

# Virtual Robot Experimentation Platform

## V-REP

[www.coppeliarobotics.com](http://www.coppeliarobotics.com)

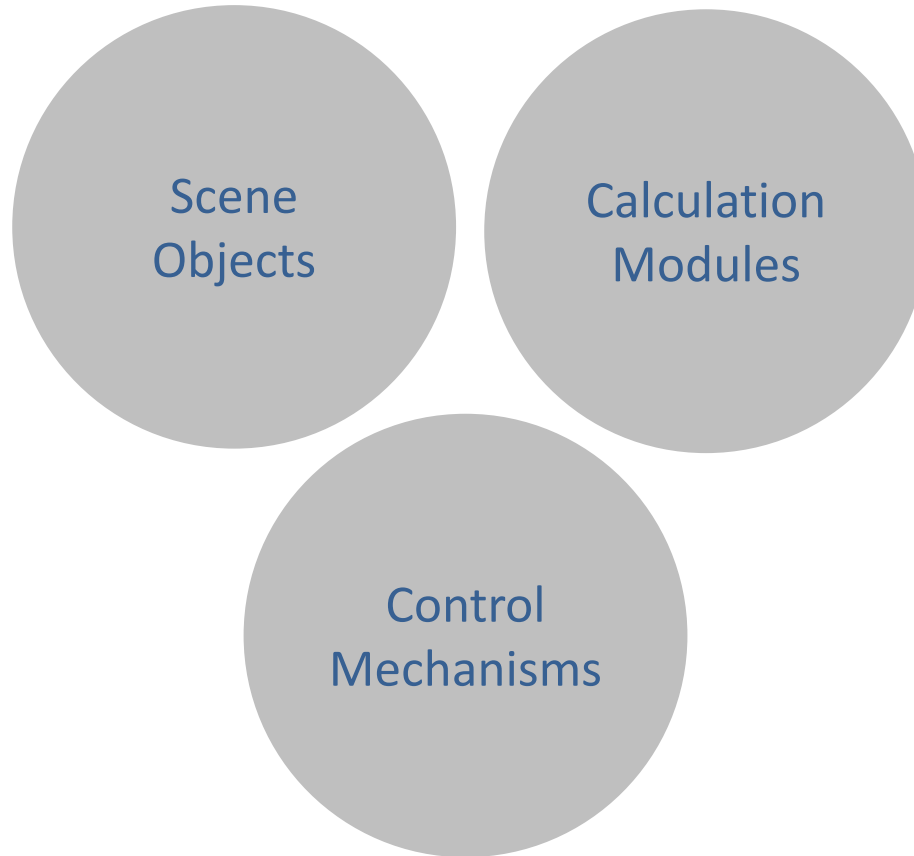
**What is it ?** General purpose robot simulator with integrated development environment

**What can it do ?** Sensors, mechanisms, robots and whole systems can be modelled and simulated in various ways >> [Play overview video](#)

**Typical applications ?**

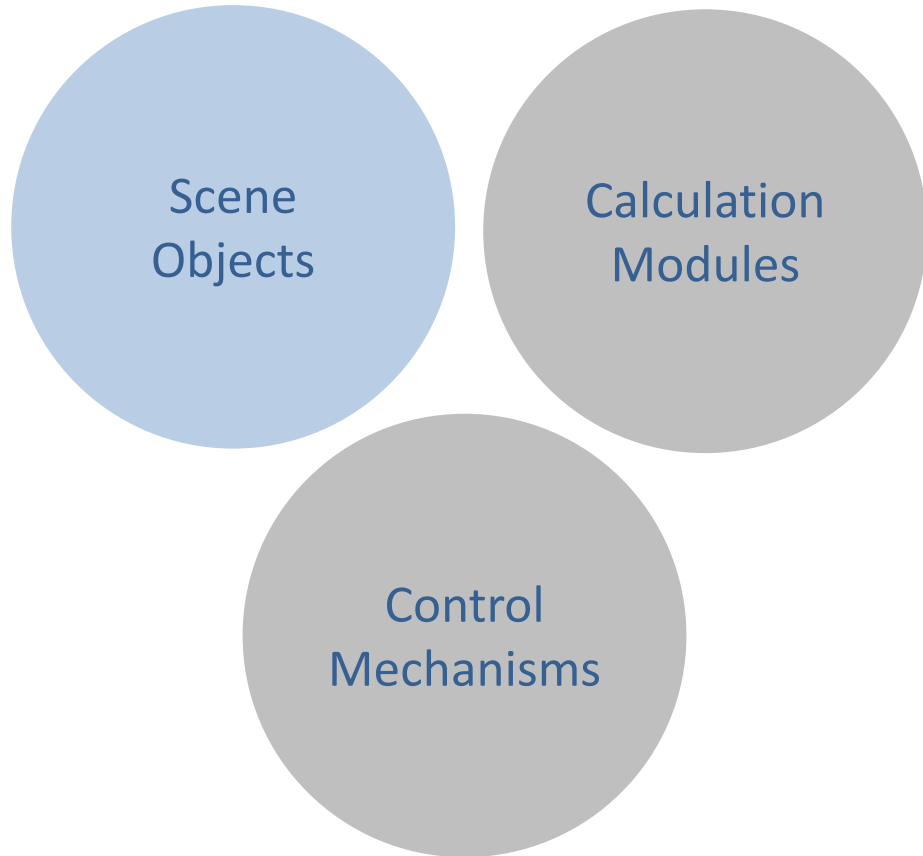
- Fast prototyping and verification
- Fast algorithm development
- Robotics related education
- Remote monitoring
- Hardware control
- Simulation of factory automation systems
- Safety monitoring
- Product presentation
- etc.

