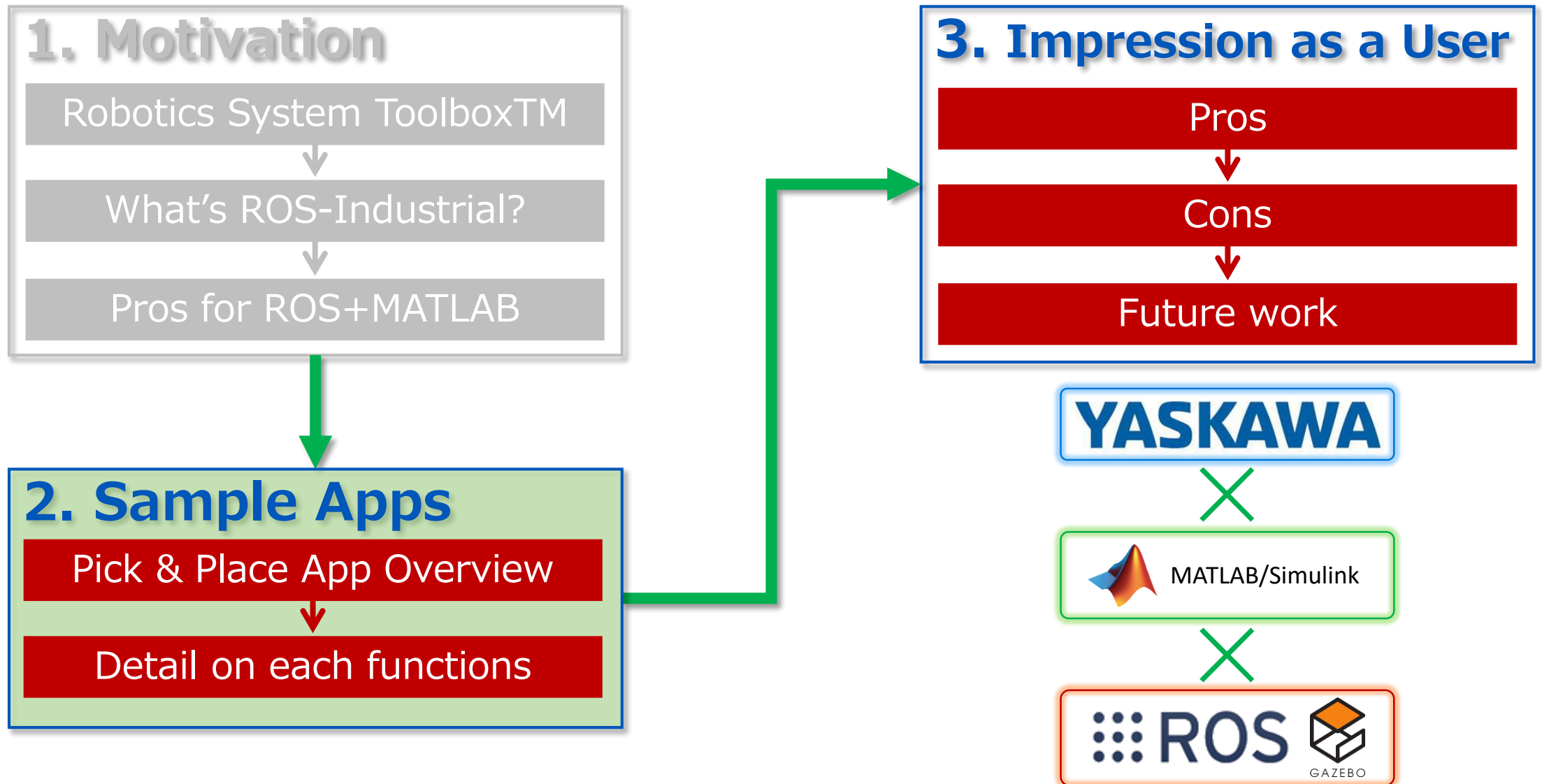
- Works with MATLAB / Simulink assets accumulated in-house
- Mainstream OS among manufacturers: ROS verification is possible based on Windows

## Easy to build various applications

- By combining various toolboxes of MATLAB, it is easy to develop advanced technology-based applications that are difficult to build with ROS alone

**Perform verification with sample application**

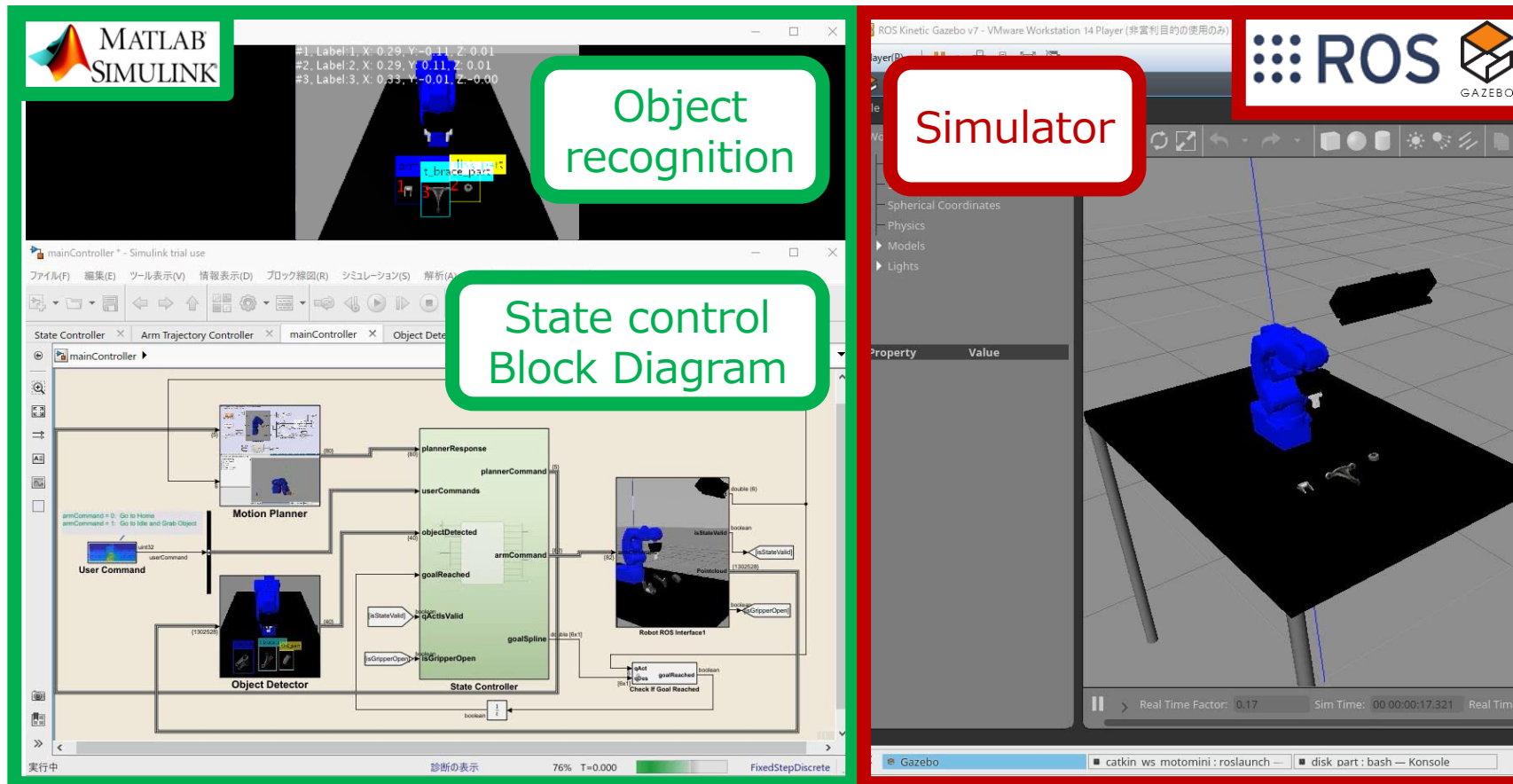
# Outline



# App demo video

## Example based system construction

- Build a system based on Example provided by Mathworks
- KUKA youBot → Yaskawa MotoMINI, SVM → YOLOv2



The image displays two side-by-side screenshots from a video demonstration. The left screenshot shows the MATLAB Simulink environment with a Simulink block diagram and a 3D visualization of a robot arm. The right screenshot shows the ROS Gazebo simulator with a 3D model of the robot arm and a console window.

**Object recognition**

**State control Block Diagram**

**Simulator**

**ROS**

**GAZEBO**

**ROS**

**Industrial solutions in asia pacific**

# App demo video

The screenshot displays a ROS Kinetic Gazebo v7 simulation environment. The main window shows a blue robot arm on a black table. The Gazebo interface includes a menu bar (File, Edit, Camera, View, Window, Help), a toolbar, and a property panel. The property panel shows the following table:

Property	Value
GUI	
Scene	
Spherical Coordinates	
Physics	
Models	
Lights	

The Simulink trial use window shows a control system diagram with the following components and connections:

- User Command** block outputs `userCommand` to the **Motion Planner** and **Object Detector** blocks.
- Motion Planner** outputs `plannerResponse` to the **State Controller** block.
- Object Detector** outputs `objectDetected` and `goalReached` to the **State Controller** block.
- State Controller** outputs `plannerCommand` to the **Motion Planner** and `armCommand` to the **Robot ROS Interface** block.
- Robot ROS Interface** outputs `gripperOpen` to the **State Controller** block.
- State Controller** outputs `gripperOpen` to the **Object Detector** block.
- State Controller** outputs `goalReached` to the **Check if Goal Reached** block.
- Check if Goal Reached** block outputs `goalReached` to the **State Controller** block.

