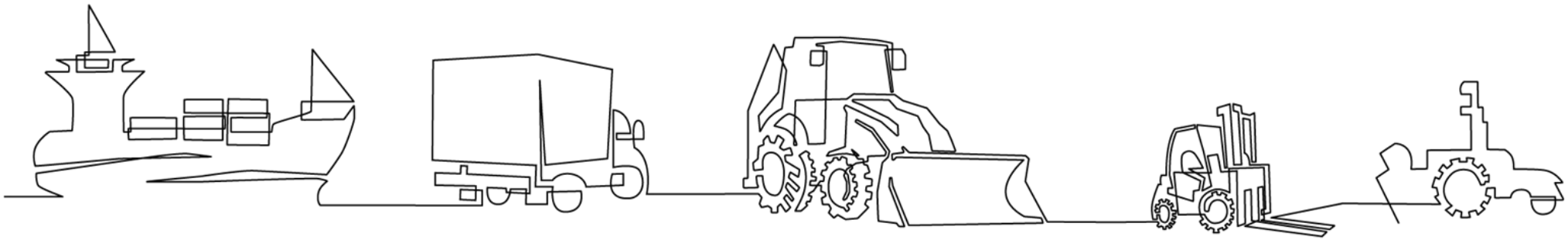


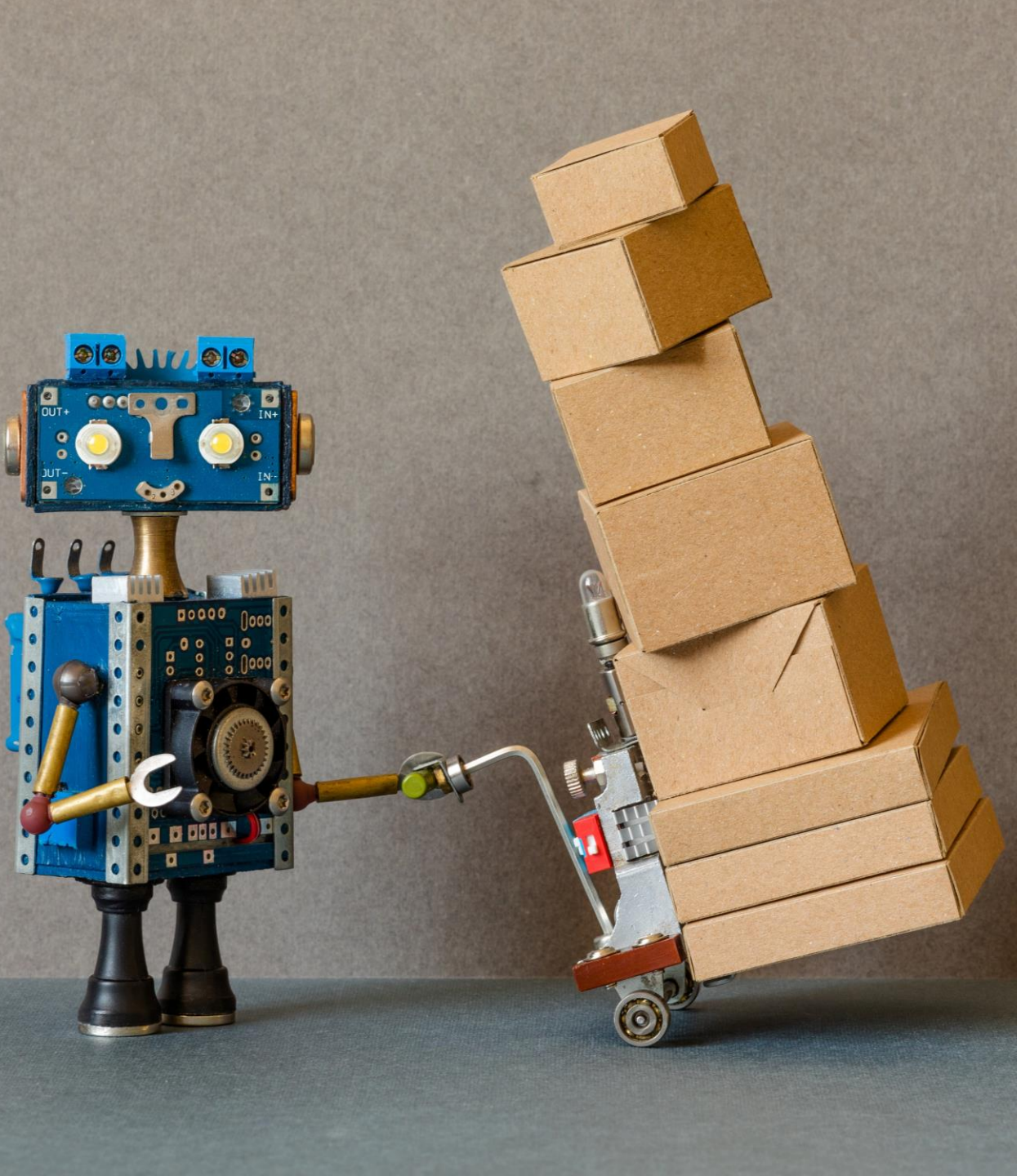
ROS AS AN ENABLER

FROM FINNISH CENTER OF EXCELLENCE TO GLOBAL FIELD AND SERVICE ROBOTICS MARKETS

FIIF - ROS SEMINAR
22.09.2022

D.Sc.(Tech.) Mika Vainio

GIM ROBOTICS



CONTENT

- BONUS
- INTRO
- COE-GIM
- A MECHATRONIC MESS
- MIDDLEWARE: GIMNET -> ROS
- ROS
- UNI->BIZ = GIM ROBOTICS
- ROS@BIZ
- ROS2@BIZ
- FUTURE

GIM ROBOTICS

NEWS: From assistant systems to autonomous trams.

Škoda anti-collision system

Copyright: Škoda Group
https://gimrobotics.fi/stop-the-press/

OUR HISTORY

GIM ROBOTICS

CoE-GIM: CENTRE OF EXCELLENCE IN GENERIC INTELLIGENT MACHINES RESEACH (2008 – 2013)

TKK

GENERAL RESEARCH GOALS OF GIM

- The focus of GIM covers mobile machines, intended to some useful work, from ordinary working machines to futuristic service robots experienced this far only in sci-fi movies.
- The future development of those machines will take place under a generic framework, which opens up novel possibilities to create new mechatronic machines through a modular design and manufacturing.

HOST ORGANIZATIONS

Automation Technology Laboratory ATL

Founded in 1985; director prof. Halme

Belongs to the Department of Automation and Systems Engineering at TKK

Institute of Hydraulics and Automation IHA

Founded in 1988; director prof. Vilenius

Belongs to the Department of Intelligent Hydraulics and Automation at TUT

GIM was founded by a common declaration 17.10.2005 and officially by Finnish Academy 1.1.2008


SICK
VOLVO

PERSONNEL

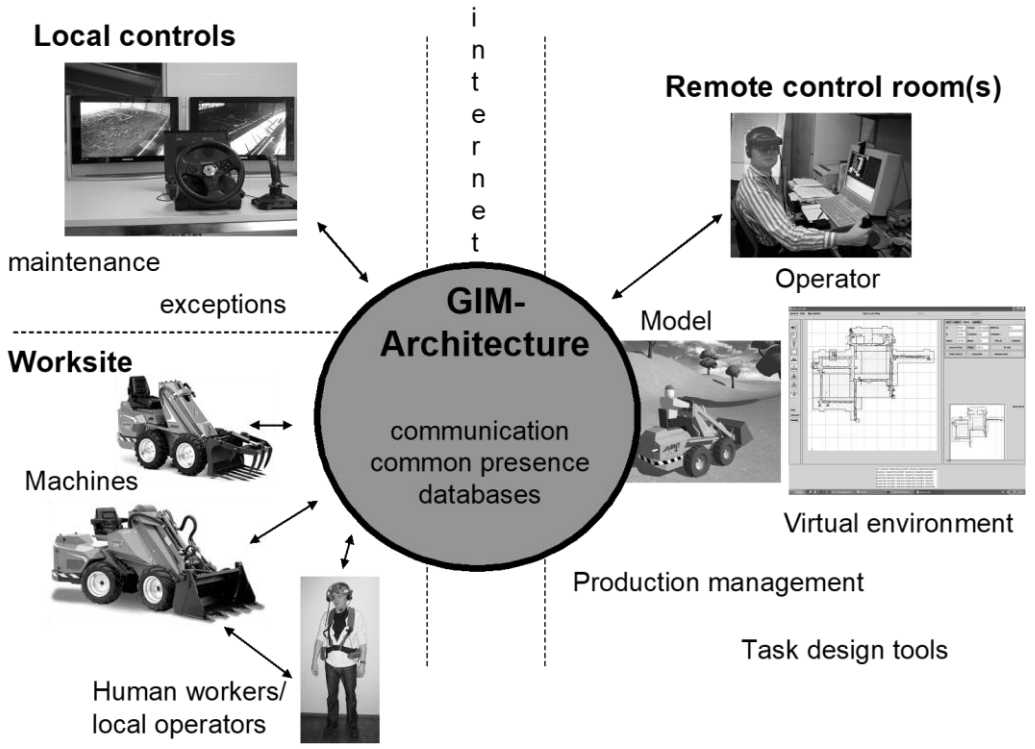
- The head of the CoE is Prof. Aarne Halme
- Staff size is about 50 including 14 professors or senior researchers, more than 30 doctoral students and some supporting personnel
- A senior researcher is responsible for tutoring and mentoring of 2 - 2.5 doctoral students
- The objective is to produce the minimum of 7 D.Sc annually