# 3 Central Elements

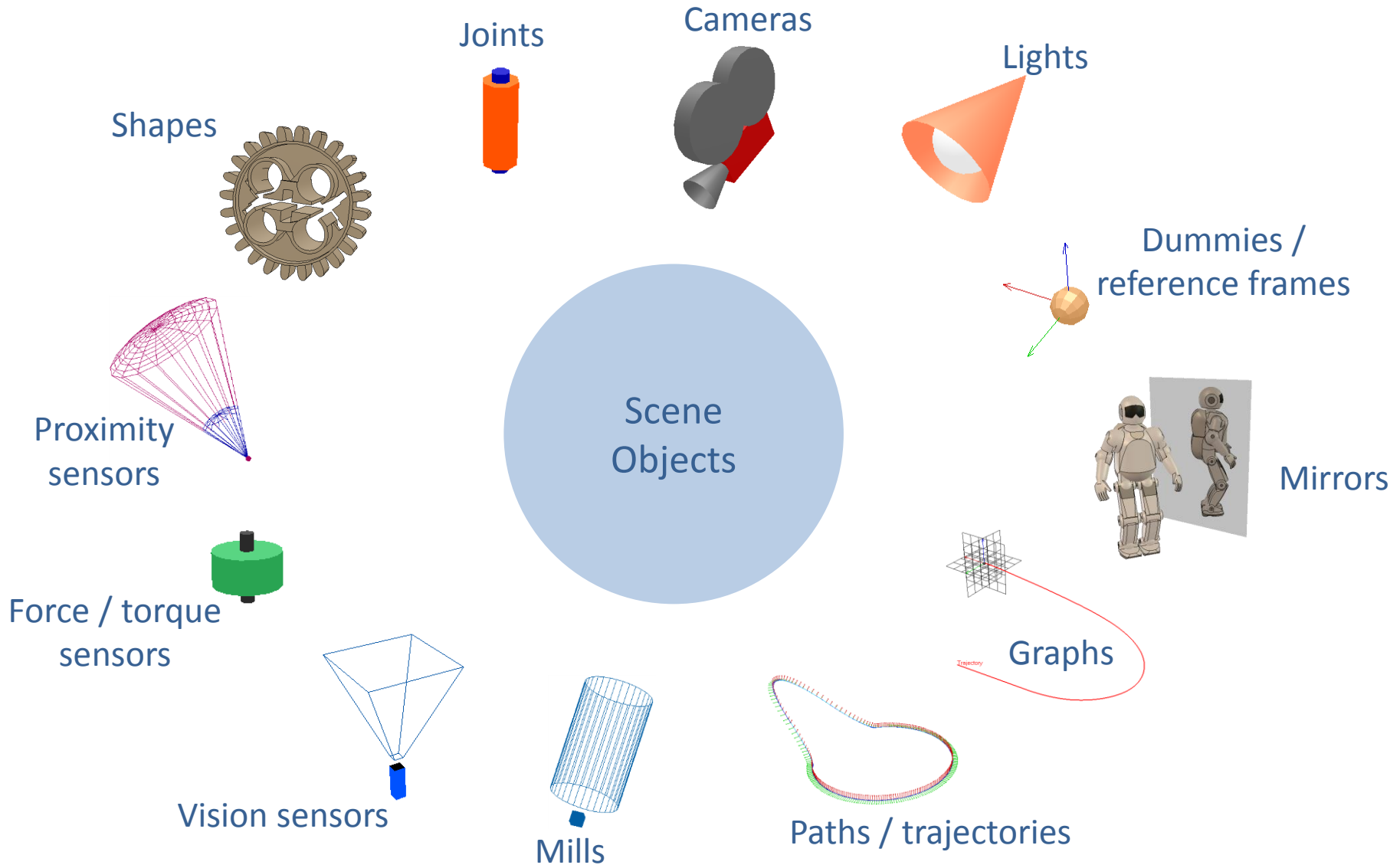


## Scene Objects

- Basic building blocks
- 12 different types
- Can be combined with each other
- Can form complex systems together with calculation modules and control mechanisms

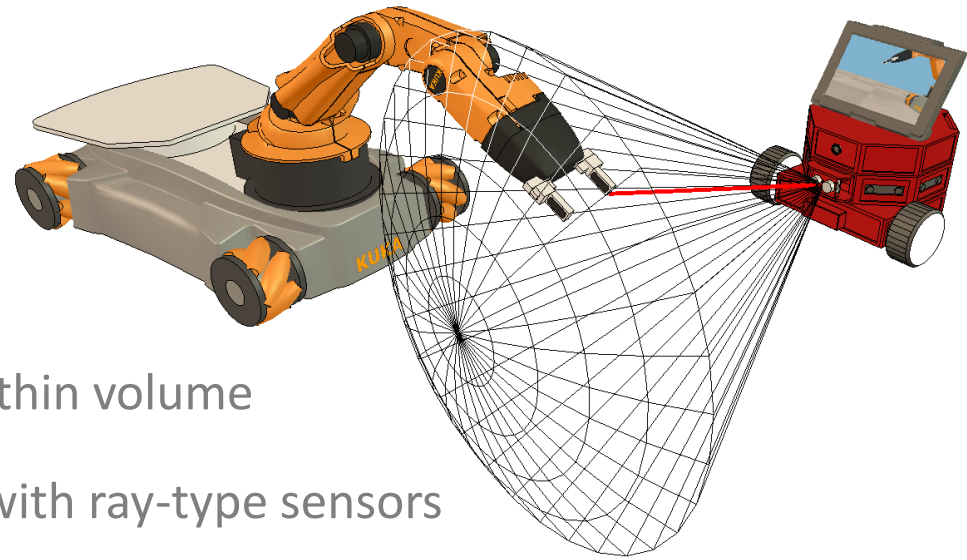


# Scene Objects



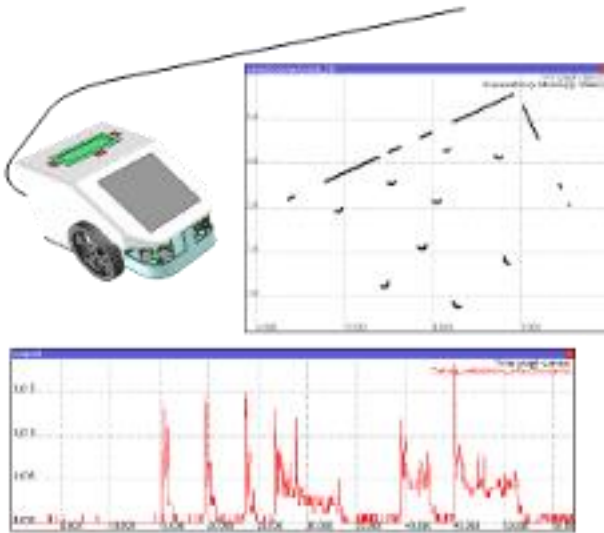
## Proximity Sensors

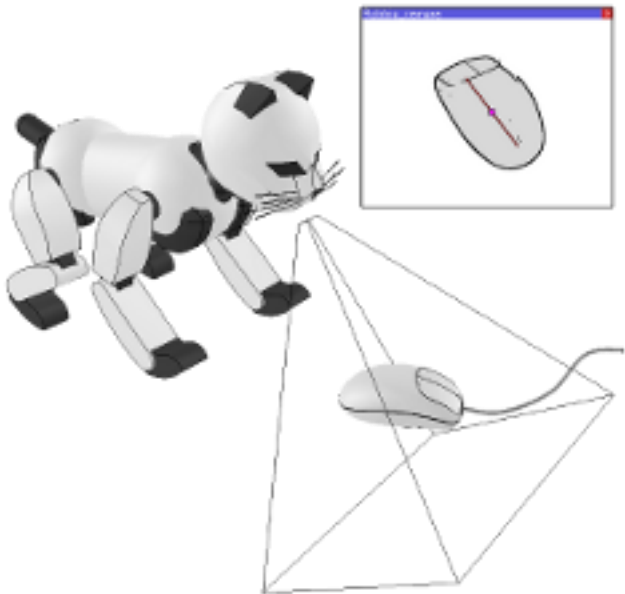
- More than simple ray-type detection
- Configurable detection volume
- Fast minimum distance calculation within volume
- Much more realistic simulation than with ray-type sensors



## Graphs

- Time graphs
- X/Y graphs
- 3D curves
- Can be exported





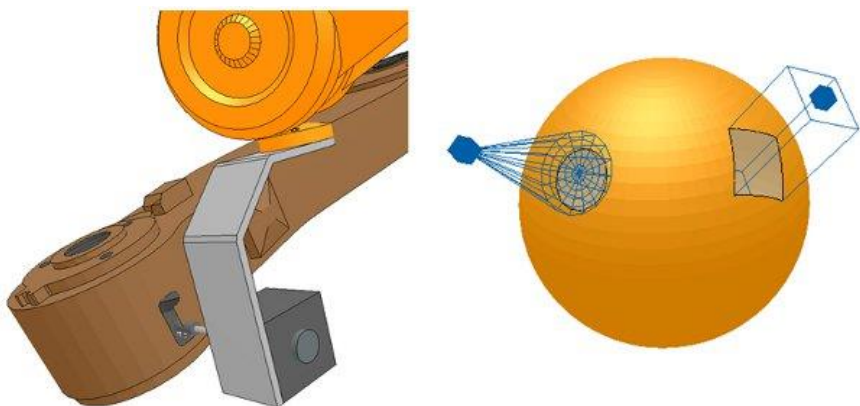
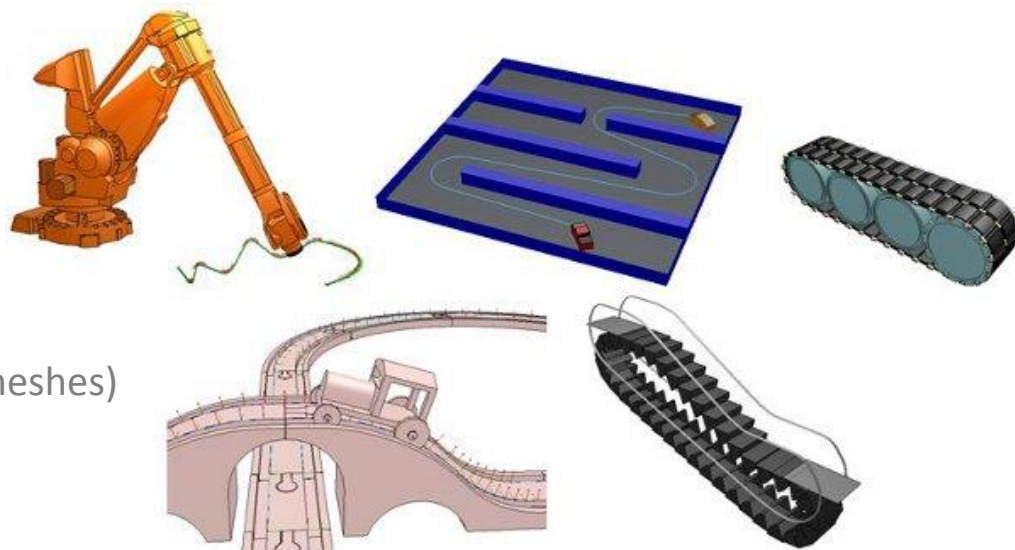
## Vision Sensors