The terminal window at the bottom shows the following output:

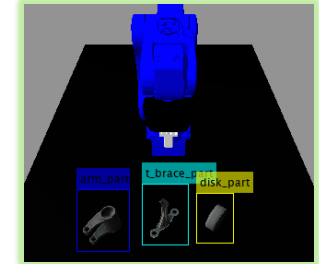
```
catkin_ws motomini : roslaunch - disk part : bash - Konsole
```

# Sample application summary

## Object recognition + position estimation



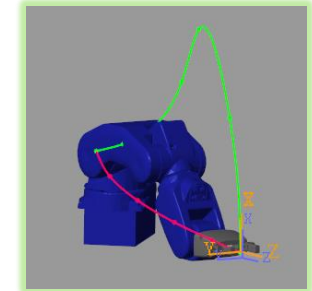
- Object recognition by deep learning based on RGBD sensor information
- Estimate the position of a 3D object



## Path plan + pick & place



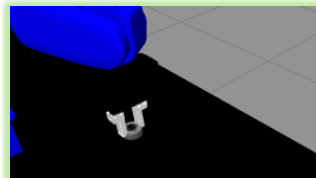
- Plan the trajectory from the robot's current posture to the recognized object position
- Control the robot based on the planned trajectory and carry out pick and place



## Voice input



- Voice input with microphone
- Control the robot according to the instructions



## MotoMINI simulation



- Utilize MotoMINI model provided by ROS-I
- Use simulator (Gazebo)

Build sample application only with  
MATLAB function + open source

# Sample app overview

## Flow of explanation

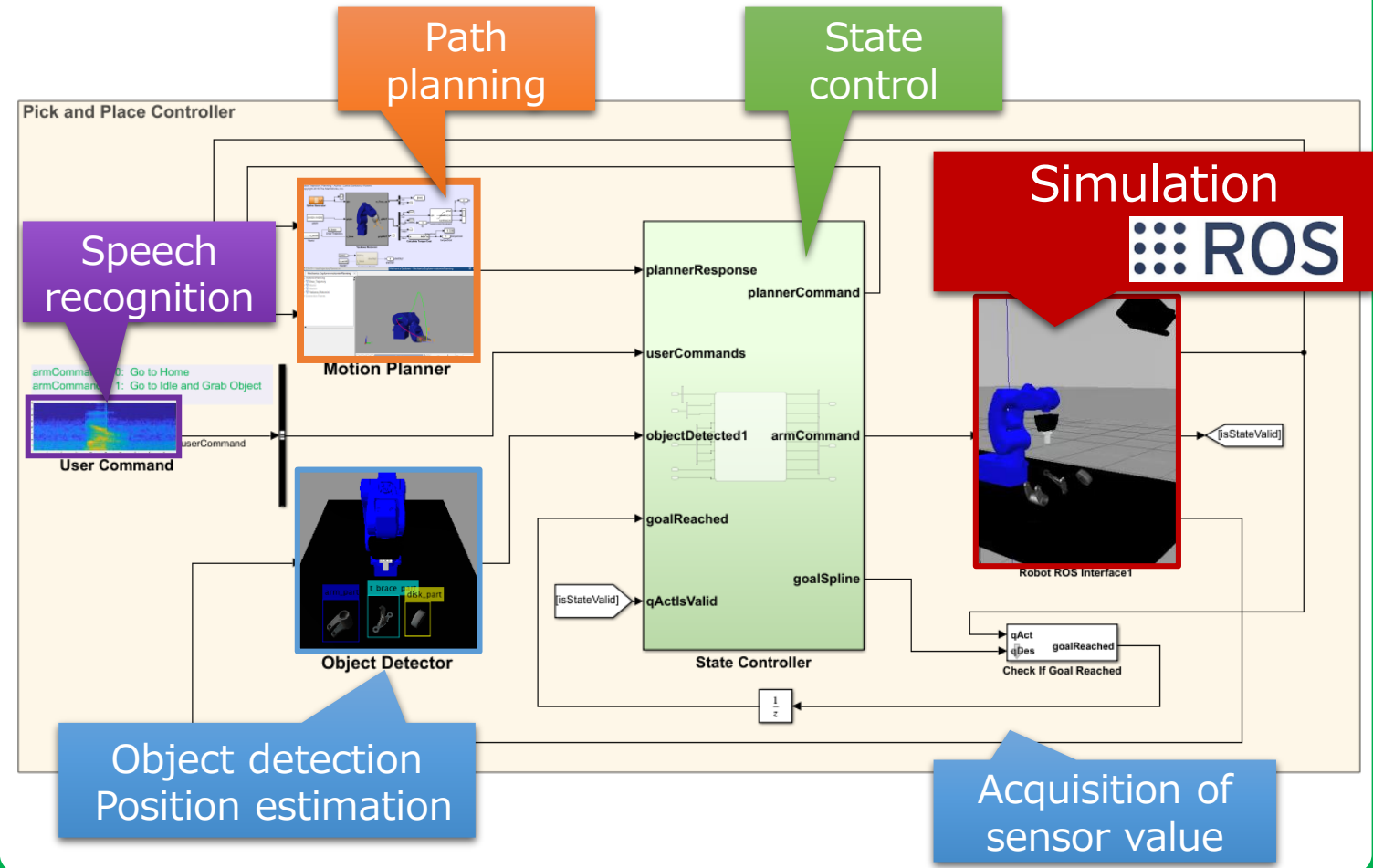
1. Object detection  
Position estimation

2. Path planning

3. Speech  
recognition

4. State machine

## Block diagram (Simulink model)



# Sample app overview : 1. Object detection

## Flow of explanation

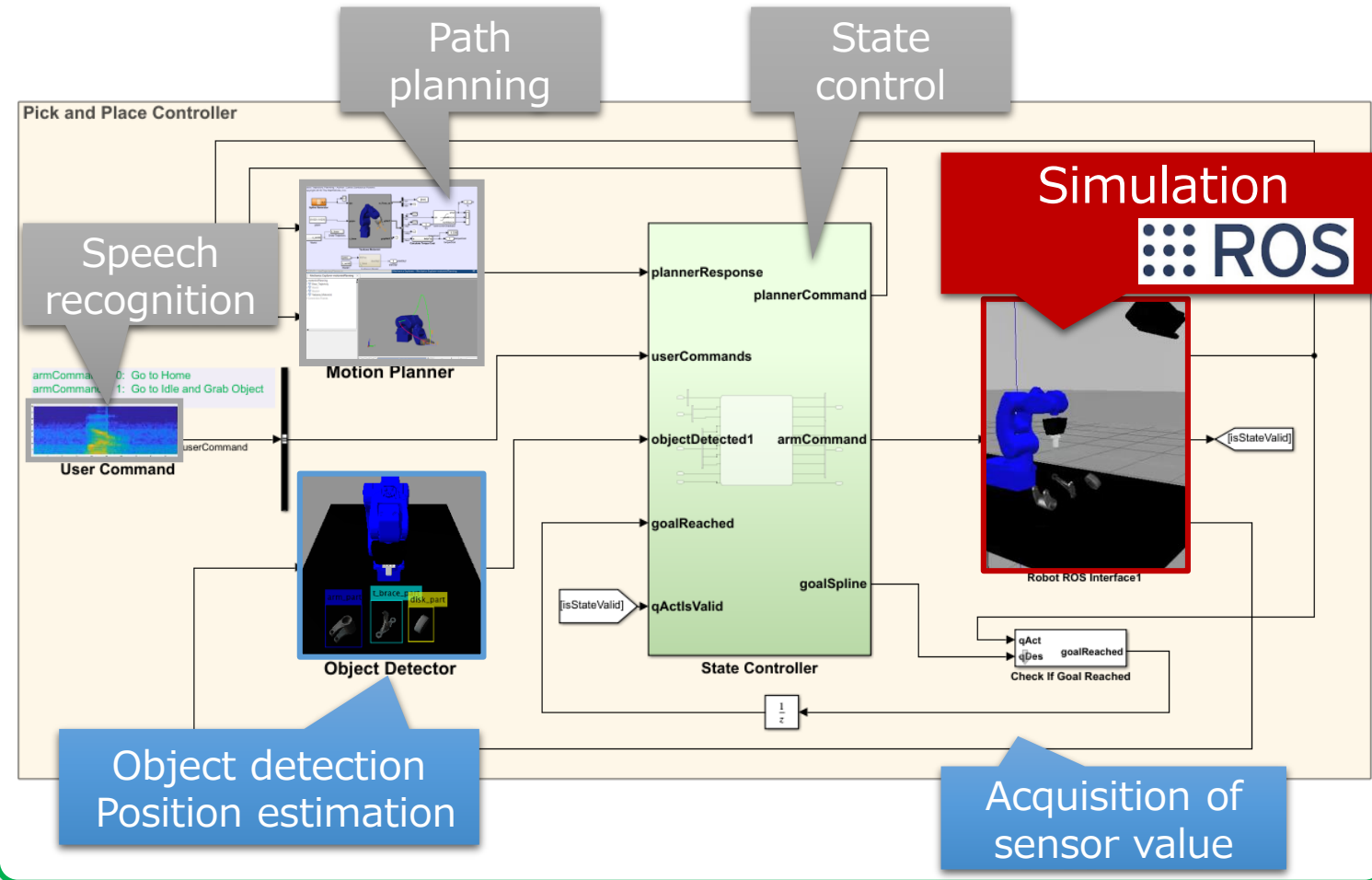
1. Object detection  
Position estimation