RESEARCH PACKAGES IN THE AGENDA

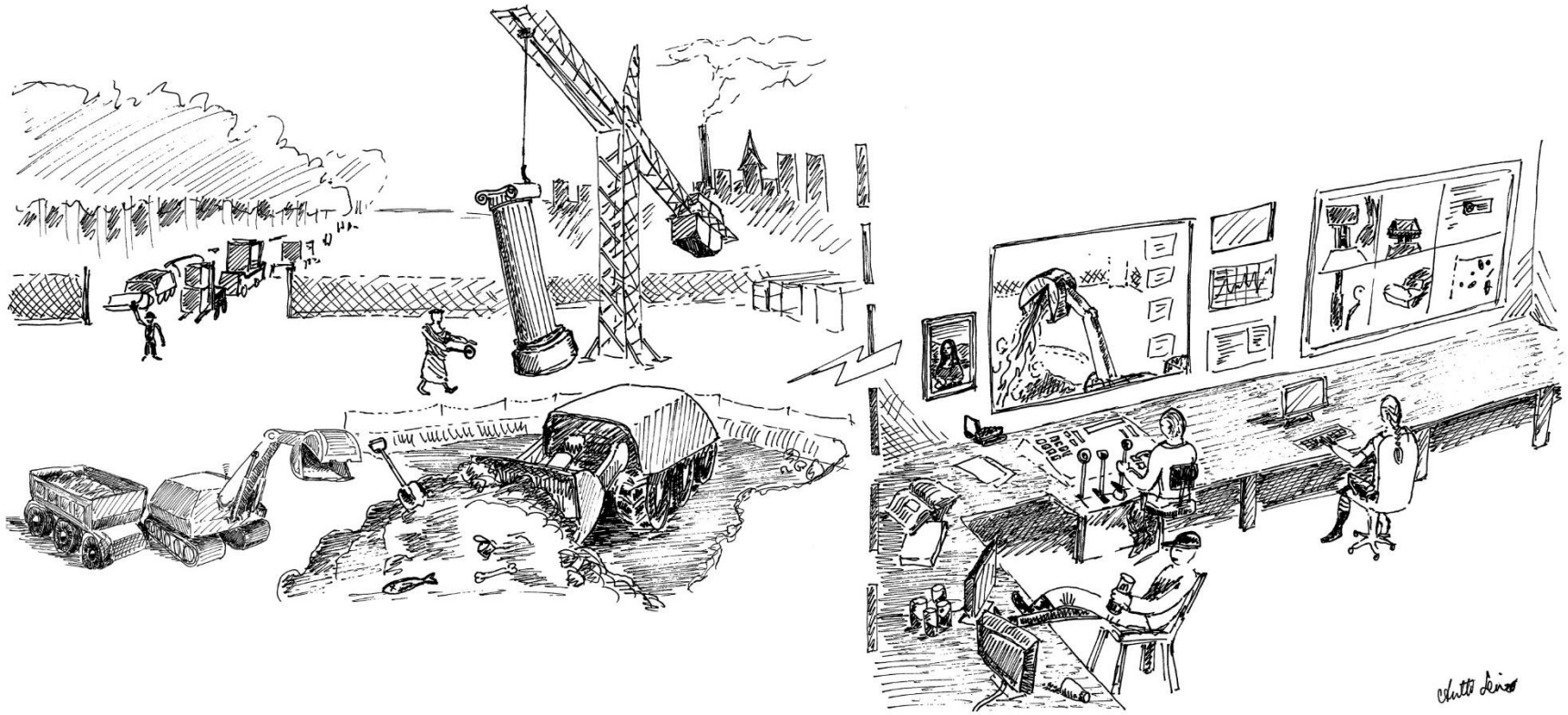
- **RP 2 Modularity of generic machines**
- **RP 3-4 Power and energy systems**
- **RP 5 Control Architectures**
- **RP 6 Perception and navigation systems**
- **RP 7 Human-Robotic Machine Interaction**
- **RP 8 Motion Systems**

GENERAL GOALS 2008-10

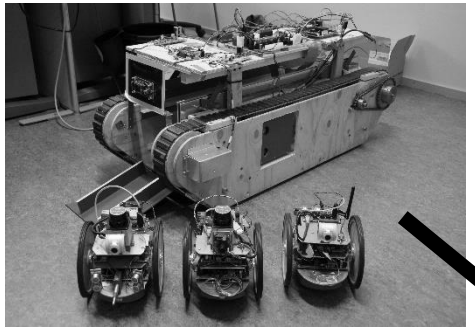
- RPs set their own detail goals.
- Common goal is to demostrate ”Future worksite” concept in practice in RP 9 (Integrator)

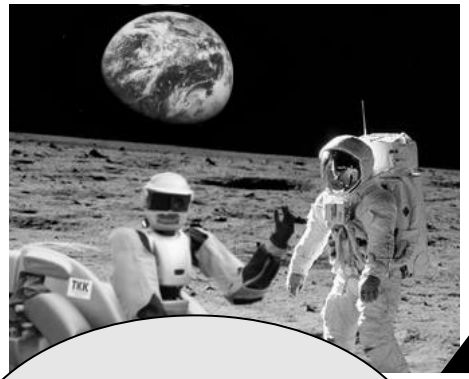


FUTURE WORKSITE CONCEPT

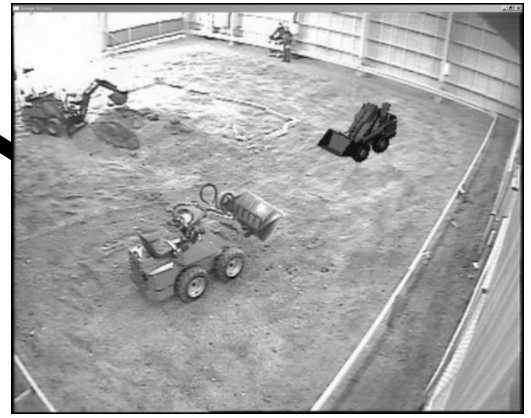


TESTBEDS





Future worksite



FUTURE WORKSITE DEMONSTRATION

- Hardware
  - 3 AVANT machines
  - GIM-machine
  - WorkPartner
  - Multi-robot test system
  - Experimental manipulator
  - ”Electronic” field worker

- All machines connected to GIMnet

MACHINES

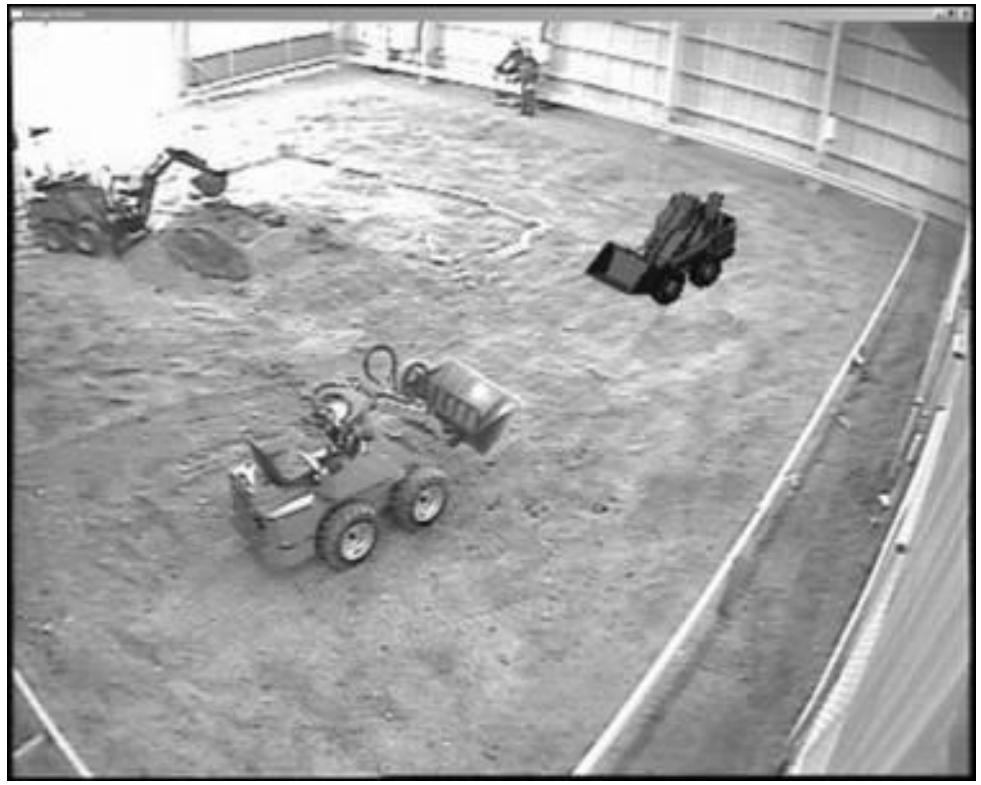
- Digital hydraulics implemented and in use
- Hybrid power systems
- Direct electro-hydraulic drives and recovery of hydraulic energy in electrical form, demonstrations
- Rolling walking and other special motion control methods demonstrations
- Navigation and environment perception modules implemented.

FUNCTIONS

- Navigation and 3 D mapping of the environment based on camera and ladar data. Flexible transition between indoor and outdoor spaces.
- Learning and execution of simple tasks
- Adaptation to environment during task execution (e.g. visual servoing)
- Interaction and collaboration with operator (localy or remotely)
- Natural communication between human and machine.
- Task planning using simulators.
- Optimization of the power system

SIMULATION

- Dynamical and simplified models of machines.
- Simulation of terrain effects. On-line updating of measured terrain parameters to the simulation model.
- FWS simulator showing all actors in the system.
- Augmented views.