- Integrated image processing
- Extendable via plugin mechanism

# Paths and Mills

## Paths

- 6 dim. trajectory definition
- Path can be shaped  
(i.e. automatically generate extruded meshes)



## Mills

- Customizable cutting volume
- Cuts shapes (i.e. meshes)



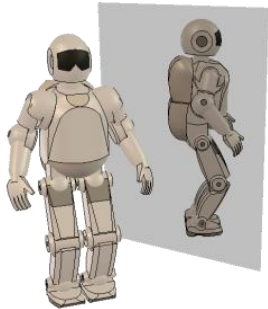


## Cameras

- Perspective / orthographic projection
- Tracking & automatic view-fitting function

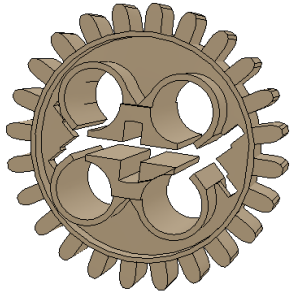
## Lights

Spotlight / directional / omnidirectional



## Mirrors

Mirror or scene / object clipping function



## Shapes

- Random mesh, convex mesh, primitive mesh or heightfield mesh
- Can be grouped/ungrouped
- Optimized for fast calculations

## Force/Torque Sensors

- Measures force and torque
- Can conditionally break apart



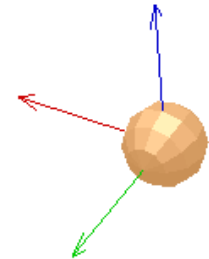
## Joints

- Revolute-type
- Prismatic-type
- Screw-type
- Spherical-type

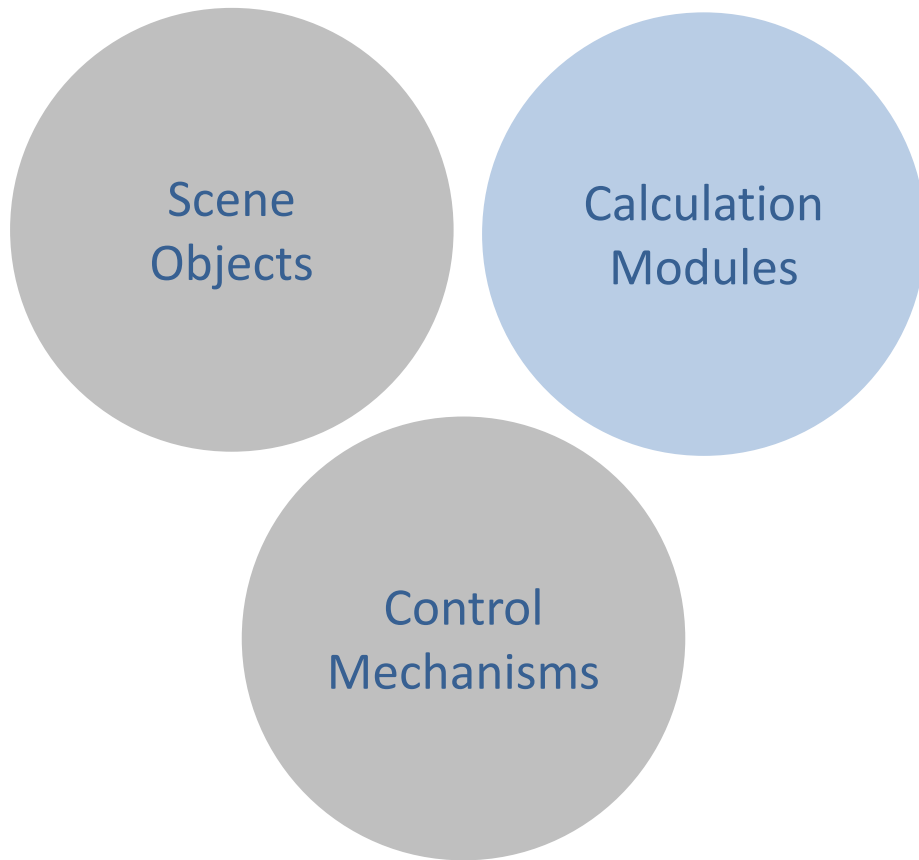


## Dummies

Auxiliary reference frame & helper object



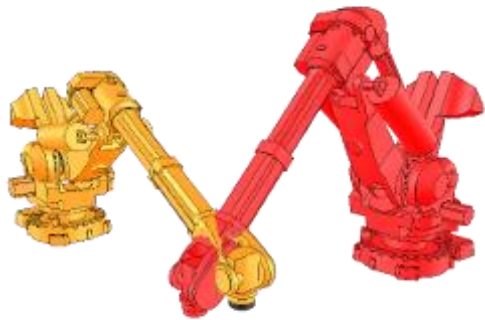
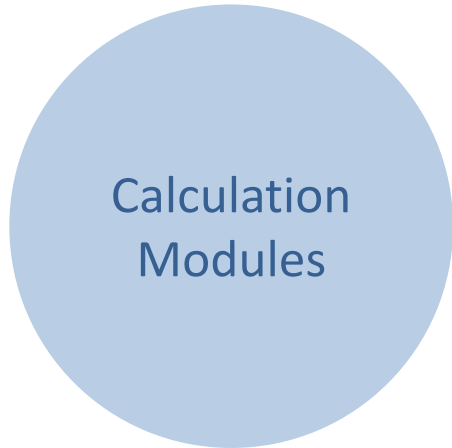
# 3 Central Elements



## Calculation modules

- 5 basic algorithms
- Can be combined with each other
- Can form complex systems together with scene objects and control mechanisms