2. Path planning

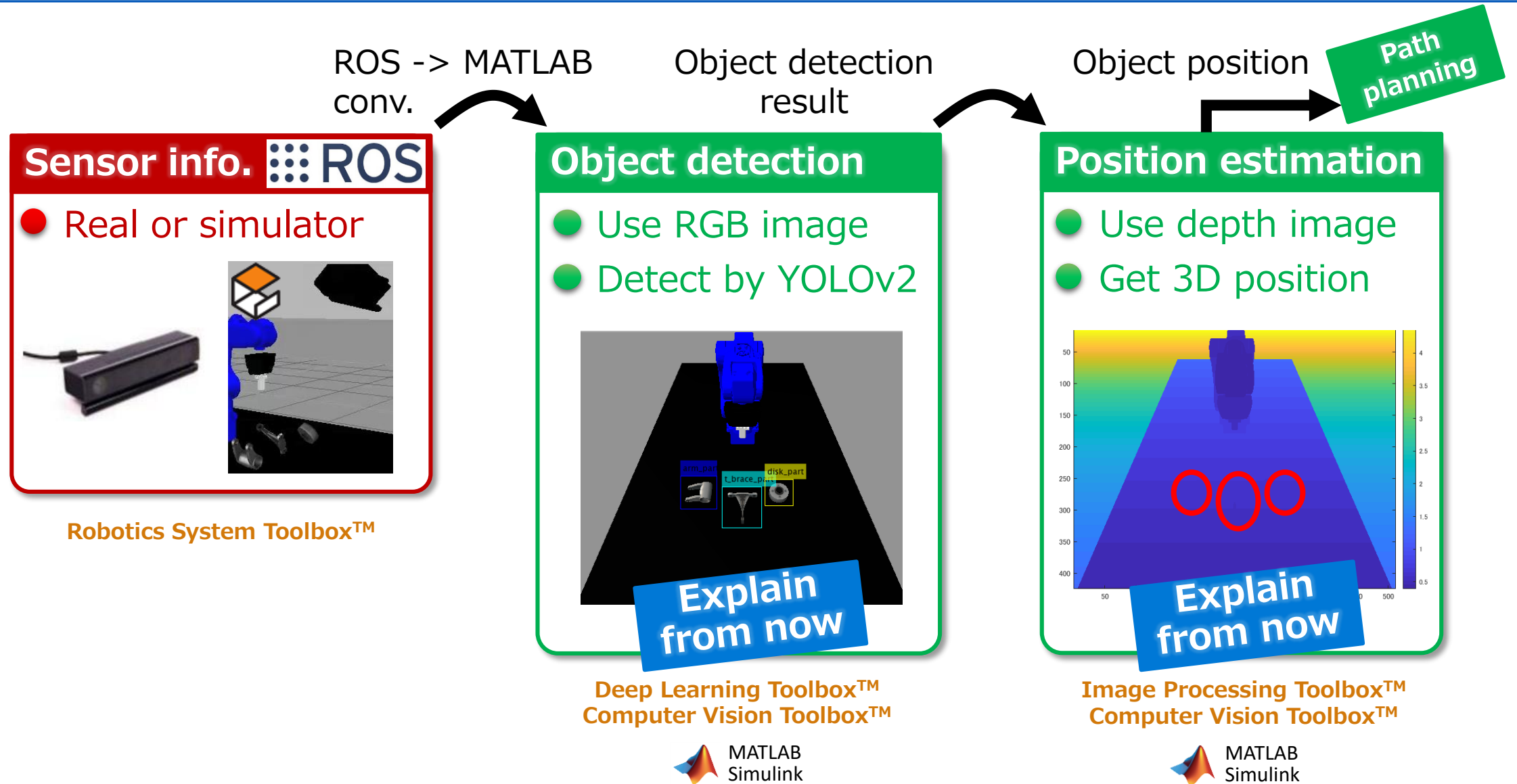
3. Speech  
recognition

4. State machine

## Block diagram (Simulink model)



# Flow of object detection + position estimation



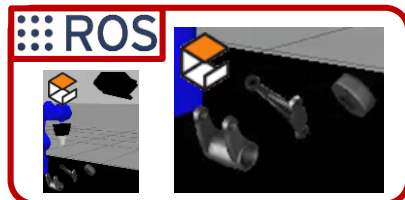


# Object recognition with deep learning (YOLOv2)

## Flow of object recognition by YOLOv2

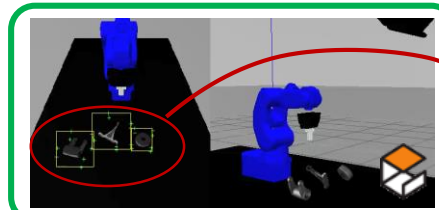
### ● Learning

Image Acquisition



Robotics System Toolbox™  
Image Processing Toolbox™

Labeling

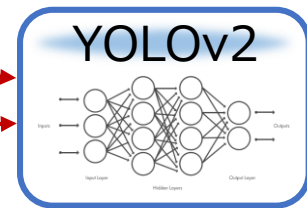


Robotics System Toolbox™

Input image

Anchor

Feature extraction + learning



Deep Learning Toolbox™

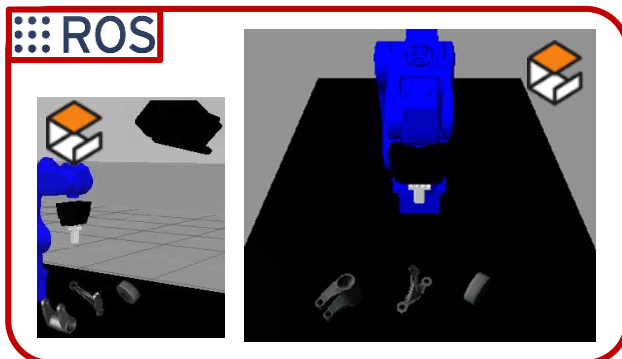
Learned model

To Recognition

Label

### ● Recognition

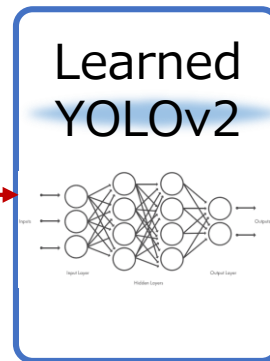
Image Acquisition



Robotics System Toolbox™

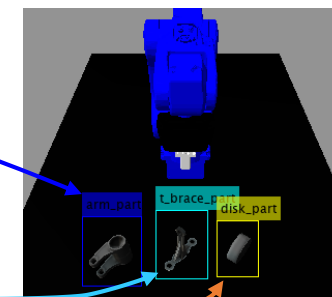