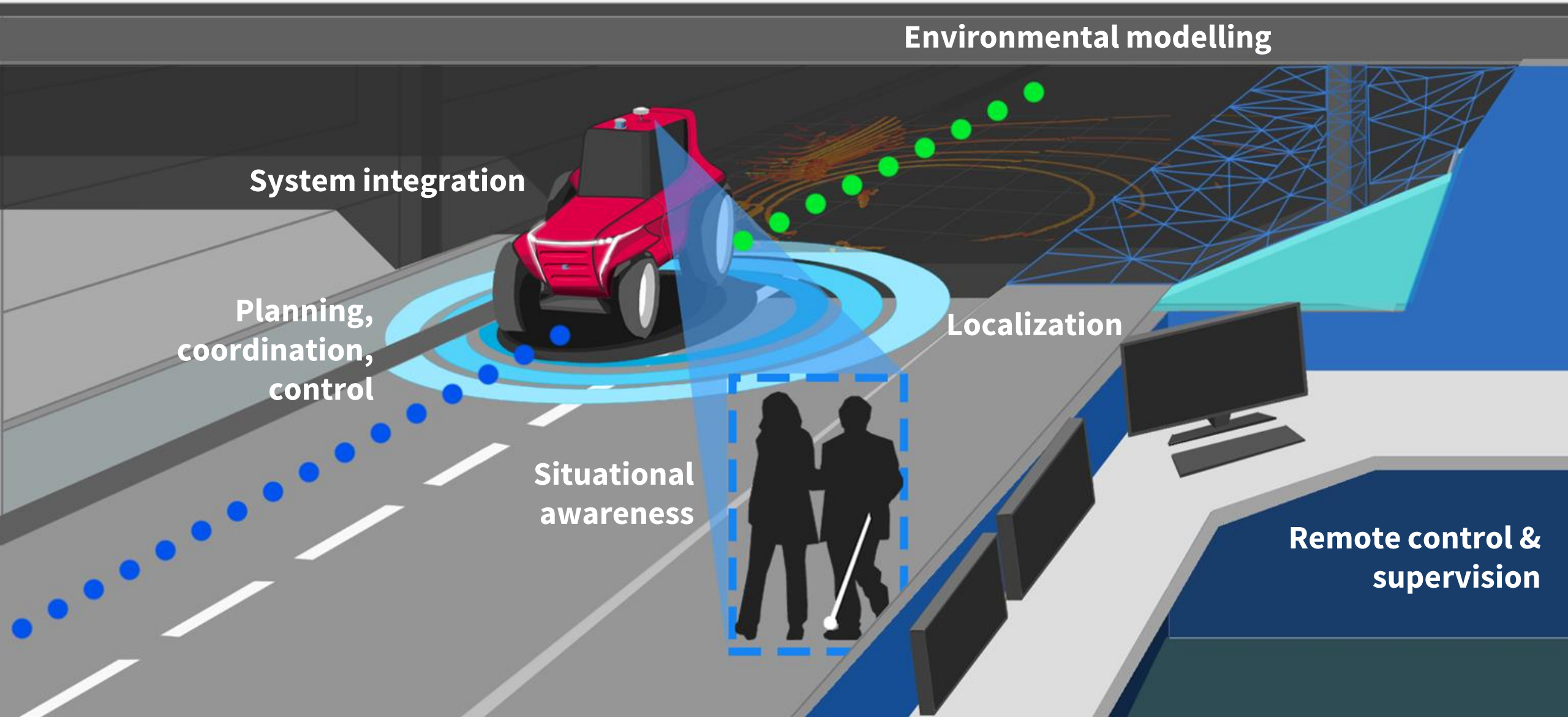


CENTRE OF EXCELLENCE IN GENERIC INTELLIGENT MACHINES RESEACH (2008 – 2013)

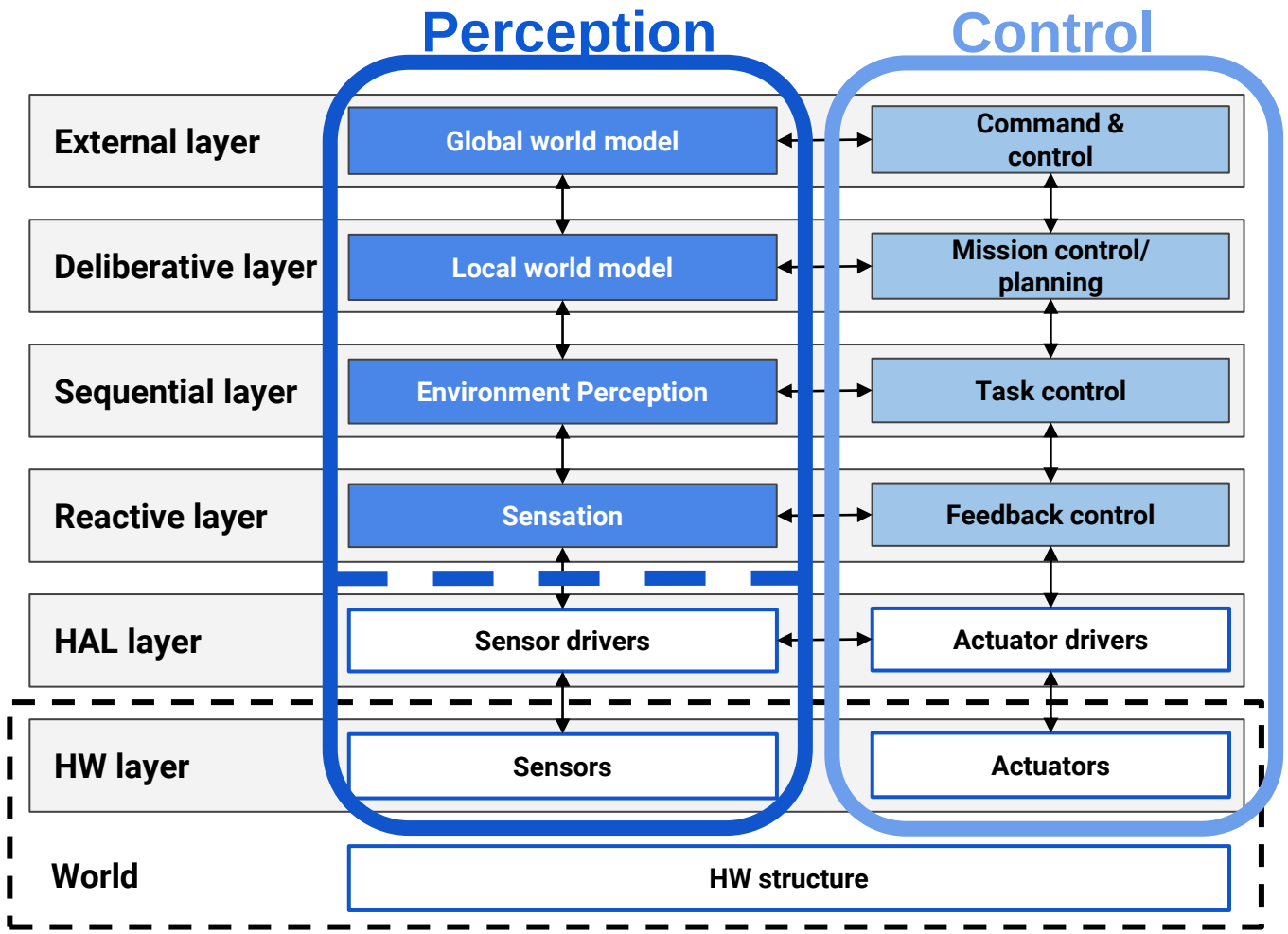
PRESENT DAY

GIM ROBOTICS

What is needed to fully automate a mobile machine?



FULL-STACK ARCHITECTURE



Legend

Generic technology solution

Application specific solutions

Platform & hardware specific solution

AN ADVANCED FIELD & SERVICE ROBOT IS A MESS, CONSISTING OF NUMEROUS MODULES, WHICH NEED TO BE ABLE TO INTERACT WITH EACH OTHER, WITH THE USER, WITH THE WORLD AND WITH SOME OTHER ROBOTS.

A MECHATRONIC MESS

GIM ROBOTICS

TO CONNECT ALL THOSE MODULES NICELY, YOU NEED A SYSTEM THAT MAKES SURE THAT THE BYTES ARE MOVING AS EXPECTED – TO RIGHT PLACE AND FAST ENOUGH.

THE MIDDLEWARE

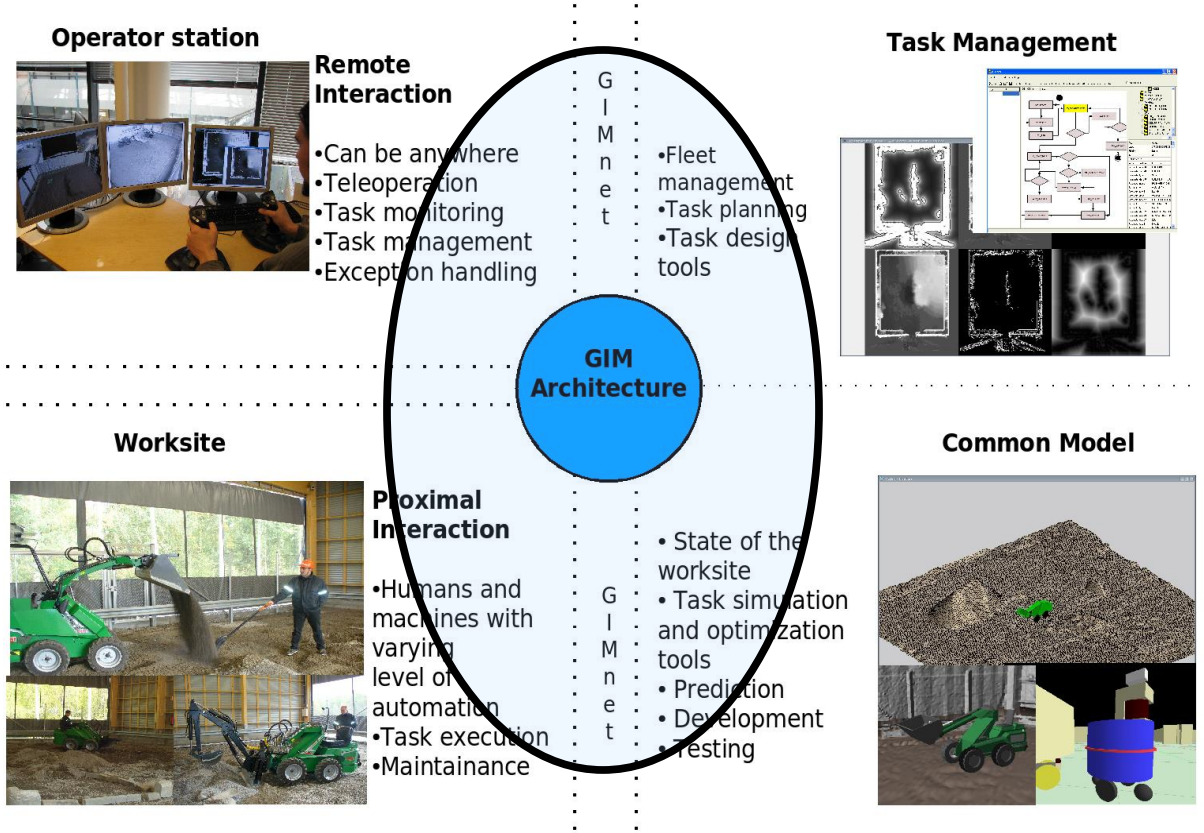
GIM ROBOTICS

OUR OWN: GIMNET

First publication 2007: Saarinen, J., Maula, A., Nissinen, R., Kukkonen, H., Suomela, J., & Halme, A. (2007). GIMnet - Infrastructure for distributed control of Generic Intelligent Machines. In *The 13th IASTED International Conference on Robotics and Applications Telematics*