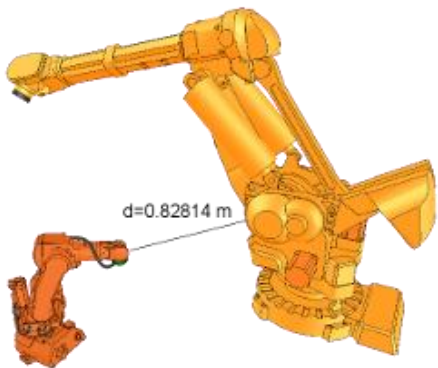
# Calculation Modules



Collision detection



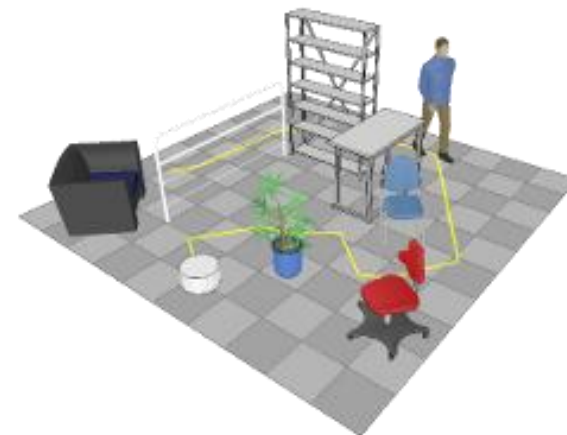
Physics / Dynamics



Minimum distance calculation



Forward / Inverse kinematics



Path / motion planning

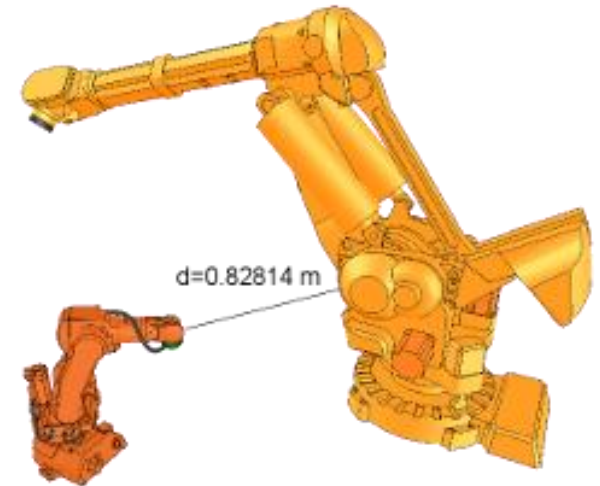
## Inverse / forward Kinematics

- Any mechanism: redundant, branched, closed, etc.
- Damped / undamped resolution
- Weighted resolution
- Conditional resolution
- Obstacle avoidance



## Minimum Distance Calculation

Any mesh (also open / concave / polygon soups)



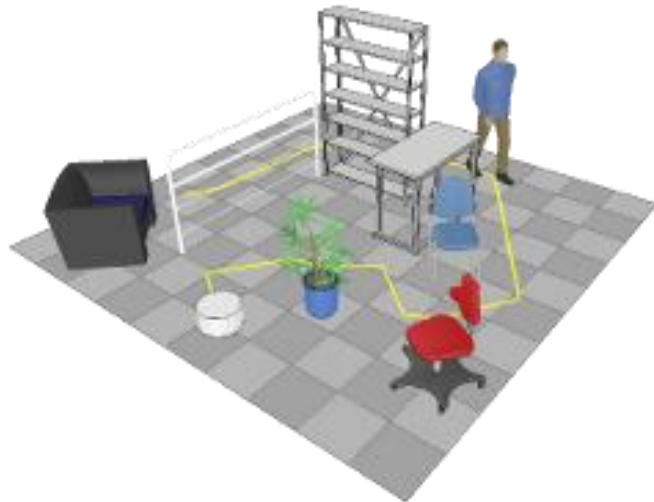
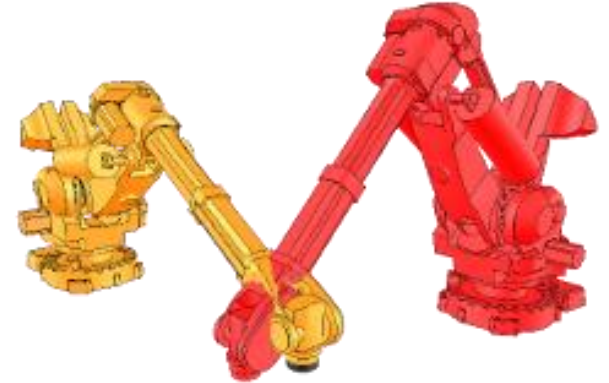


## Dynamics / Physics

- 3 physics engines: **Bullet Physics**  
**Open Dynamics Engine**  
**Vortex Dynamics**
- Simple mouse click to switch
- Dynamic particles to simulate air or water jets
- Can work hand-in-hand with kinematics module

## Collision Detection

Any mesh (also open / concave / polygon soups)



## Path / Motion Planning

- Holonomic in 2-6 dimensions
- Non-holonomic for car-like vehicles
- Motion planning for kinematic chains

# 3 Central Elements

A diagram showing three overlapping circles. Two circles at the top are light gray and labeled 'Scene Objects' and 'Calculation Modules'. A third circle at the bottom is light blue and labeled 'Control Mechanisms'.

Scene  
Objects

Calculation  
Modules

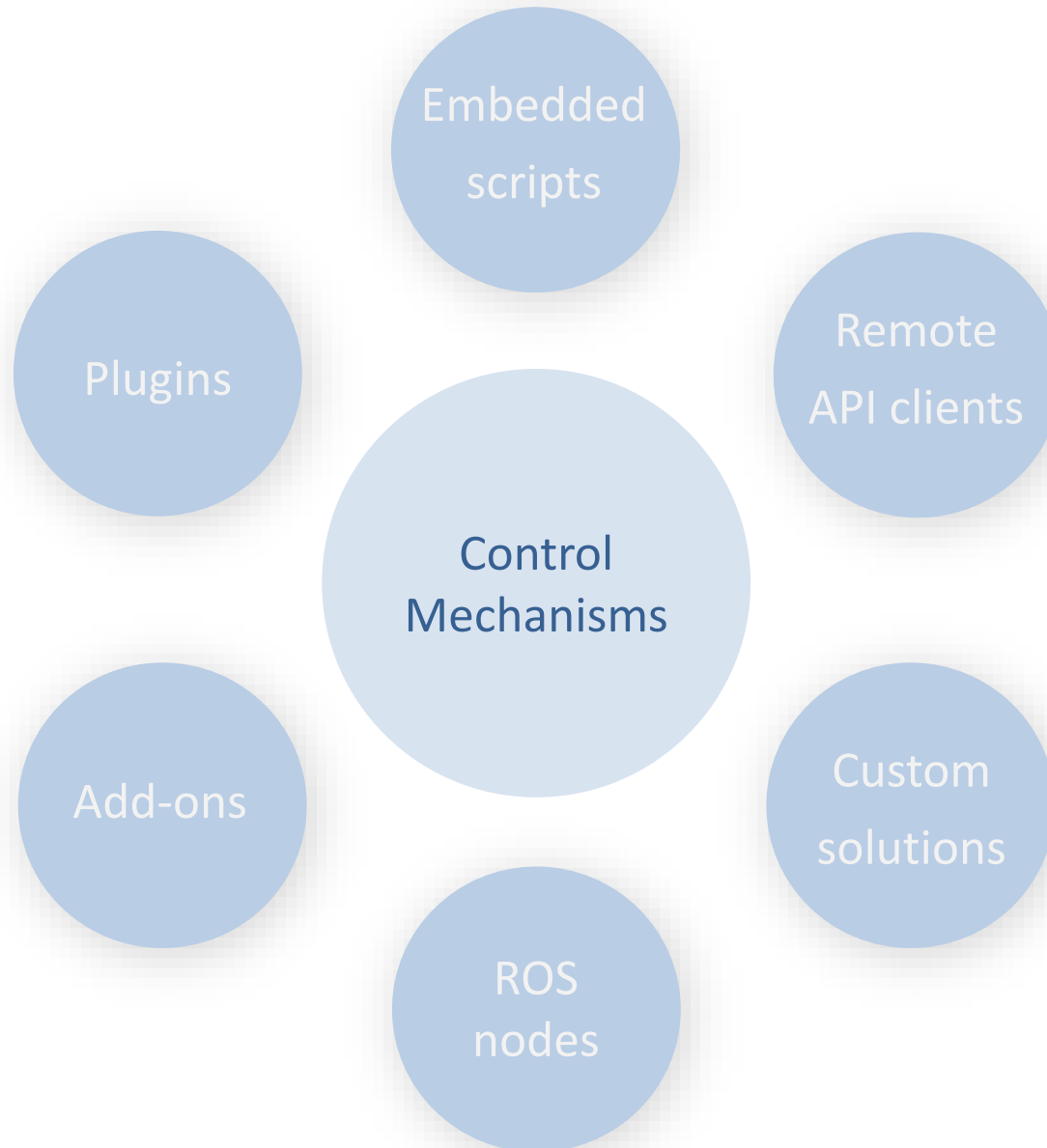
Control  
Mechanisms

## Control Mechanisms

- 6 methods or interfaces
- >7 languages
- 6 methods can be used at the same time, and even work hand-in-hand