End to End Network

Input image



Deep Learning Toolbox™

Bounding box estimation



Extract work

To position estimation

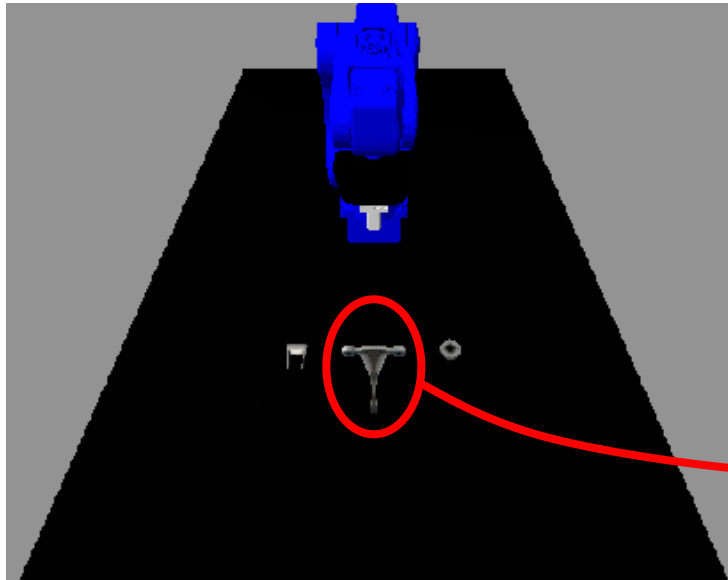
# Position estimation with point cloud

## Position estimation by point cloud

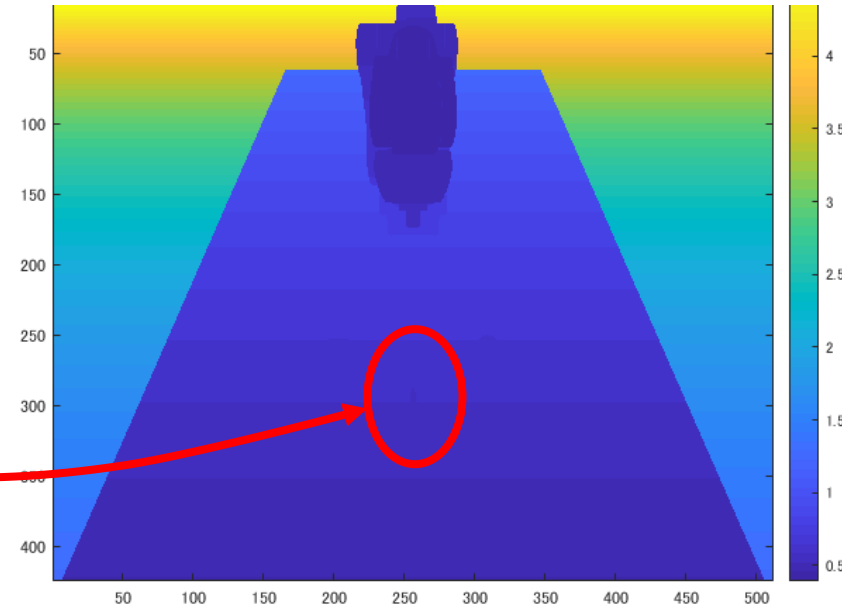


Computer Vision Toolbox™

- Use of both RGB image and depth image data by RGBD sensor



Object detection with RGB image



Get the depth of the corresponding position in the depth image

# Sample app overview : 2. Path planning

## Flow of explanation

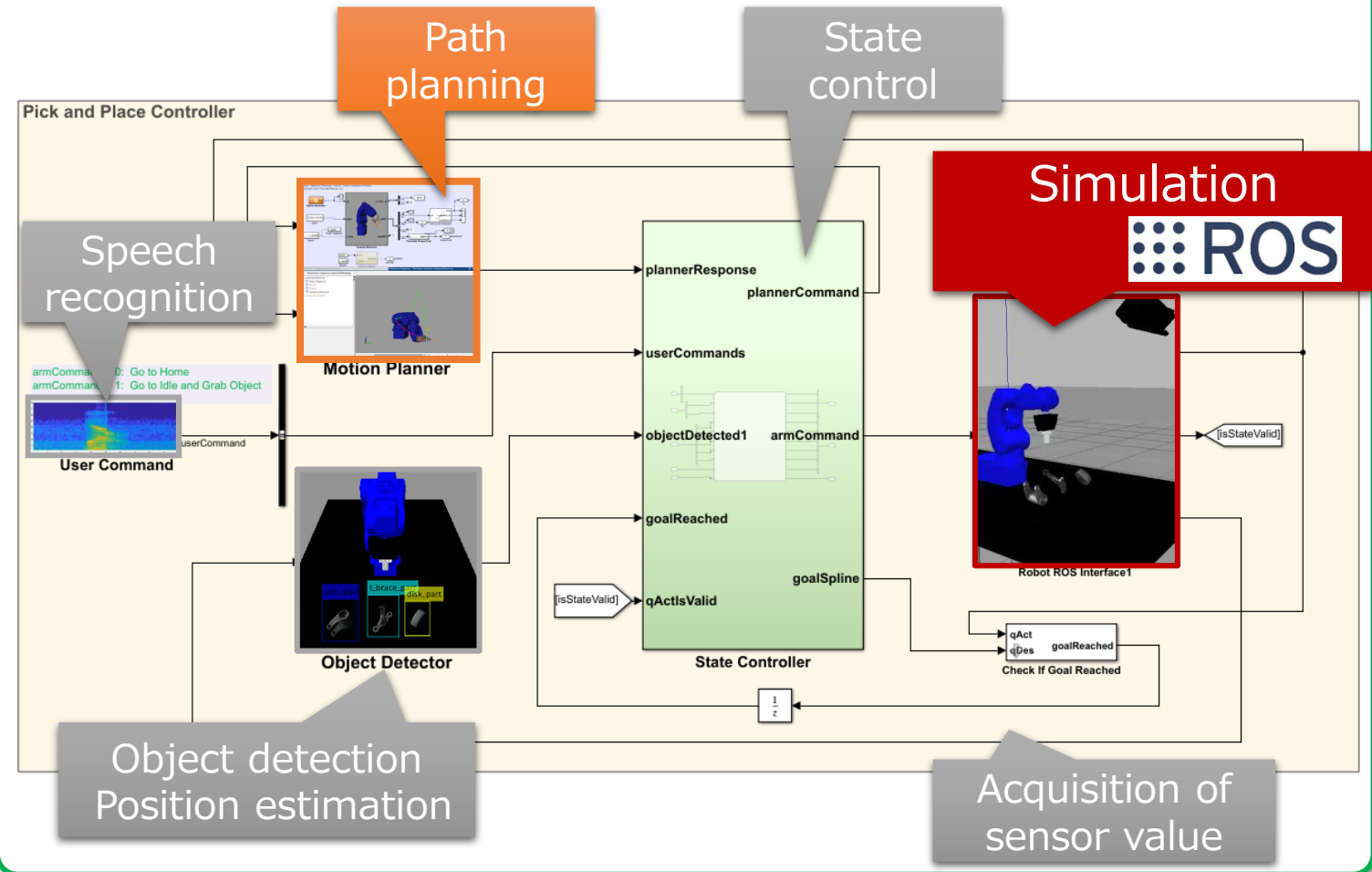
1. Object detection  
Position estimation

2. Path planning

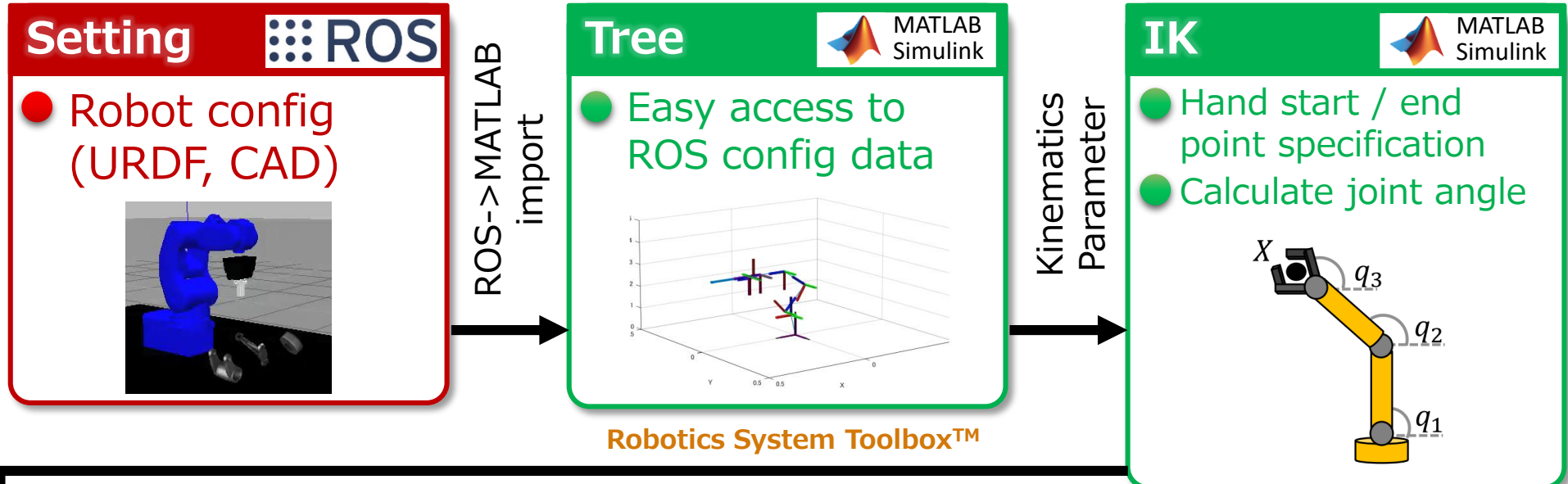
3. Speech  
recognition

4. State machine

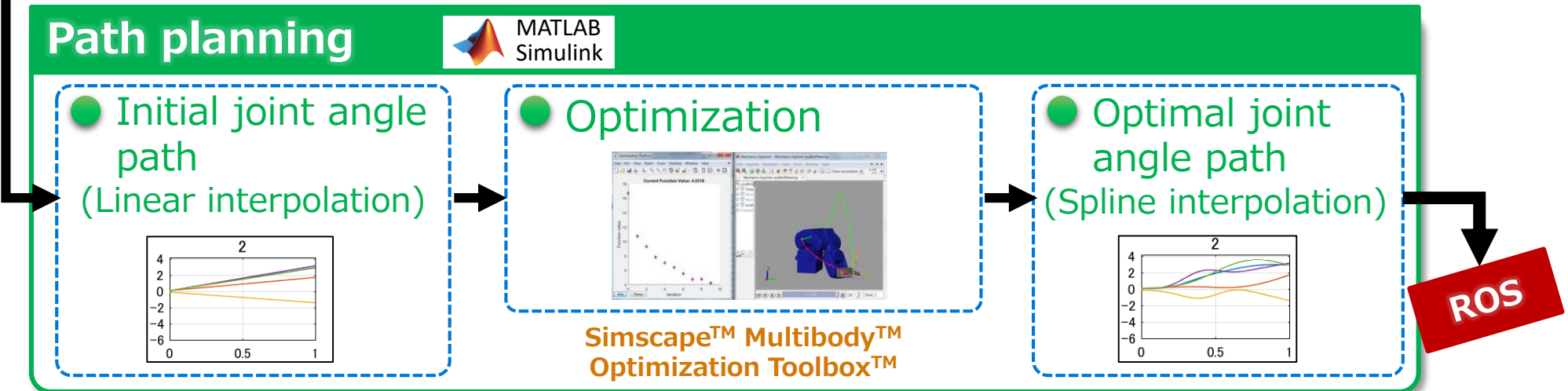
## Block diagram (Simulink model)