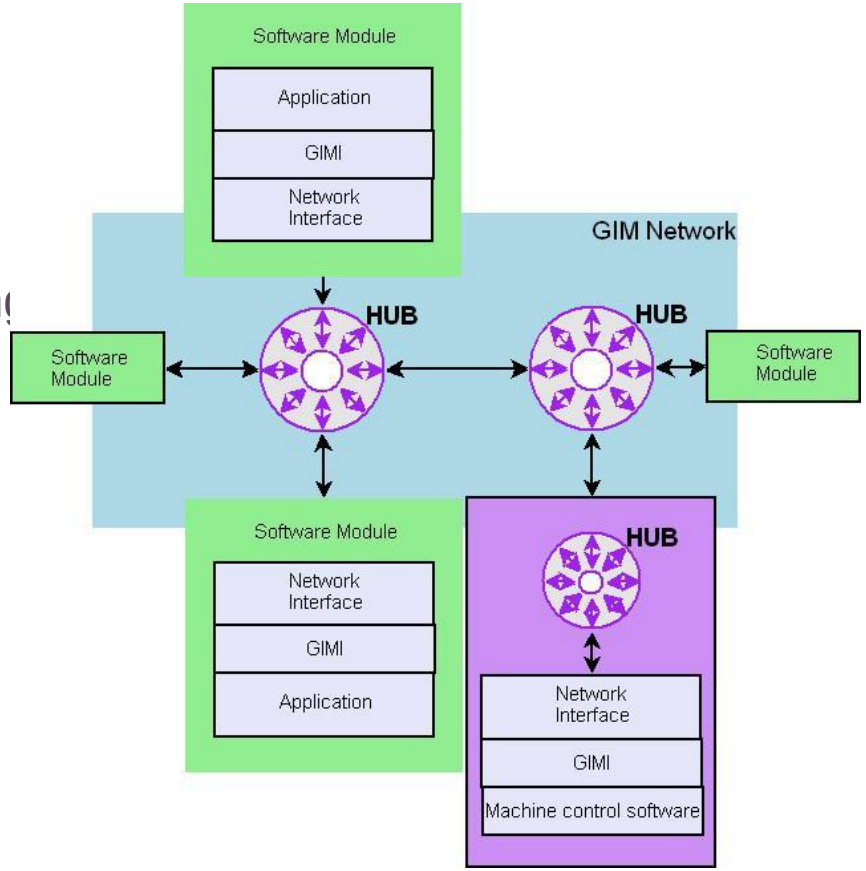
GIM ROBOTICS

Architecture



GIMnet

- GIMnet is a Remote Process Communication system
- Hybrid architecture
  - a VPN-type of solution allows bypassing of firewalls, while allowing p2p
- Network layer consists of hubs
- Hubs connect to each other and nodes (“clients”) connect to hubs
- Client-side libraries for ease-of-use
  - User side library GIMI



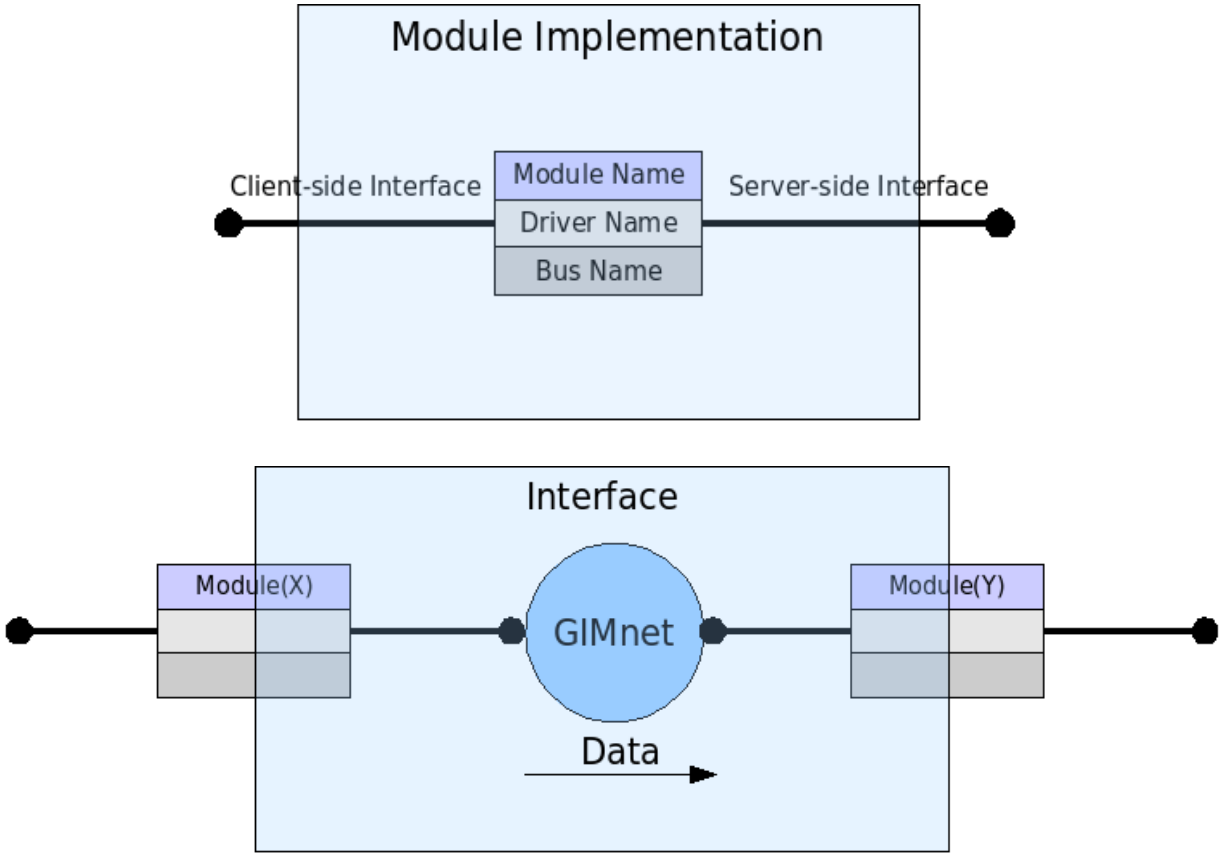
GIMnet features

- Distributed name and ID service (tcpHub)
- Unicast, multicast, broadcast (tcpHub + GIMI)
- Synchronized and unsynchronized data transmission
- Automatic hub-to-hub and client-to-hub reconnect
- In-built service based messaging
  - Provided and accepted
  - Service registration, subscription and listing