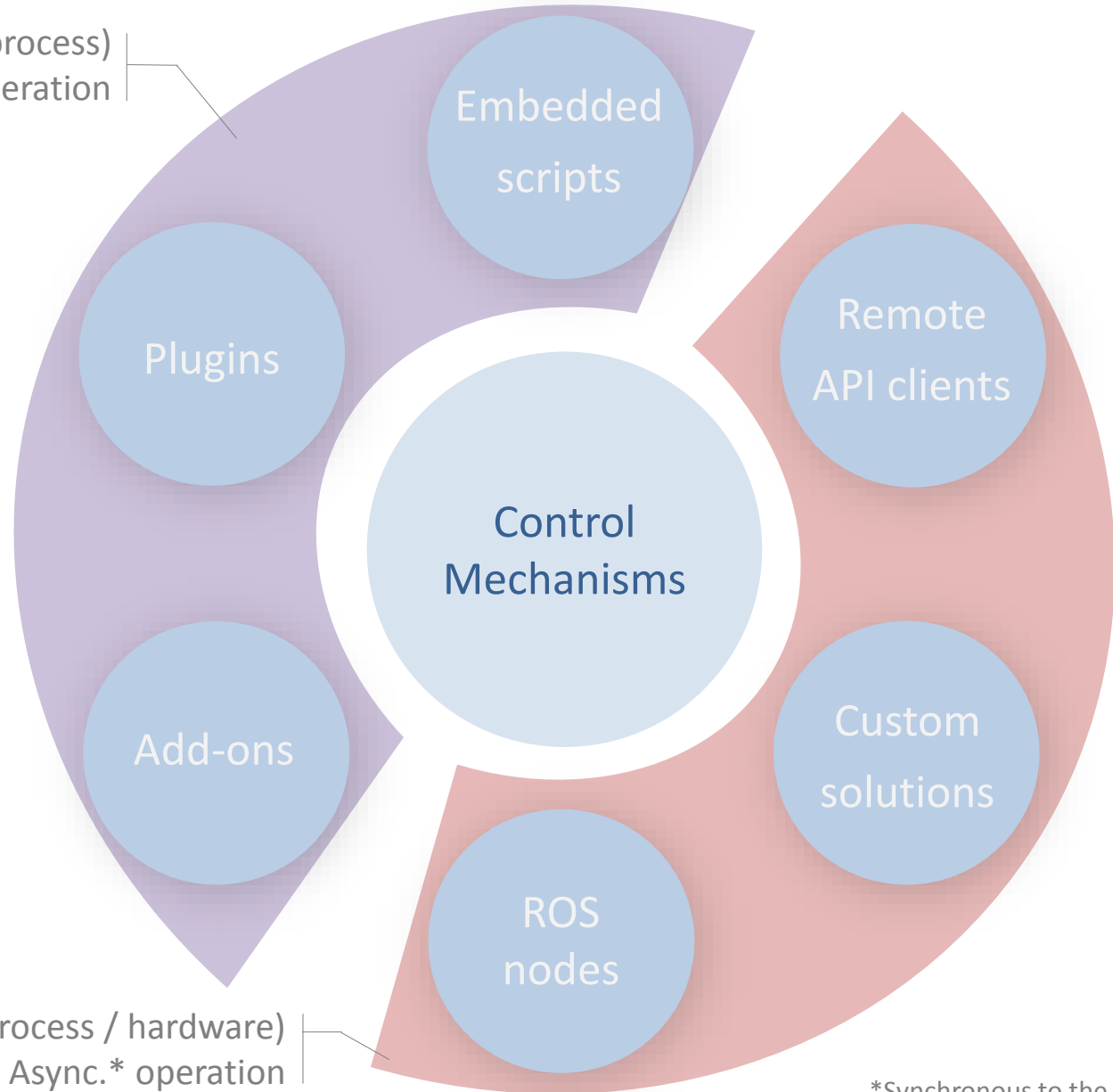


# Control Mechanisms



# Local and Remote Interfaces

Local (i.e. same process)  
Sync.\* or async.\* operation



Remote (i.e. different process / hardware)  
Async.\* operation

\*Synchronous to the simulation loop

# Local Interfaces

## Plugins

- > 400 API functions. Extendable
- C/C++ interface
- Can customize the simulator
- Can register new embedded script commands

## Embedded scripts

- > 300 API functions. Extendable
- Can be attached to any scene object
- Many Lua extension libraries available
- Threaded or non-threaded. Threads can be synchronized easily
- Various types: main script, child scripts, callback scripts (e.g. custom joint controllers)
- Lua interface
- Lightweight and easy to program
- Extremely portable solution

## Add-ons

- > 300 API functions. Extendable
- Lua interface
- Can customize the simulator
- Lightweight and easy to set-up
- Many Lua extension libraries available

Remote  
API clients

## Remote API

- > 100 API functions. Extendable
- C/C++, Python, Java, Matlab, Octave & Urbi interfaces
- Data streaming and partitioning modes
- Lightweight and easy to use

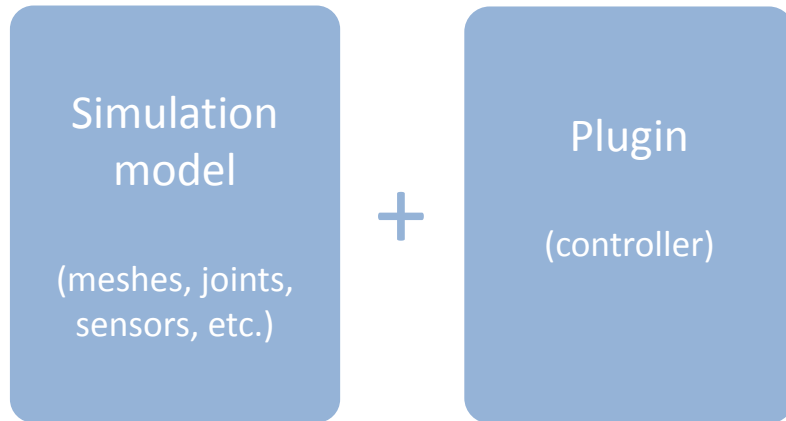
ROS  
nodes

## ROS Interface

- > 100 services, >30 publisher types, >25 subscriber types. Extendable
- Publishers/subscribers can be enabled via service calls, or via an embedded script function call