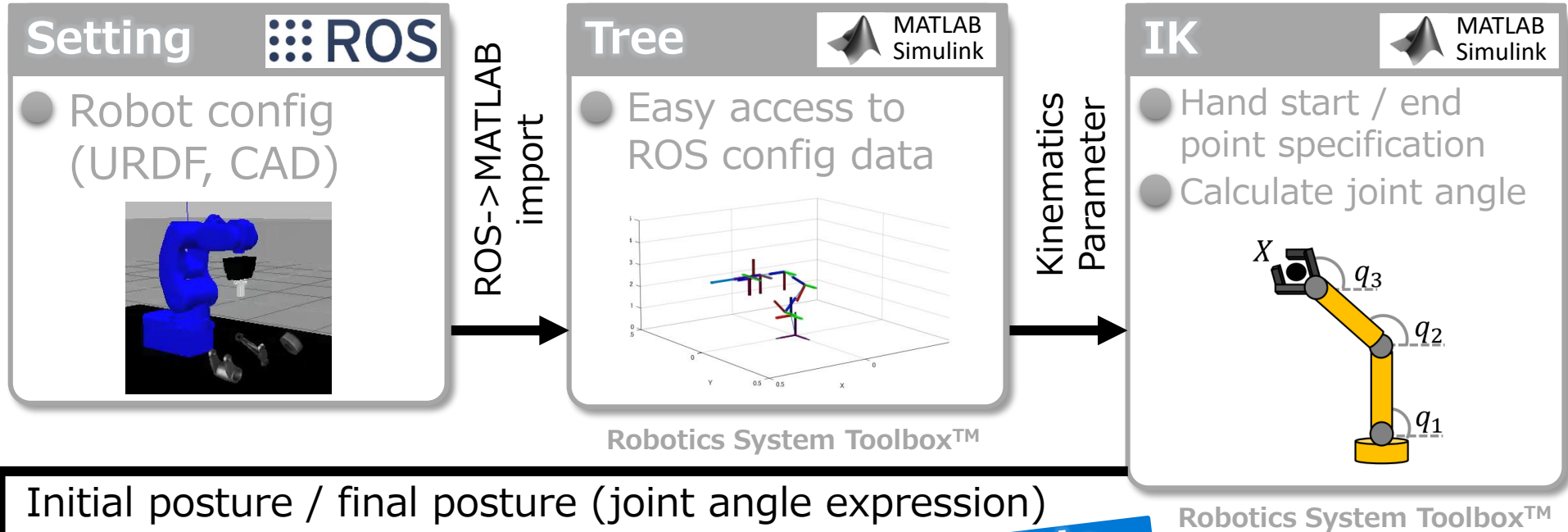
# Path planning flow



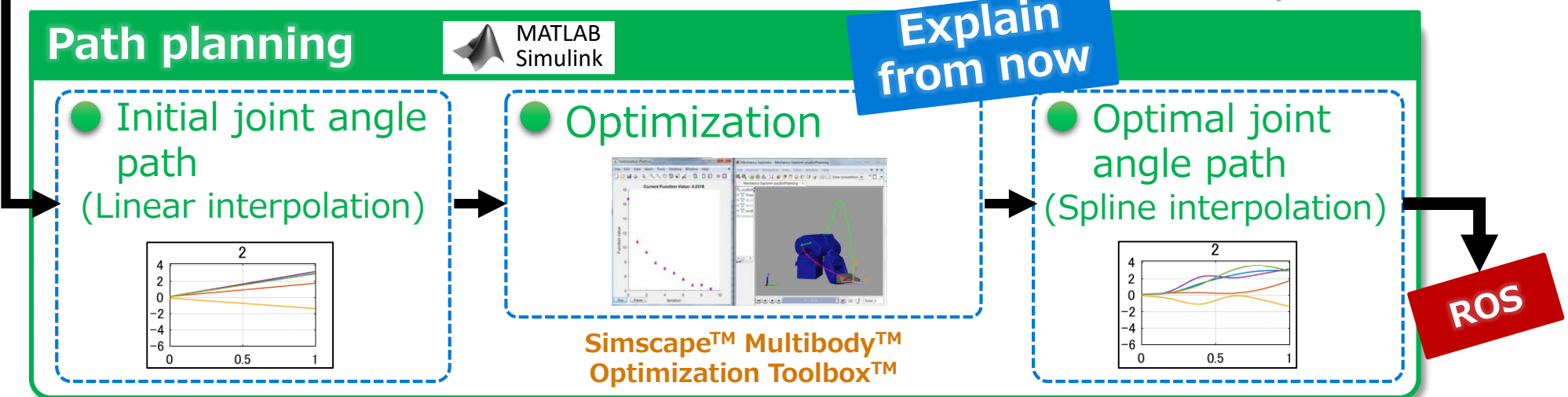
Initial posture / final posture (joint angle expression)



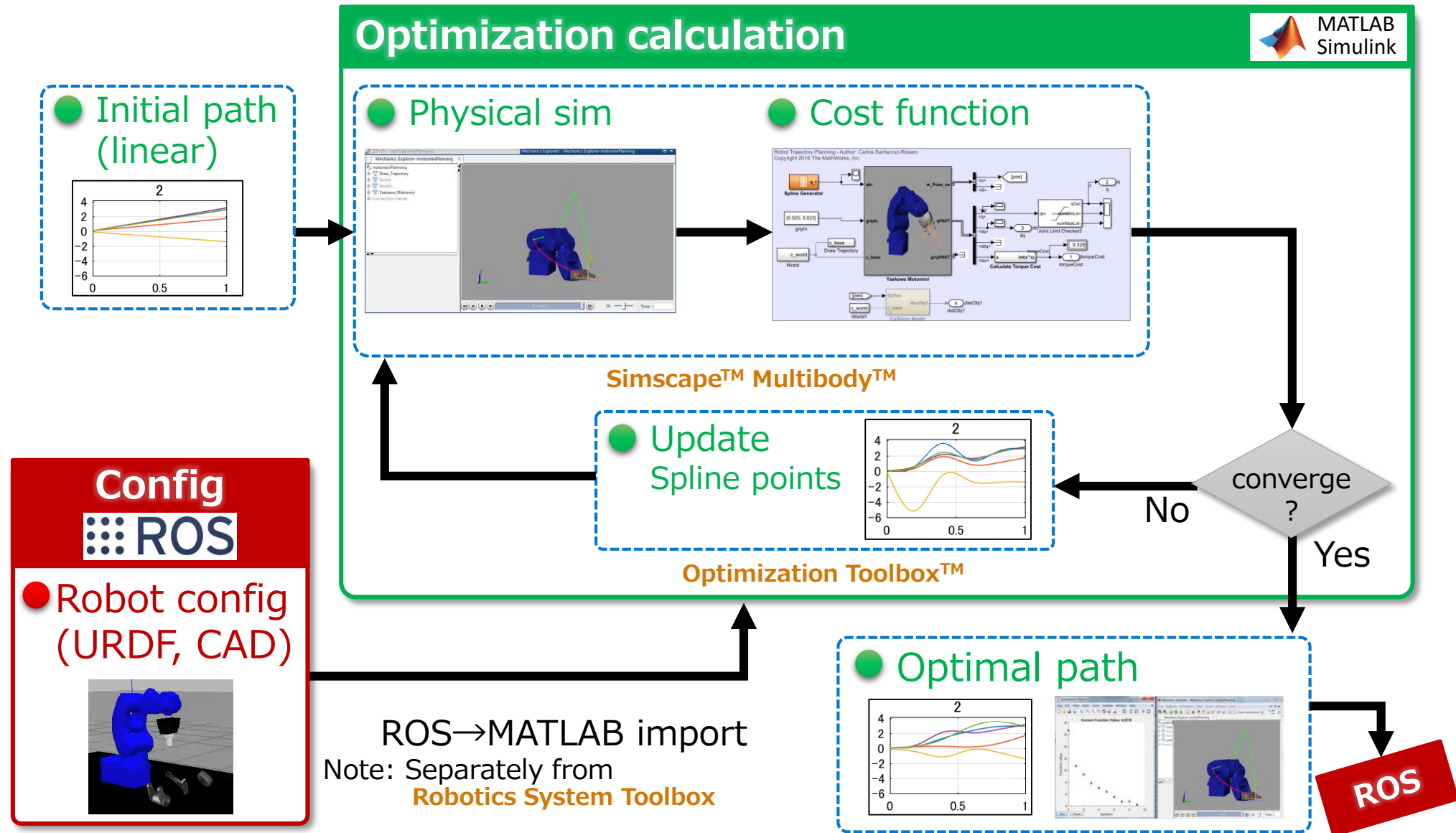
# Path planning flow



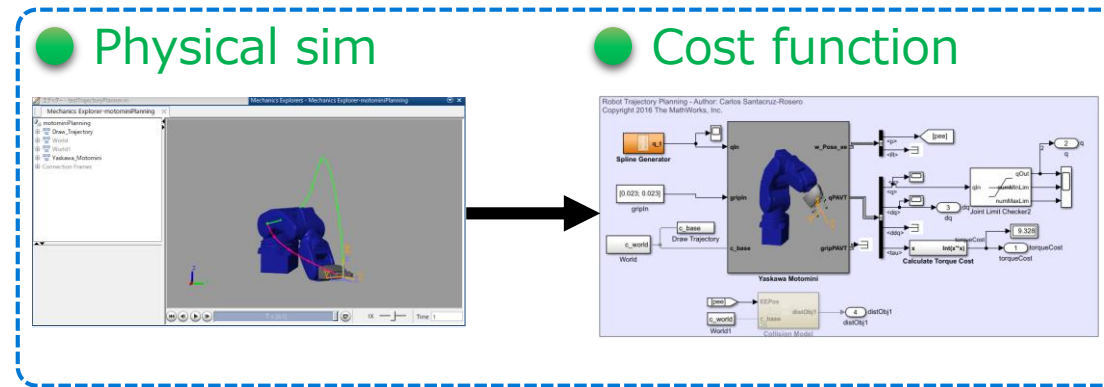
Initial posture / final posture (joint angle expression)