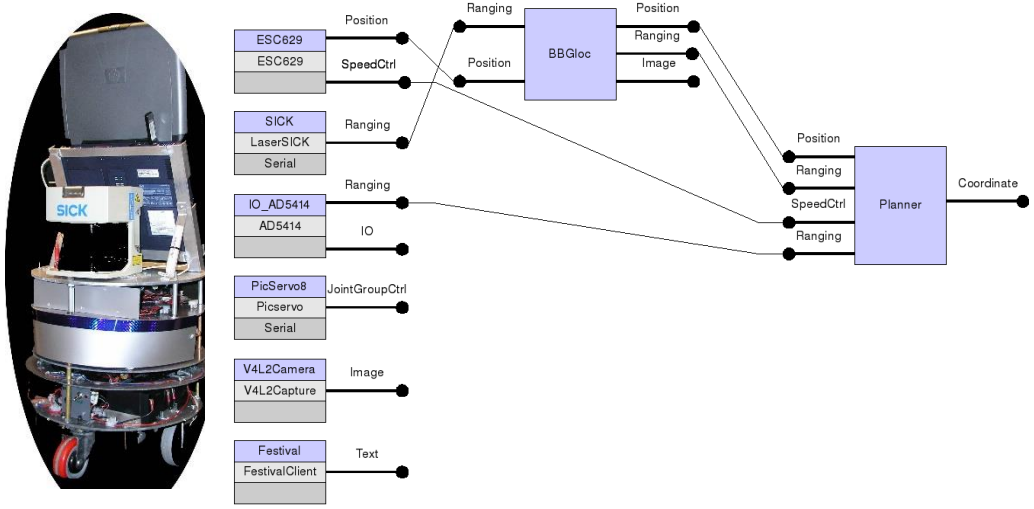
Machine Control Interface - MaCI

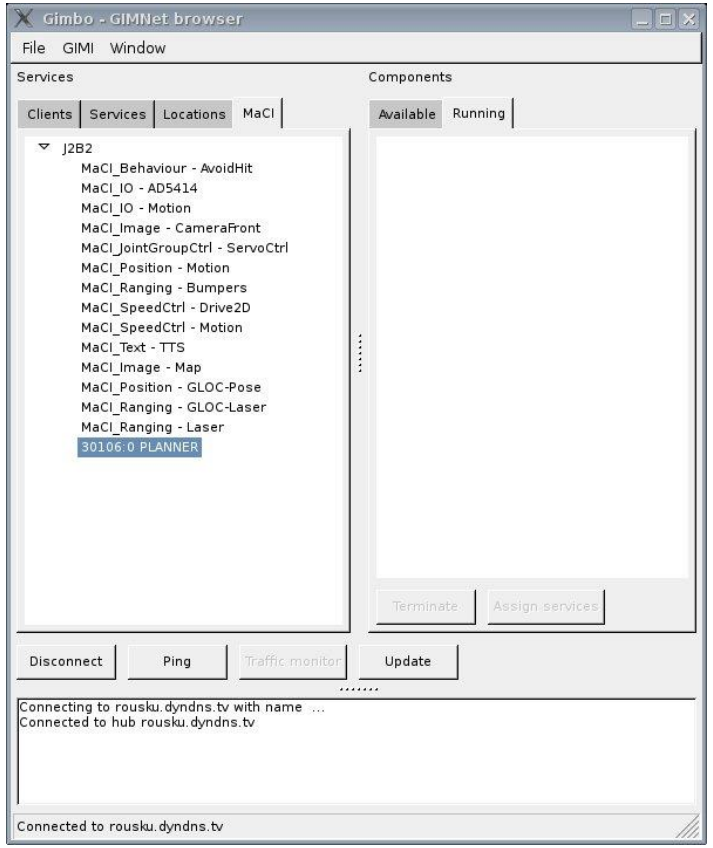
- Service oriented, modular, reusable, robot control library
- Communication based on GIMnet
- Module is an interface implementation
- Interface acts as a Hardware Abstraction Layer
- Interface consists of a data description, a ”server” and ”client”

MaCI - module and interface



GIMnet/MaCI Example





GIMNET -> ROS

- GIMNET EVENTUALLY HAD TO BE PUT ASIDE, BECAUSE ROS PROVIDED A SUPERIOR ECOSYSTEM AND TOOLS THAT SAVE A LOT OF EFFORT.
- VISUALIZATION, DIAGNOSTICS, DATA RECORDING, AND GEOMETRY UTILITIES TO NAME A FEW.

GIM ROBOTICS

ROS

The Robot Operating System (ROS) is a set of software libraries and tools that help you build robot applications. From drivers to state-of-the-art algorithms, and with powerful developer tools, ROS has what you need for your next robotics project. And it's all open source.

SOURCE: http://wiki.ros.org/ROS/Introduction

ROS

ROS (**R**obot **O**perating **S**ystem) is an open-source, meta-operating system for your robot. It provides the services you would expect from an operating system, including hardware abstraction, low-level device control, implementation of commonly-used functionality, message-passing between processes, and package management. It also provides tools and libraries for obtaining, building, writing, and running code across multiple computers.

SOURCE: http://wiki.ros.org/ROS/Introduction

DISTRIBUTED COMPUTATION

Many modern robot systems rely on software that spans many different processes and runs across several different computers:

- Some robots carry multiple computers, each of which controls a subset of the robot's sensors or actuators.
- Even within a single computer, it's often a good idea to divide the robot's software into small, stand-alone parts that cooperate to achieve the overall goal.
- When multiple robots attempt to cooperate on a shared task, they often need to communicate with one another to coordinate their efforts.
- Human users often send commands to a robot from a laptop, a desktop computer, or mobile device. We can think of this human interface as an extension of the robot's software.

ROS.org

SOFTWARE REUSE

The rapid progress of robotics research has resulted in a growing collection of good algorithms for common tasks such as navigation, motion planning, mapping, and many others. The existence of these algorithms is only truly useful if there is a way to apply them in new contexts, without the need to reimplement each algorithm for each new system.

ROS can help in at least two important ways:

- ROS's standard packages provide stable, debugged implementations of many important robotics algorithms.

- ROS's message passing interface is becoming a *de facto* standard for robot software interoperability, which means that ROS interfaces to both the latest hardware and to implementations of cutting edge algorithms are quite often available. For example, the ROS website lists hundreds of publicly-available ROS packages. This sort of uniform interface greatly reduces the need to write "glue" code to connect existing parts.

ROS.org

RAPID TESTING

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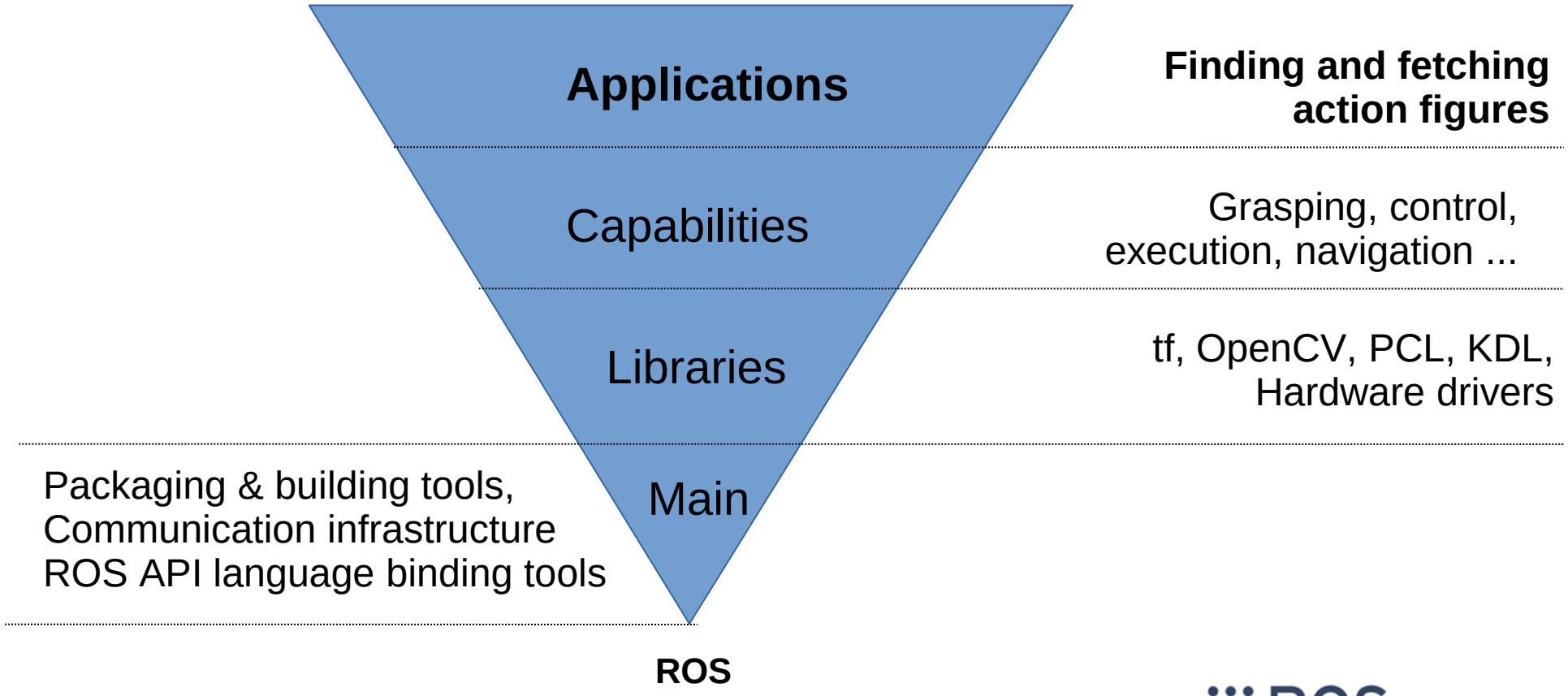
ROS.org

What does ROS get you ?



ROS.org

ROS Tools

- roscore
- roscd
- rosmsg
- rostopic
- rosservice
- roswtf
- rosrun
- roslaunch
- rviz
- rosed
- rosparam
- rqt_logger_level
- rqt_console
- rqt_graph
- catkin_create_pkg
- catkin_make

ROS.org

rostopic

The rostopic command-line tool displays information about ROS topics. Currently, it can display a list of active topics, the publishers and subscribers of a specific topic, the publishing rate of a topic, the bandwidth of a topic, and messages published to a topic. The display of messages is configurable to output in a plotting-friendly format.

- **This is the current list of supported commands:**

• rostopic bw	display bandwidth used by topic
rostopic delay	display delay for topic which has header
rostopic echo	print messages to screen
rostopic find	find topics by type
rostopic hz	display publishing rate of topic
rostopic info	print information about active topic
rostopic list	print information about active topics
rostopic pub	publish data to topic
rostopic type	print topic type