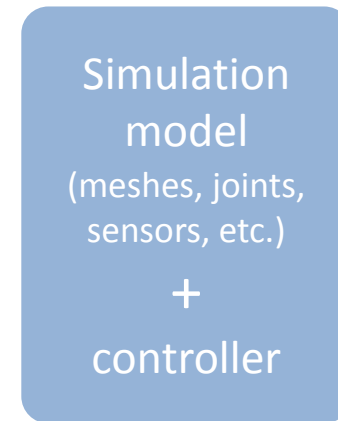
## Controller Integration

Plugins



2 items

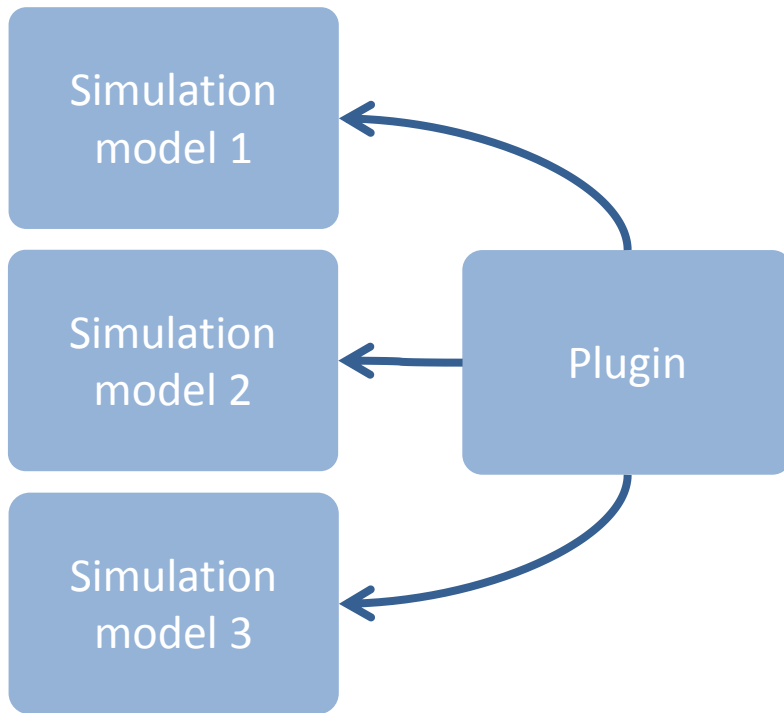
Embedded scripts



1 item

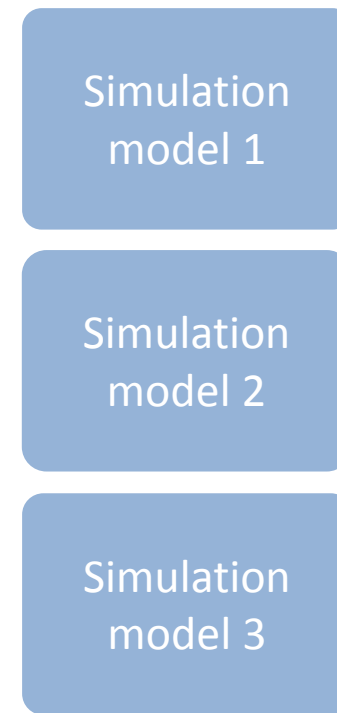
## Scalability

Plugins



Plugin has to manage instances

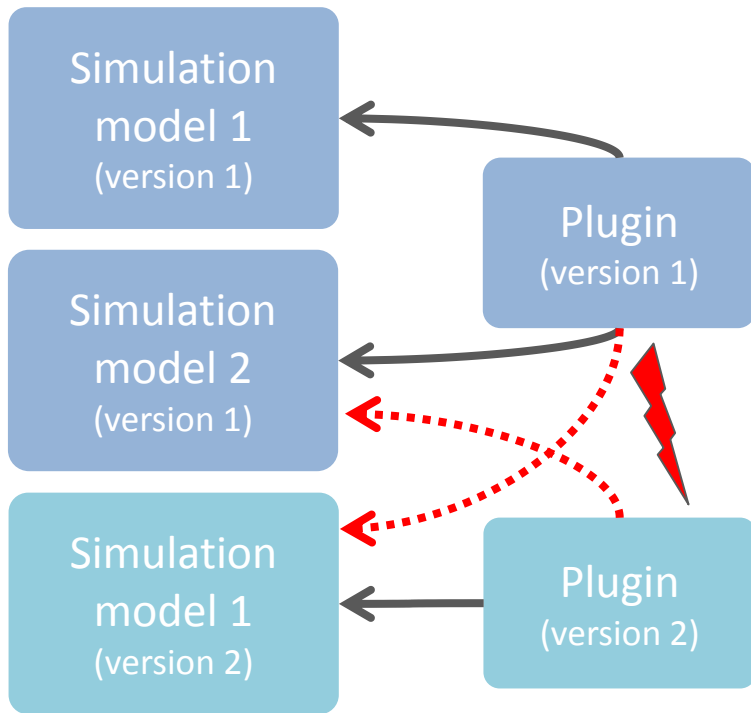
Embedded scripts



Scalability is inherent

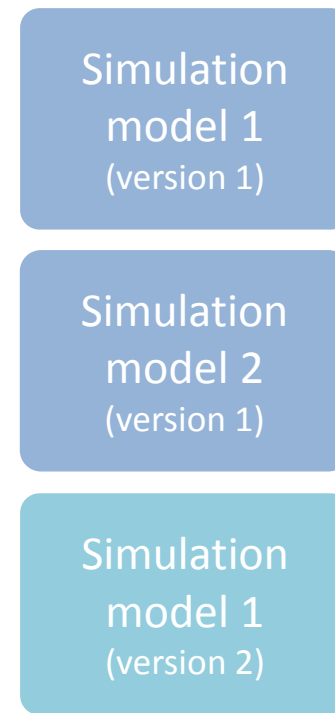
## Version Conflicts

Plugins



High chances for conflicts

Embedded scripts



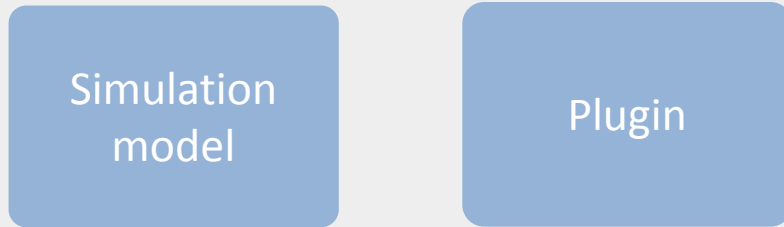
No chances for conflicts

## Portability

### Plugins

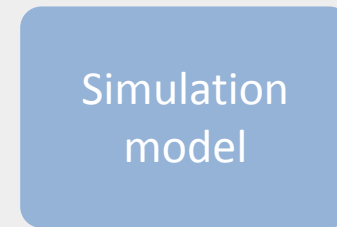
### Embedded scripts

Same OS



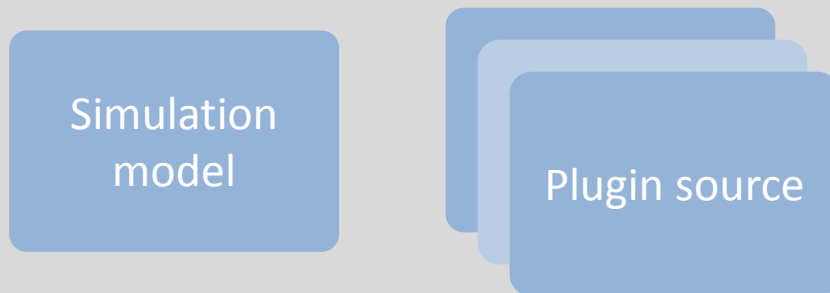
**2 files**

Same OS



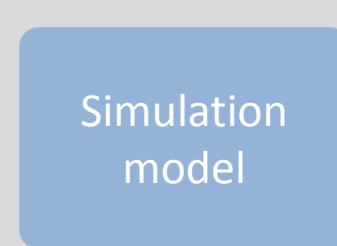
**1 file**

Different OS



**Many files**  
**Compilation required**  
**OS-specific problems**

Different OS



**1 file**  
**No compilation required**  
**No OS-specific problems**



## Other Considerations

### Plugins

Creation, compilation and installation difficulty:

**High**

Model modification difficulty:

**High**

Maintenance over the years:

**OS-dependent**

**Compiler-dependent**

**Framework-dependant**

### Embedded scripts

Creation, compilation and installation difficulty:

**Low**

Model modification difficulty:

**Low**

Maintenance over the years:

**OS-independent**

**Compiler-independent**

**Framework-independant**

## Synchronization with Simulation Loop

Plugins

Embedded scripts

Non-threaded

Control routine called at each simulation pass

Easy

Non-threaded

Control routine called at each simulation pass

Easy

Threaded

Complex synchronization mechanism required

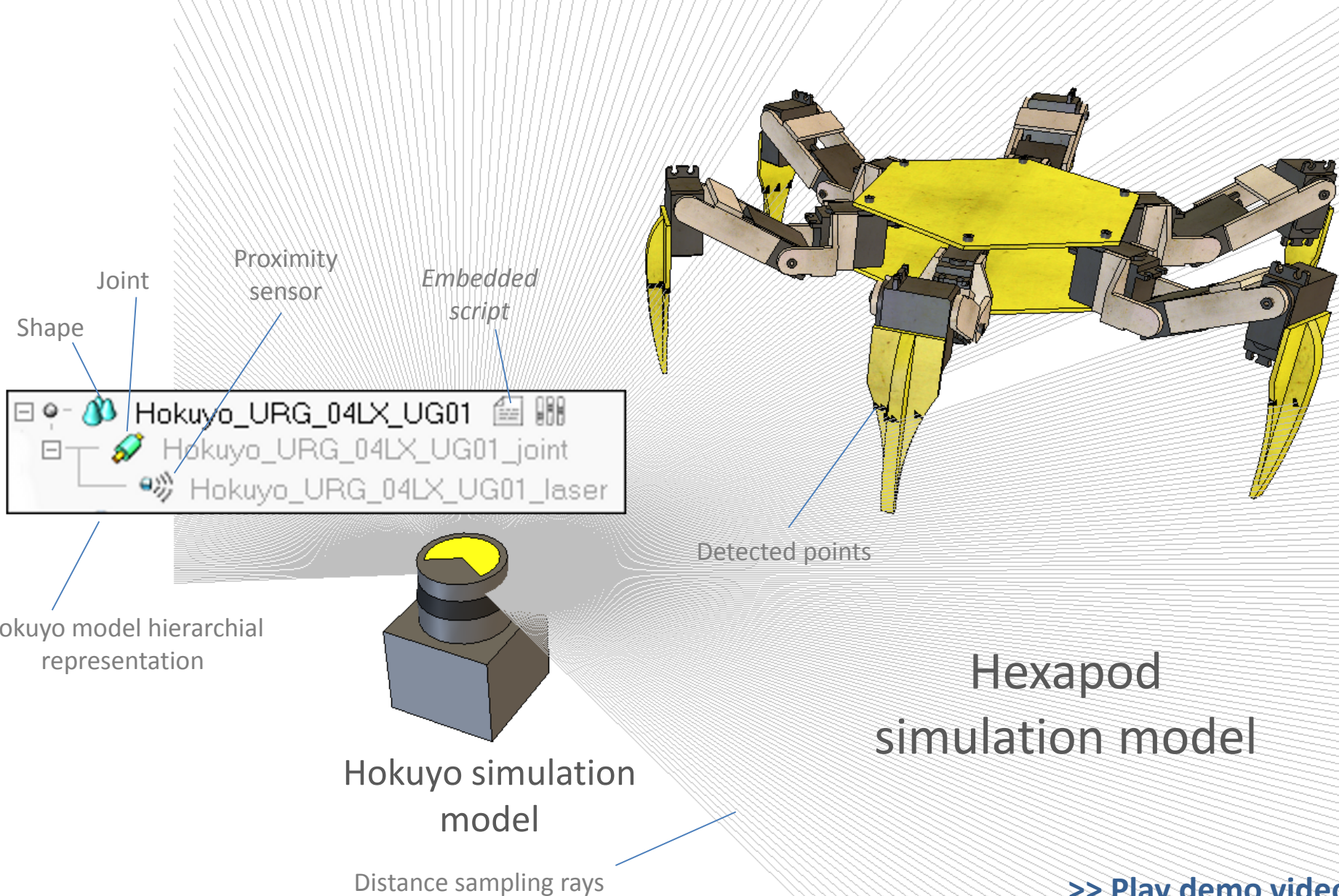
Difficult

Threaded

Control routine thread can behave as a coroutine  
e.g. `simSwitchThread()`  
`simSetThreadSwitchTiming(delay)`  
`simSetThreadIsFree(isFree)`  
`simSetThreadResumeLocation(location,order)`

Easy

# Embedded Scripts – Simple Example

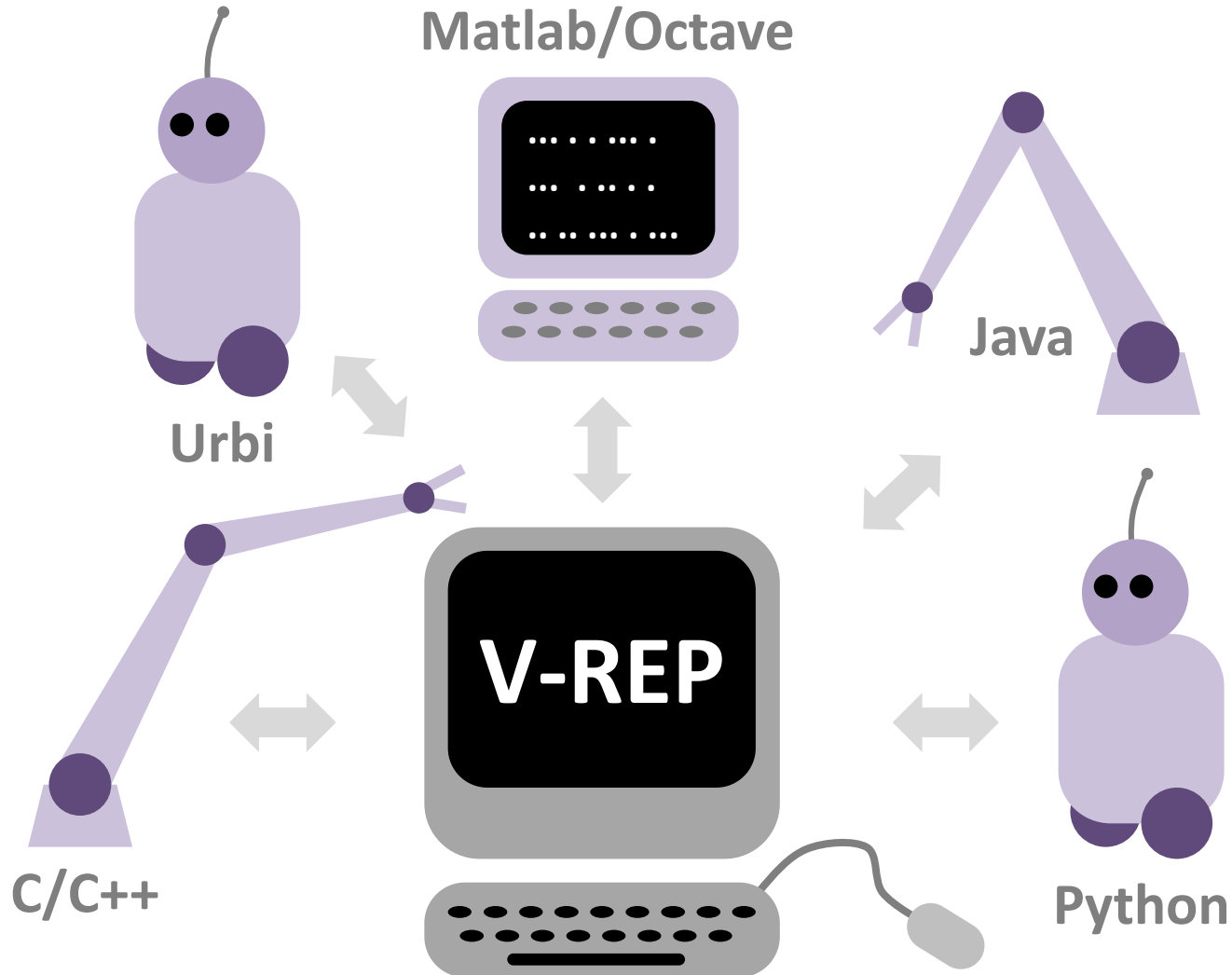


Hexapod simulation model

[>> Play demo video](#)