# Optimization overview



# Optimization overview: Main points

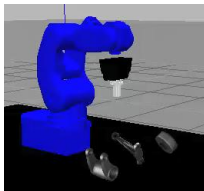


Simscape™ Multibody™

## Config

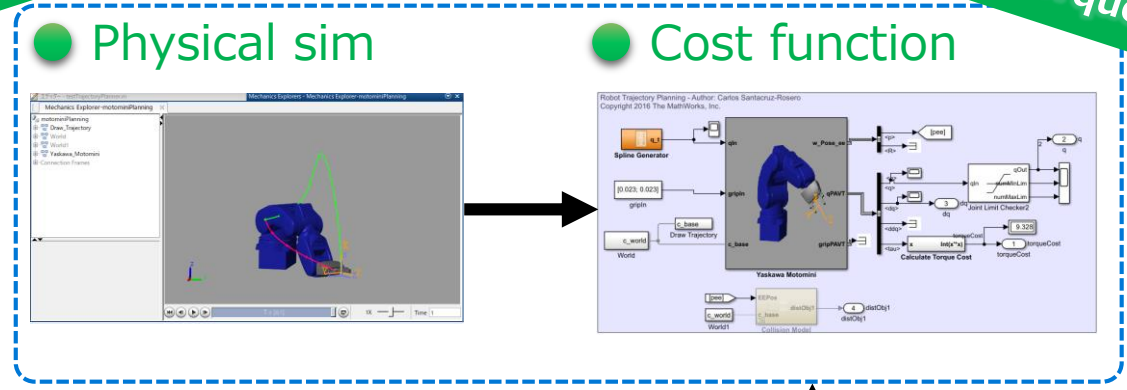
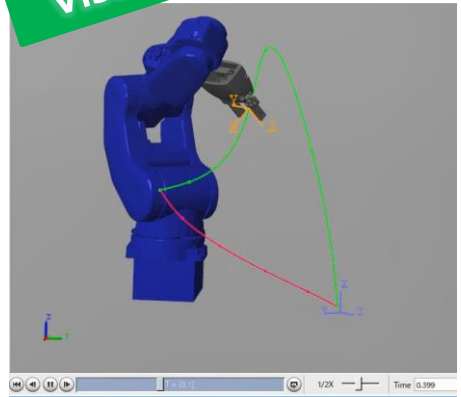
ROS

- Robot config (URDF, CAD)

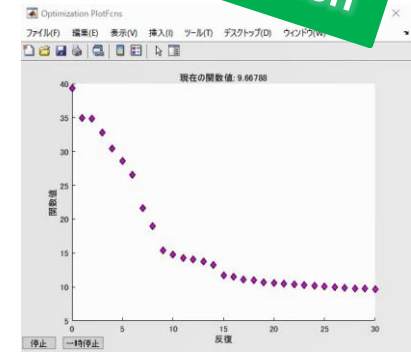


# Optimization overview : Main points

IK simulation  
Visualization of 3D motion



Calculate torque by simulation  
Total torque cost optimization



**Config**  
ROS

● Robot config (URDF, CAD)

**CAD import**      MATLAB Simulink

STL

The CAD import process shows a 3D model of a cylinder being imported into Simulink, where it is represented as a 'cylinder\_1\_RIGID' block in a mechanical system.

**URDF import**      MATLAB Simulink

The URDF import process shows a 3D model of a robot arm being imported into Simulink, where it is represented as a complex mechanical system with various joints and links.

剛体 (Rigid Body)      拘束 (Constraints)      カ・トルク (Force/Torque)      座標・座標変換 (Coordinate/Transformation)

- 剛体: Body Elements, Inertia, Solid
- 拘束: Constraints, Angle Constraint, Distance Constraint
- カ・トルク: Forces and Torques, Internal Force Inverse Square Law Force
- 座標・座標変換: Frames and Transform, Reference Frame, Rigid Transform



# Sample app overview : 3. Speech recognition

## Flow of explanation

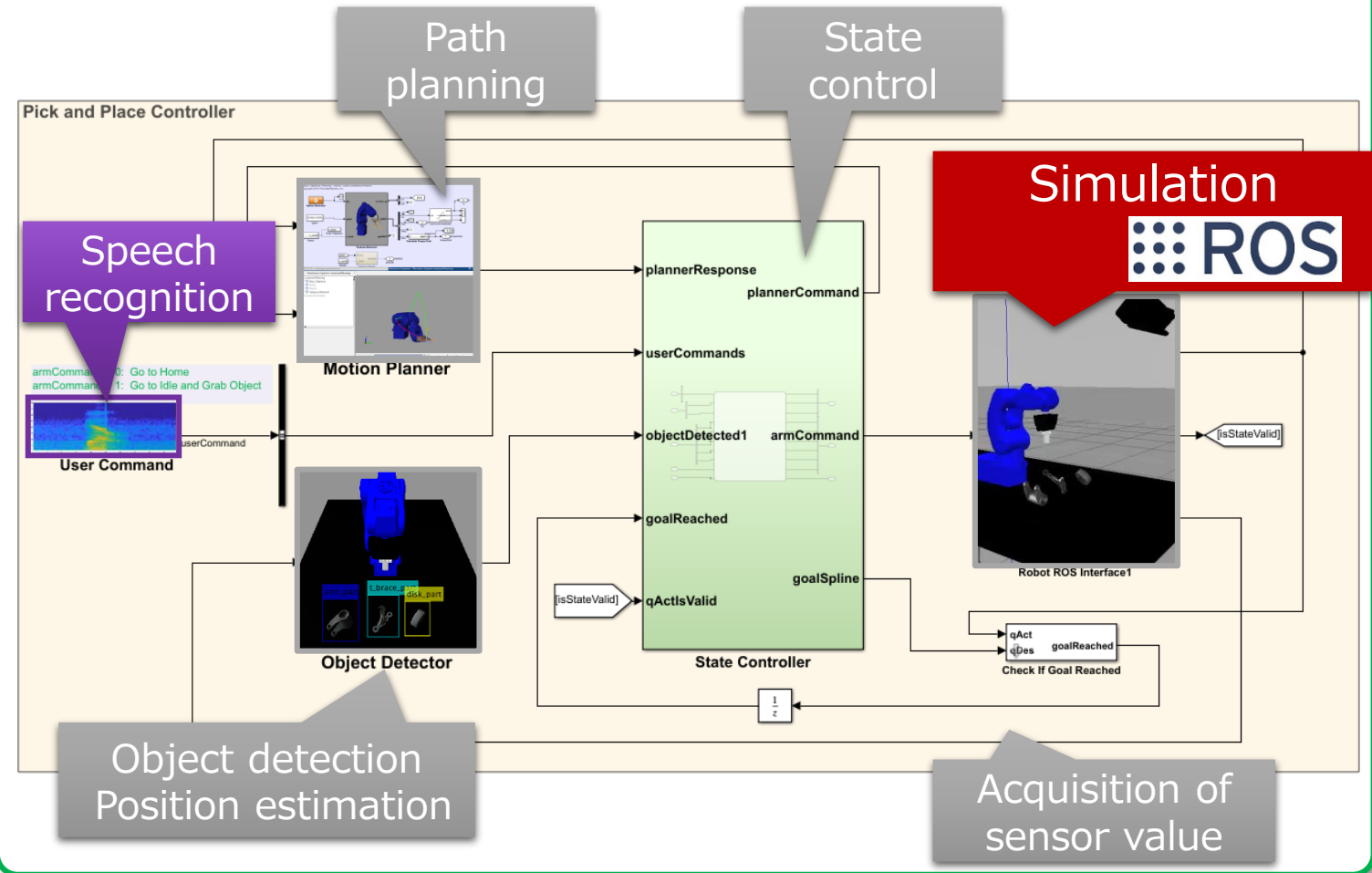
1. Object detection  
Position estimation