ROS.org

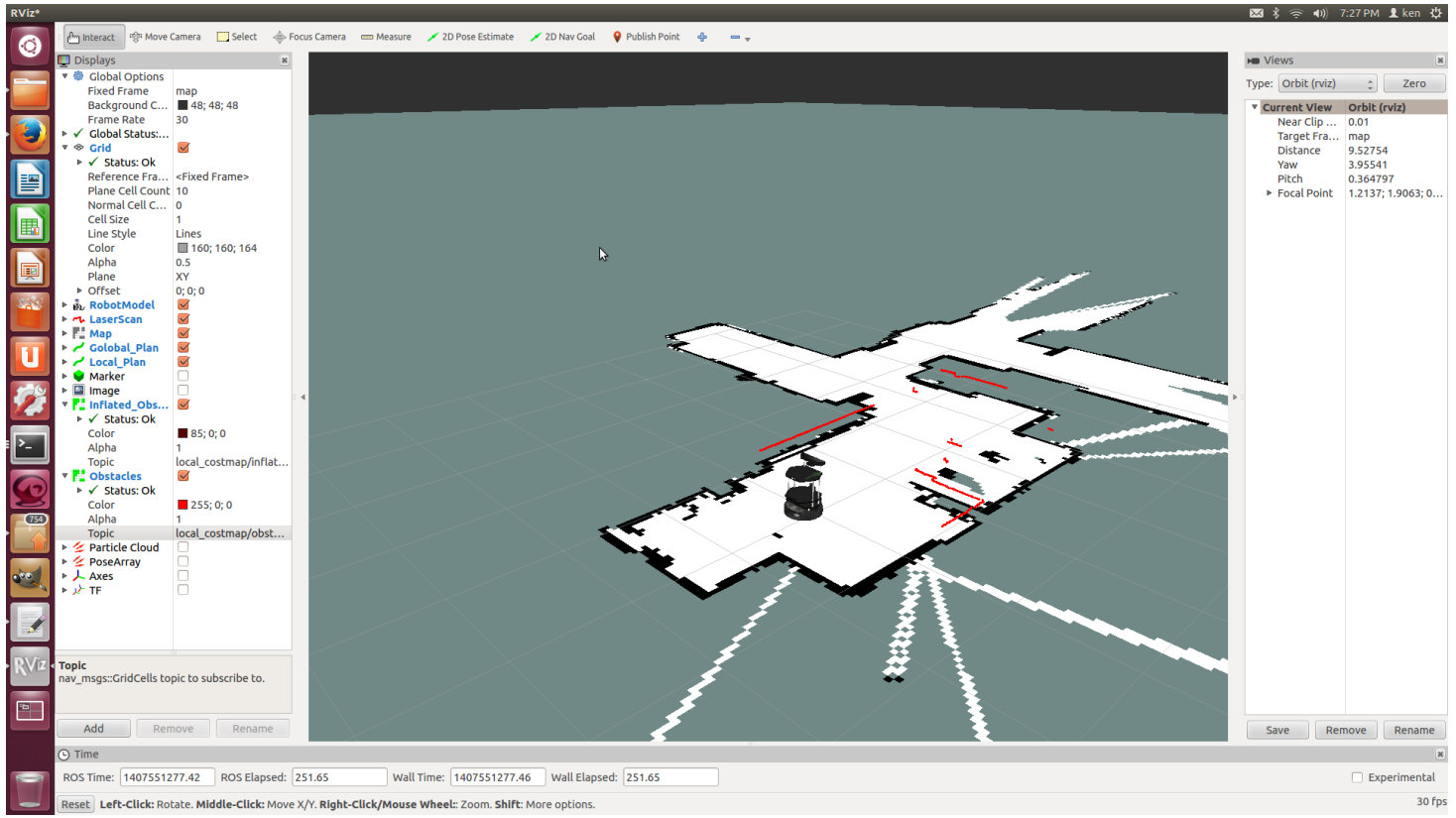
roswtf

roswtf is a tool for diagnosing issues with a running ROS system. Think of it as a FAQ implemented in code.

roswtf looks for many, many things, and the list is always growing. There are two categories of what it looks for: file-system issues and online/graph issues.

For file-system issues, roswtf looks at your environment variables, package configurations, stack configurations, and more. It can also take in a roslaunch file and attempt to find any potential configuration issues in it, such as packages that haven't been built properly.

For online issues, roswtf examines the state of your current graph and tries to find any potential issues. These issues might be unresponsive nodes, missing connections between nodes, or potential machine-configuration issues with roslaunch.

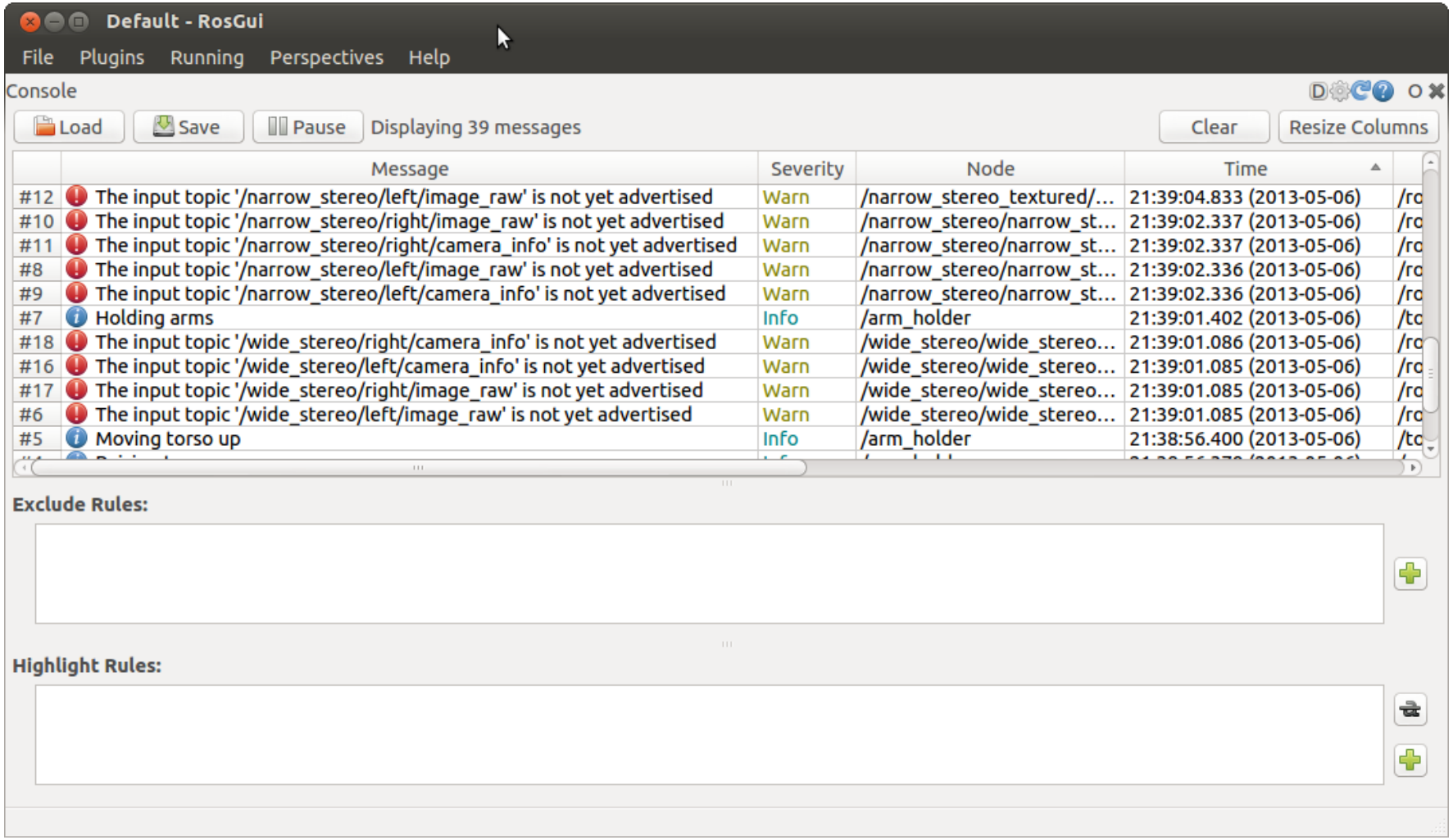


rviz

rviz is 3D visualizer for displaying sensor data and state information from ROS. Using rviz, you can visualize your robot's current configuration on a virtual model of the robot. You can also display live representations of sensor values coming over ROS Topics including camera data, infrared distance measurements, sonar data, and more.

http://wiki.ros.org/rviz/

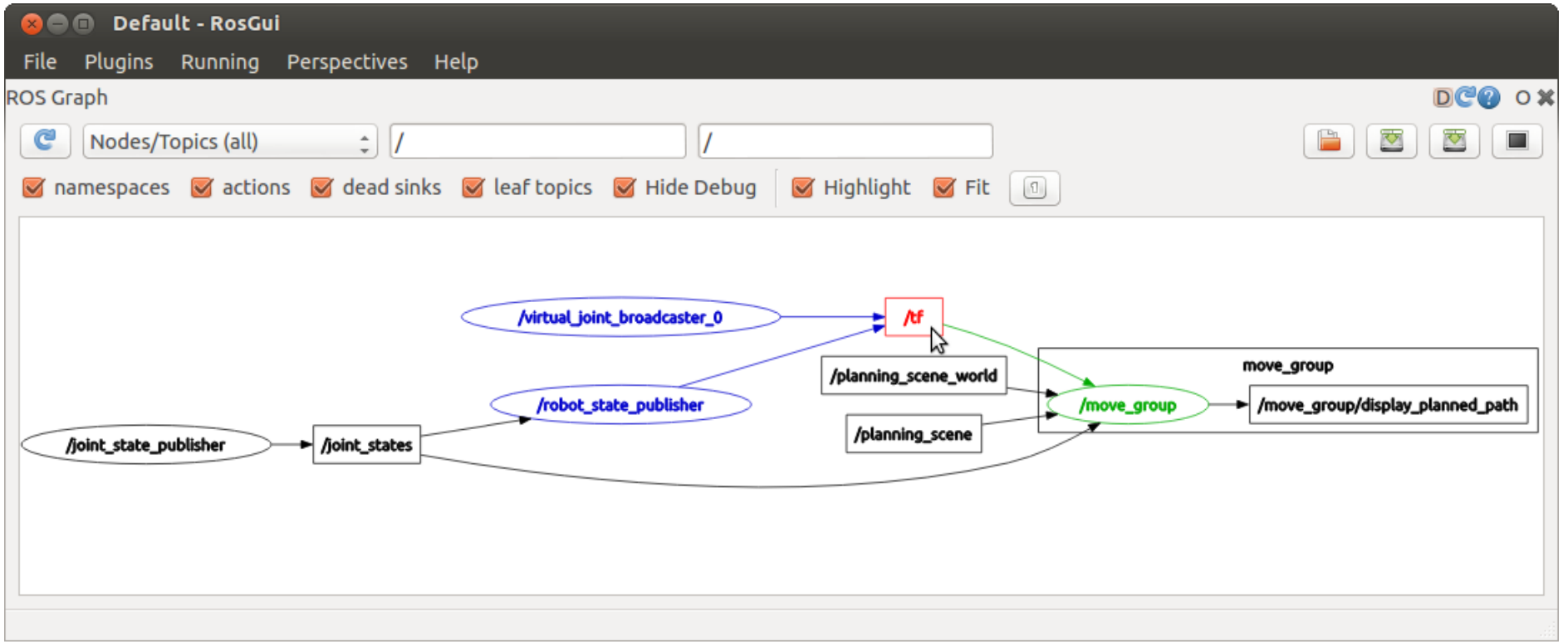
ROS.org



rqt_console

Provides a GUI plugin for displaying and filtering ROS messages.