2. Path planning

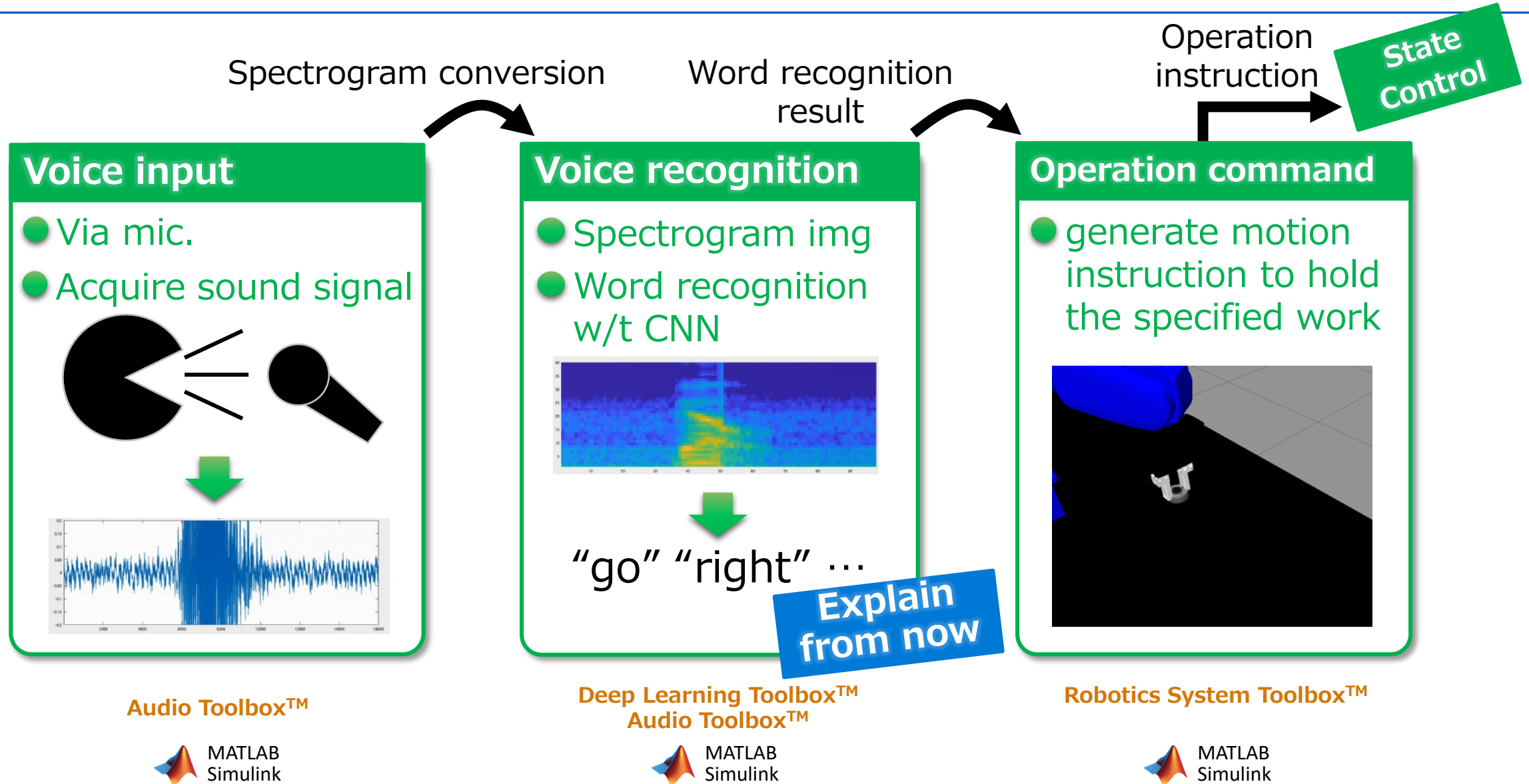
3. Speech recognition

4. State machine

## Block diagram (Simulink model)



# Speech recognition flow

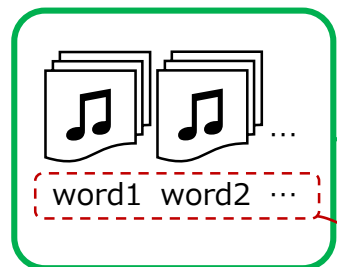


# Speech recognition Using deep learning (CNN)

## Flow of speech recognition w/t CNN

### ● Learning

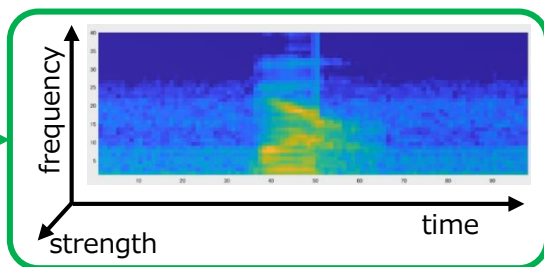
Voice data set



Audio Toolbox™

Conv.

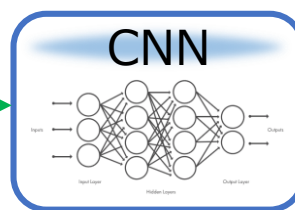
Spectrogram image



Audio Toolbox™

Input  
img

Feature extraction +  
learning



Deep Learning  
Toolbox™

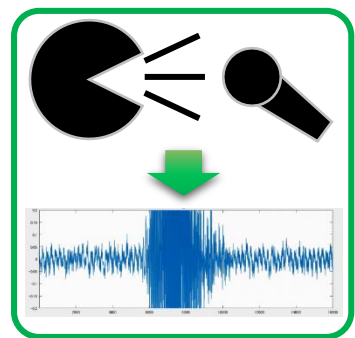
Label

Learned  
Model

Recognition

### ● Recognition

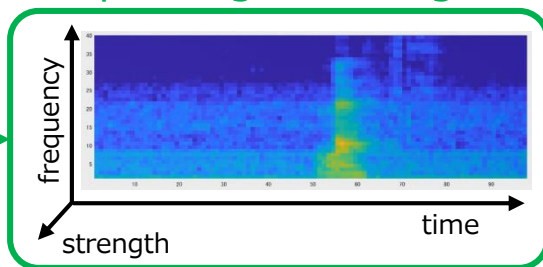
Voice input



Audio Toolbox™

Conv.

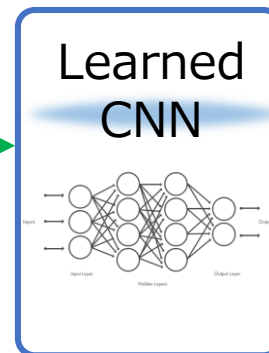
Spectrogram image



Audio Toolbox™

Input  
img

Feature extraction +  
classification

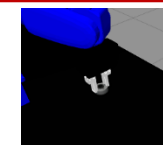


Deep Learning  
Toolbox™

Word recognition

Motion: go, stop  
Place: left, center, right

Motion instruction  
generation



State  
Control

# Sample app overview : 4. State machine

## Flow of explanation

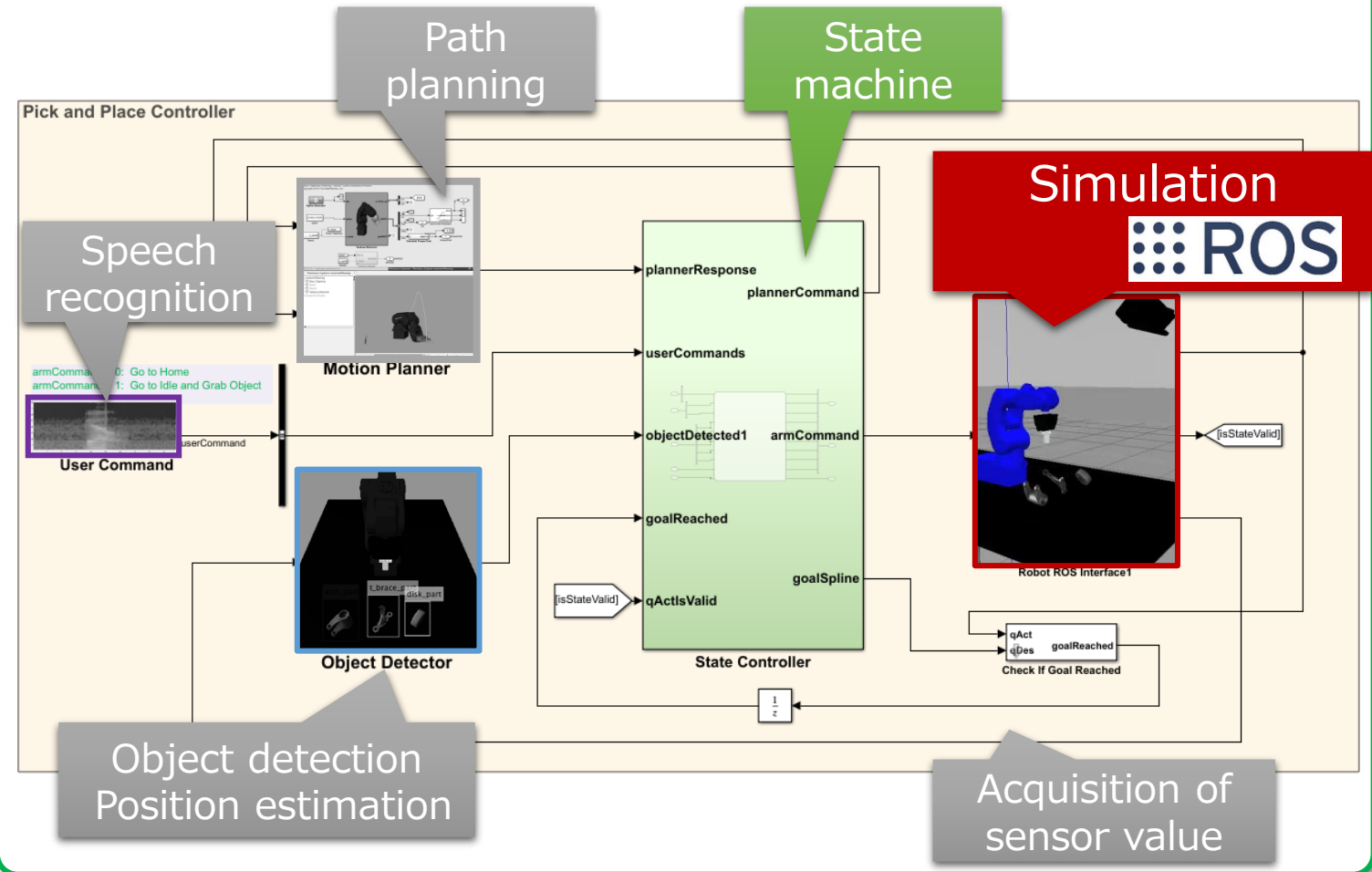
1. Object detection  
Position estimation

2. Path planning

3. Speech  
recognition

4. State machine

## Block diagram (Simulink model)



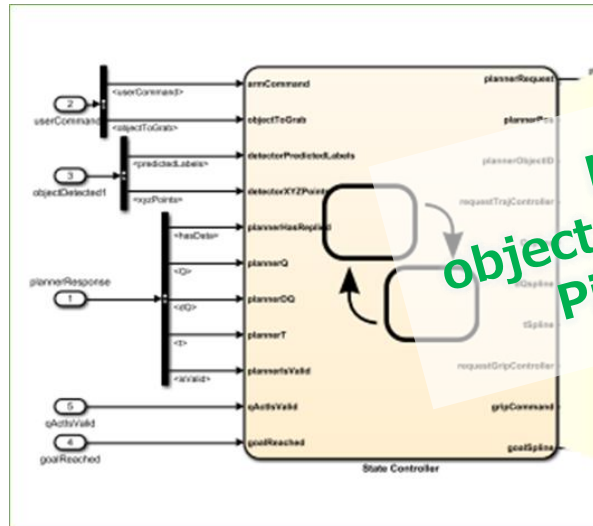
# State machine

## Control modules by state transition



Stateflow®

### State management of manipulator



Loop of object recognition & Pick & Place

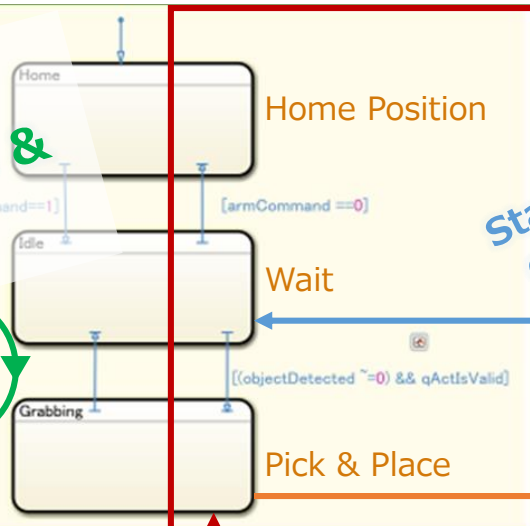
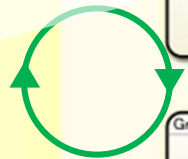
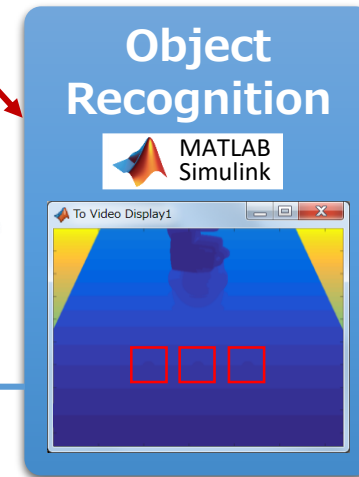
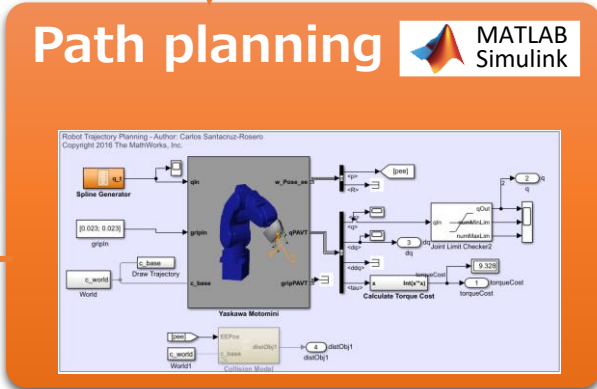


image :: ROS

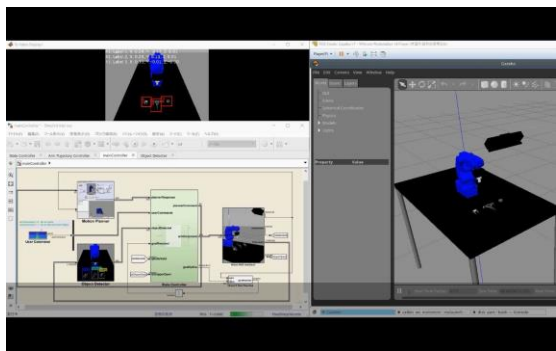


State transition during object detection

Path planning based on object position



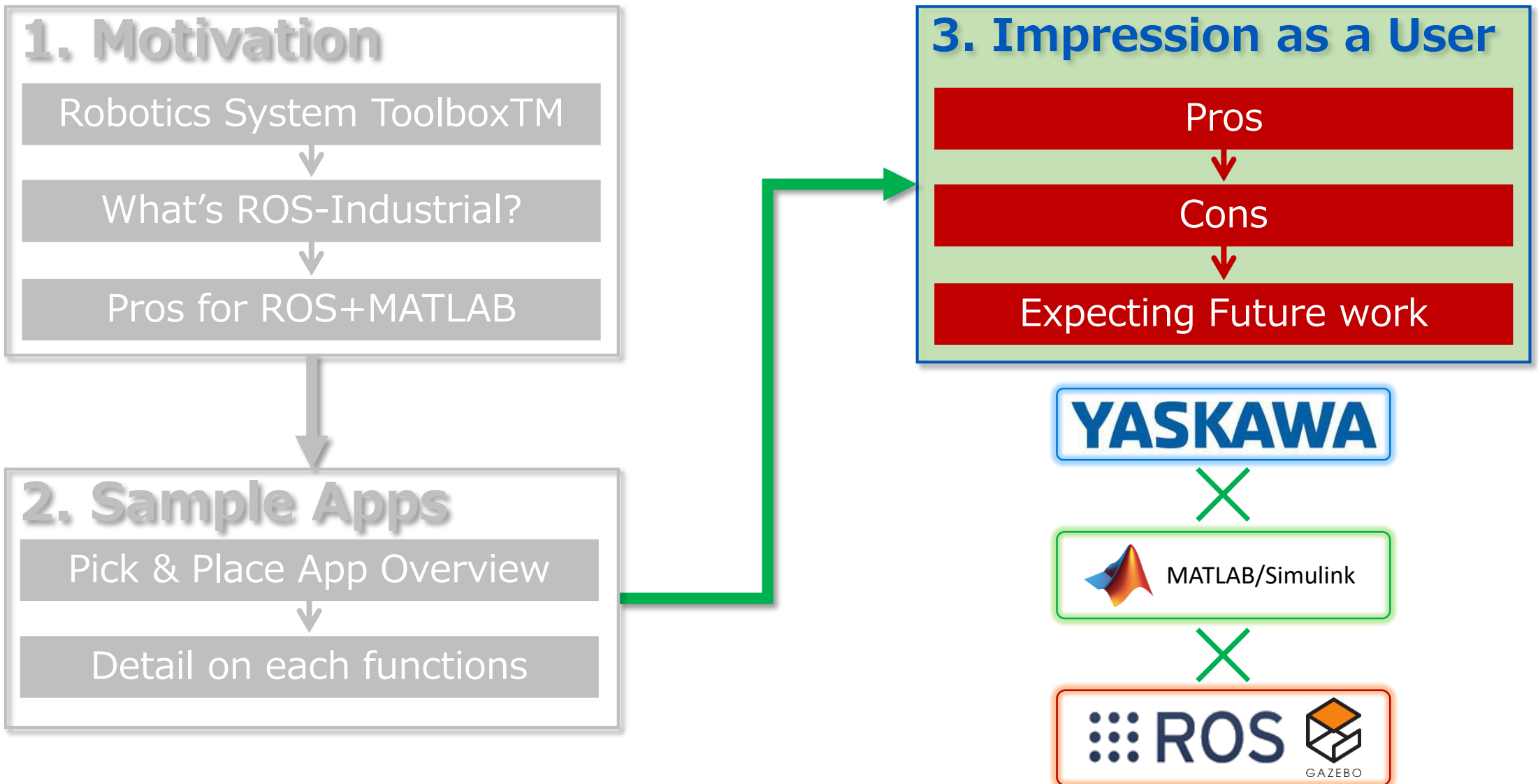
Path planning



Joint path Open/close

Pick and place Completion

# Outline



# Impression & Requests as a User of MATLAB

## Pros

- Easy collaboration with advanced functions
  - ROS alone can not be handled as easily as MATLAB
- Highly compatible with ROS, such as URDF, TF, Gazebo I/F too.
- Easy to use sequencer and blocking GUI such as StateFlow and Simulink
- Development based on Example enables early startup of prototypes

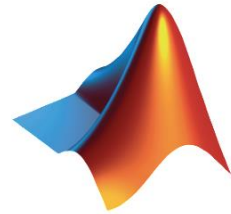
## Cons

- Processing takes time → Speeding up with Coder is also possible
- The parts requiring tuning are dispersed when changing the robot
- Some apps require to load the robot model separately for each toolbox

## Expecting Future work

- Import MATLAB motor and other models as Gazebo plug-in
- Need a sample where ROS for Windows and MATLAB work together
  - Currently there is only the tutorials where ROS runs on Linux on VM
- Support for ROS 2 and V-REP too!

# YASKAWA



MATLAB/Simulink

 ROS



GAZEBO



# Labeling for YOLOv2

## Training data



- Place works with random sets of position and posture
- Automatically capture parts images with various poses
- Automatically estimate bounding boxes and labels

## Gazebo



- Replace works from MATLAB
- Send images to ROS