ROS.org



rgt_graph

rqt_graph provides a GUI plugin for visualizing the ROS computation graph. It visualizes the publish subscribe relationships between ROS nodes

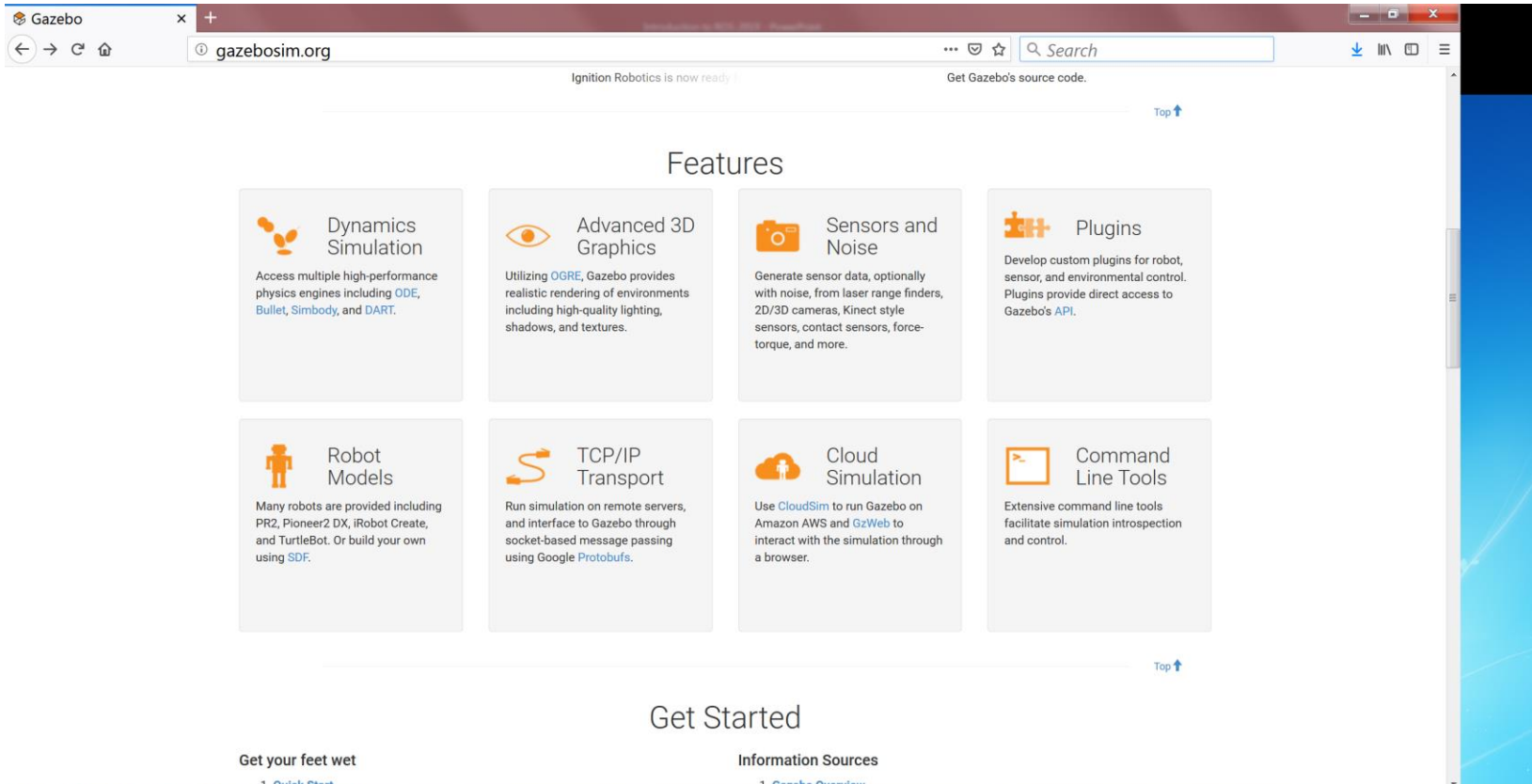
ROS.org

GAZEBO

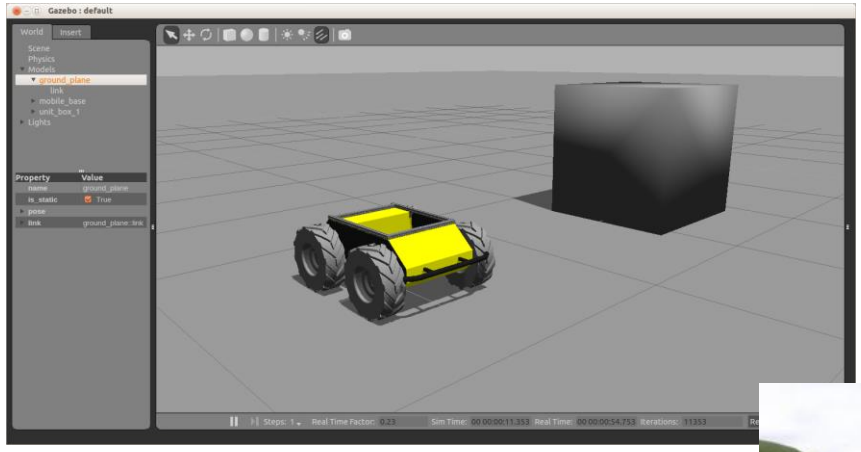
Why Gazebo?
Robot simulation is an essential tool in every roboticist's toolbox. A well-designed simulator makes it possible to rapidly test algorithms, design robots, perform regression testing, and train AI system using realistic scenarios. Gazebo offers the ability to accurately and efficiently simulate populations of robots in complex indoor and outdoor environments. At your fingertips is a robust physics engine, high-quality graphics, and convenient programmatic and graphical interfaces. Best of all, Gazebo is free with a vibrant community.

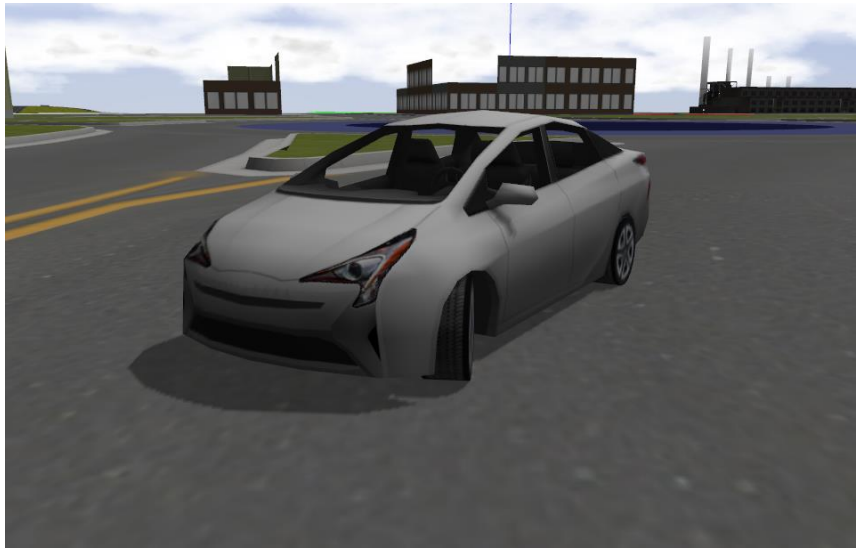
http://gazebosim.org/

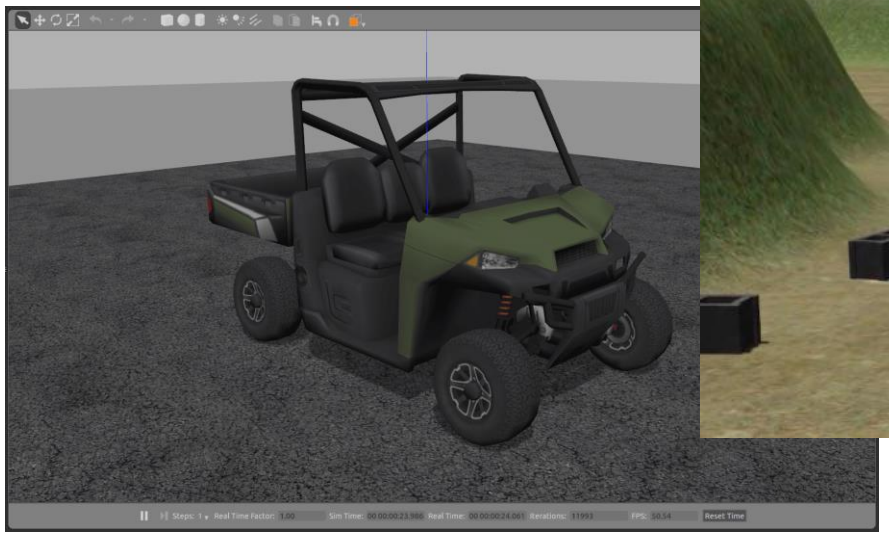
- **gazebo_ros_pkgs** is a set of ROS packages that provide the necessary interfaces to simulate a robot in the Gazebo 3D rigid body simulator for robots. It integrates with ROS using ROS messages, services and dynamic reconfigure.

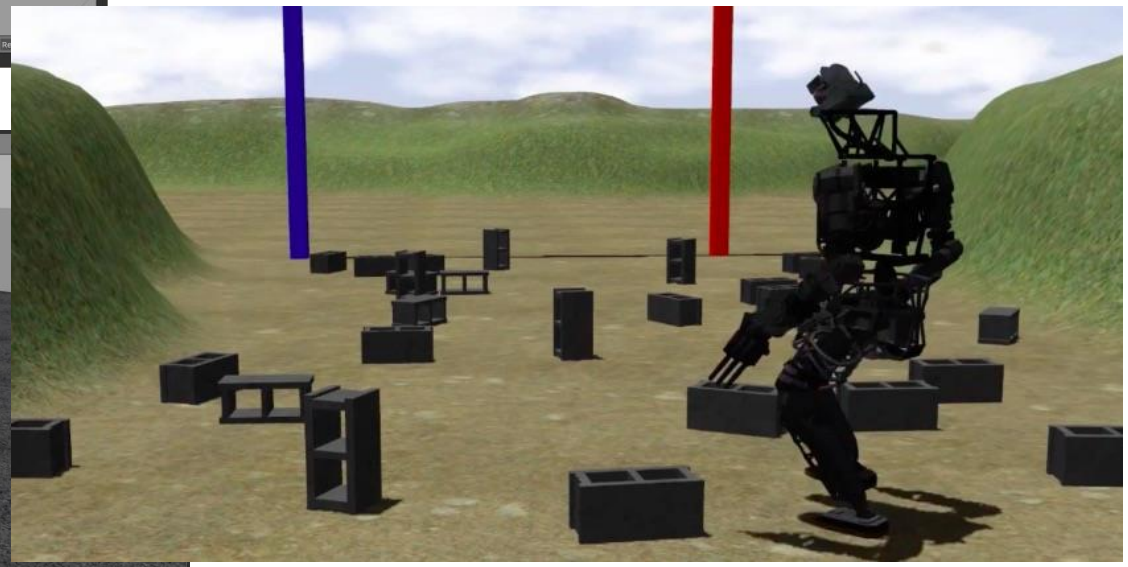


GAZEBO


Gazebo : default
World
Insert
Scene
Physics
Models
ground_plane
link
mobile_base
unit_box_1
Lights
Property
Value
name
ground_plane
is_static
True
pose
link
ground_plane::link







GIM ROBOTICS

UNI -> BIZ







1985 - 2014

GIM ROBOTICS

sensible4

2020 - 2022

CoE GIM

2014

2017

Prof Aarne Halme founded AutLab TKK

1985

2007 - 2013

- Close Collaboration with Finnish Machine Manufacturing Industry
- More than 20M “investment” in basic research
- Research quality code

- Served over 50 clients from which 10 are Fortune 500 companies
- Project Based Revenue (Robotics Experts)
- Re-invest profits & Public funding in R&D
- Productization pt 1

- S4 Investment & co-development
- Productization of core technology
- Industrial quality SW products

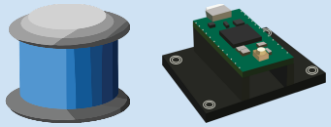
GIM ROBOTICS' ENGINEERS

- 10 senior with more than 200 years of experience on mobile robotics
- Around 40 robotics professionals
- Tight R&D cooperation with sister company Sensible founded in 2017.
- Together around 100 professional engineers and scientists

GIM ROBOTICS

POSITION

Component provider
(LiDARS, RaDARS, processors, actuators, ...)



Automation technology provider

GIM ROBOTICS

Machine manufacturer, OEM

Service provider
(Municipality, construction company, mine operator, ...)

End user

GIM ROBOTICS

Our customers want to increase level of autonomy in order to improve: efficiency, quality and safety.

GIM ROBOTICS

ROS FOR GIM

- ROS PROVIDES A SUPERIOR ECOSYSTEM AND TOOLS THAT WILL SAVE A LOT OF EFFORT.
- VISUALIZATION, DIAGNOSTICS, DATA RECORDING, AND GEOMETRY UTILITIES TO NAME A FEW.
- HAVING THESE EXISTING TOOLS OUT-OF-THE-BOX IS INCREDIBLY VALUABLE FOR COMPANIES LIKE GIM ROBOTICS, WHO WANT TO FOCUS ON STATE-OF-THE-ART ALGORITHM DEVELOPMENT.
- THIS WAY WE CAN FOCUS ON WHAT MATTERS, AND CREATE MORE CUSTOMER VALUE FASTER THAN MANY COMPETITORS.

GIM ROBOTICS

ROS2 FOR GIM

GIM ROBOTICS

- While ROS has been a great solution for research, proof-of-concept, and pilot cases, it has to be admitted it has some limitations when making safety-critical systems.

- Although based on practical experience it is very reliable, it’s hard to get it certified, as it doesn’t meet various complex requirements from quality and safety standards.

- This is one of the key reasons why ROS2 was developed. The main benefit is that it changed the underlying communication protocol to DDS (Data Distribution Service).

- DDS enables easier compliance with standards such as ISO 26262 or IEC 61508 — and it’s already used in financial systems and space systems, among others.

ROS2 FOCUSES ON FOUR NEW USE CASES WHICH ARE:

- real-time systems
- small embedded platforms
- non-ideal networks
- cross-platform

PEAMS: PLATFORM ECONOMY FOR AUTONOMOUS MOBILE MACHINES SOFTWARE (ROS2)

https://www.fima.fi/projects/platform-economy-for-autonomous-mobile-machines-software-development/

FUTURE

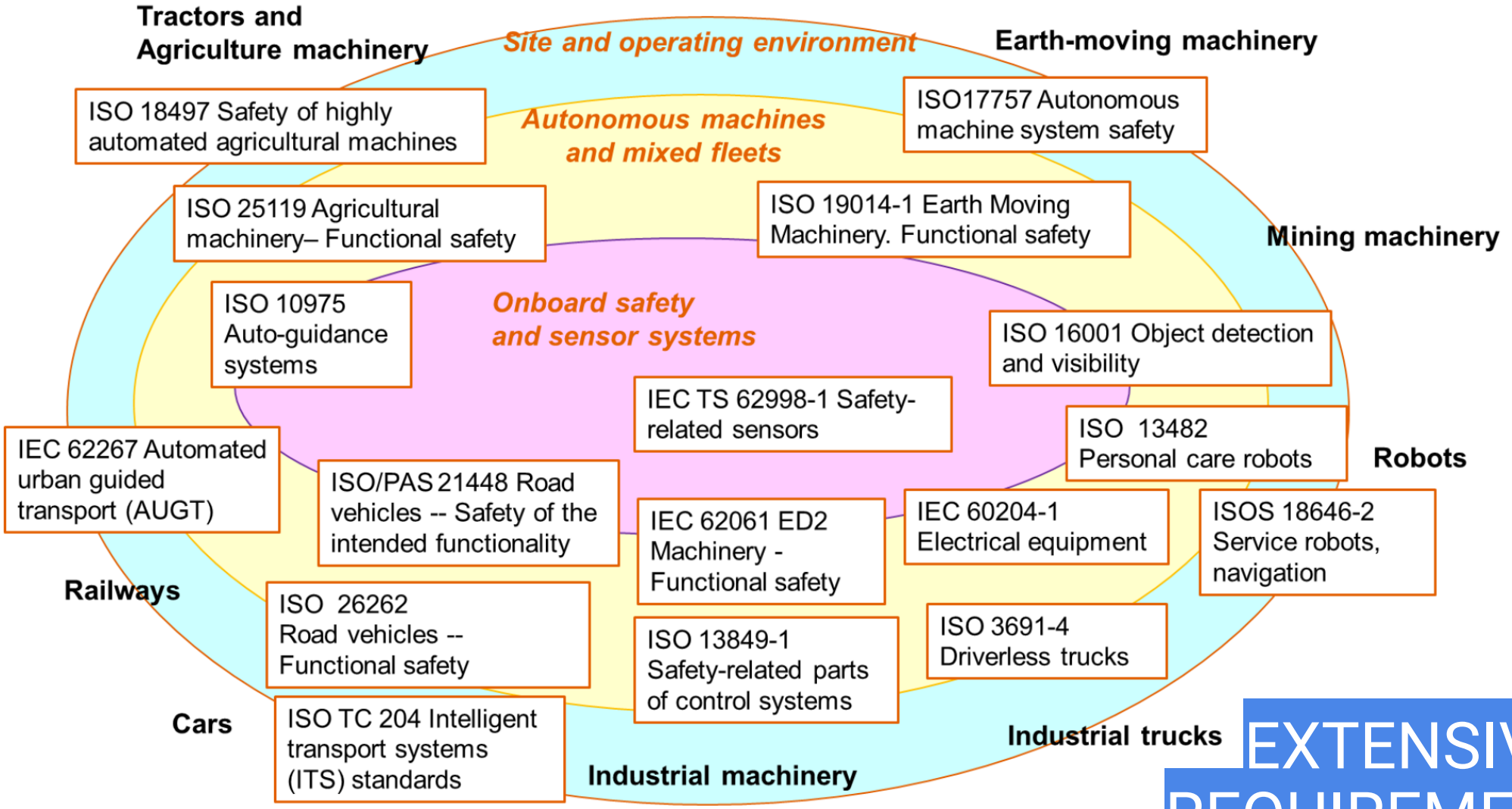
SOME MAIN CHALLENGES

GIM ROBOTICS

SITUATIONAL AWARENESS

(Figure: Shutterstock/AimoKinnas)


SITUATIONAL AWARENESS.



EXTENSIVE REQUIREMENTS

Source: Tiusanen, Risto, Malm, Timo and Ronkainen, Ari. "An overview of current safety requirements for autonomous machines – review of standards" *Open Engineering*, vol. 10, no. 1, 2020, pp. 665-673. https://doi.org/10.1515/eng-2020-0074

BRIGHT FUTURE

A SELECTION OF OUR PUBLIC USE CASES

GIM ROBOTICS


Päivää!
A-473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futurice
bestmile
cap-digital
BookIT
TwinswHeel
FORUM VIRIUM HELSINKI
eit Digital
GIM ROBOTICS
GIM ROBOTICS

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GIM ROBOTICS