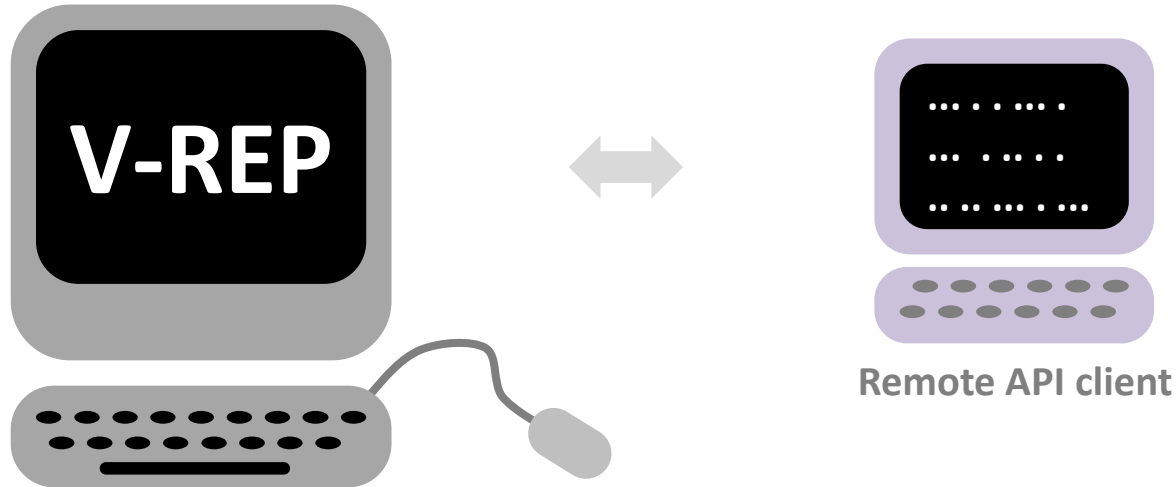
# Remote API Advantages 1/2

Runs on any hardware, lightweight, several languages



# Remote API Advantages 2/2

Very easy to use, almost like a *regular API*



Remote API function

Regular arguments

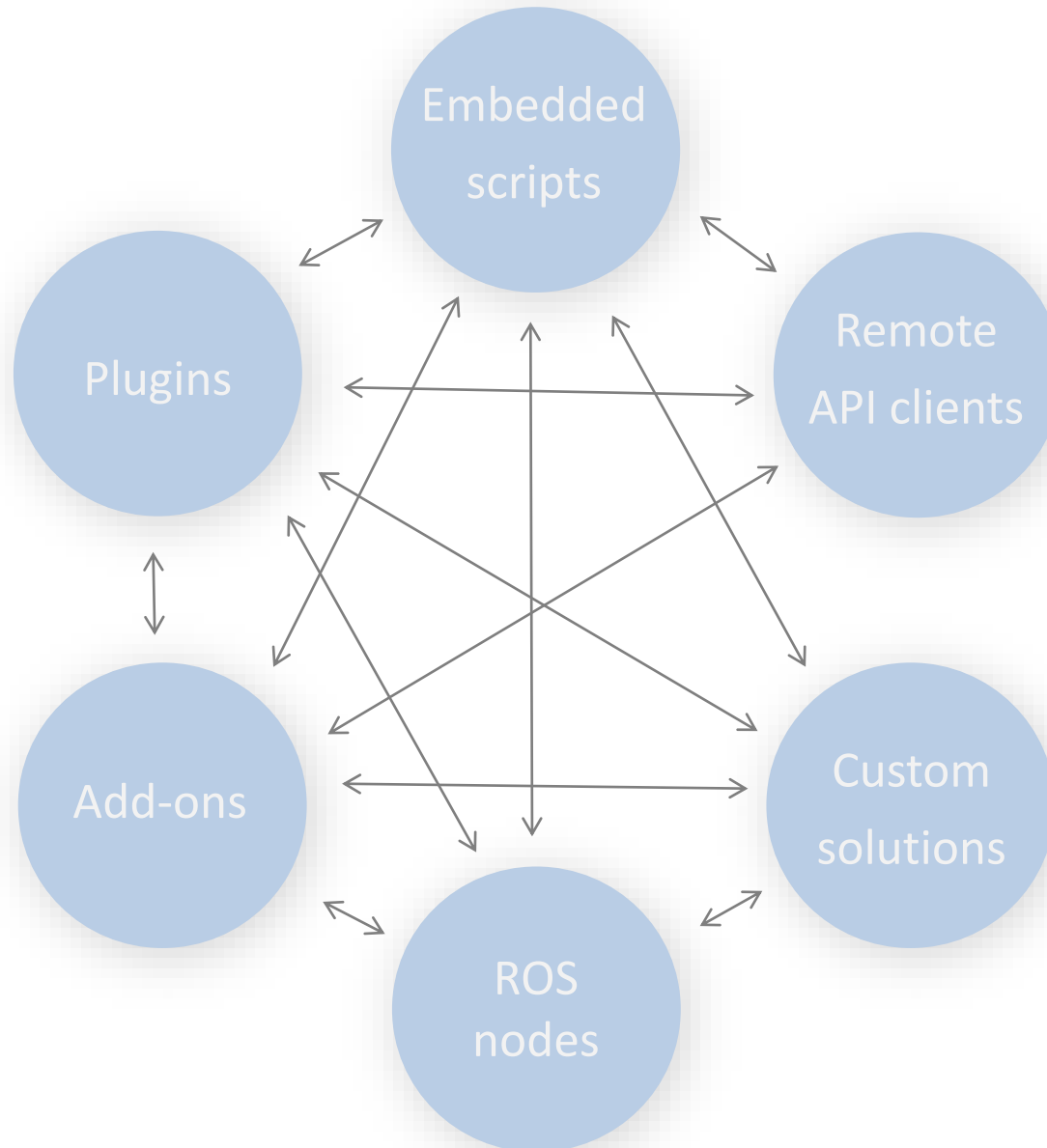
```
int returnCode=simxGetJointPosition(jointHandle,&position,operationMode);
```

- `simx_return_ok`
- `simx_return_timeout_flag`
- `simx_return_novalue_flag`
- `simx_return_remote_error_flag`
- `simx_return_local_error_flag`
- etc.

Blocking mode

- `simx_opmode_oneshot`
- `simx_opmode_oneshot_wait`
- `simx_opmode_streaming`
- `simx_opmode_discontinue`
- `simx_opmode_buffer`
- etc.

# Collaborative Control Mechanisms



# Example of Collaborative Mechanism 1 / 3



Remote  
API client

Appends coordinate information to the signal „objCreation“

```
int pos[3]={1.0f,2.0f,3.0f};  
simxAppendStringSignal("objCreation", (simxChar*)pos, 3*4, simx_opmode_oneshot);
```

Creates cylinders at the coordinates indicated in the signal „objCreation“

```
signalData=simGetStringSignal("objCreation")  
simClearStringSignal("objCreation")  
if signalData then  
  data=simUnpackFloats(signalData)  
  for i=0, (#data-1)/3, 1 do  
    handle=simCreatePureShape(2, 22, {0.1, 0.1, 0.1}, 0.1)  
    simSetObjectPosition(handle, -1, {data[3*i+1], data[3*i+2], data[3*i+3]})  
  end  
end
```

Embedded  
script

# Example of Collaborative Mechanism 2 / 3



Plugin

```
void SCRIPT_DO_SOME_MAGIC_CALLBACK(SLuaCallBack* p)
{
    ... ( gets called when a script calls „simExt_doSomeMagic“ )
}

// Initialization phase of plugin: register new script commands:
#define SCRIPT_DO_SOME_MAGIC "simExt_doSomeMagic"
int inArgs[]={2,sim_lua_arg_int,sim_lua_arg_float|sim_lua_arg_table};

simRegisterCustomLuaFunction(SCRIPT_DO_SOME_MAGIC,strConCat("number value1,
    number value2=",SCRIPT_DO_SOME_MAGIC,"(number index,table inVals)"),
    inArgs,SCRIPT_DO_SOME_MAGIC_CALLBACK);
```

Registers and handles the custom API function „simExt\_doSomeMagic“

Calls the custom API function „simExt\_doSomeMagic“

```
returnData1,returnData2=simExt_doSomeMagic(arg1,arg2)
```

Embedded  
script



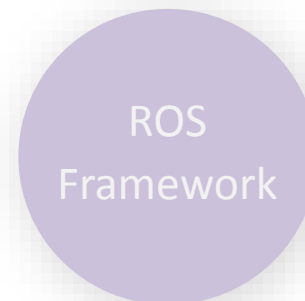
# Example of Collaborative Mechanism 3 / 3

```
-- Following in the script initialization phase (executed just once):  
  
-- Retrieve the handle of the vision sensor we wish to stream:  
visionSensorHandle=simGetObjectHandle('Vision_sensor')  
  
-- Now enable topic publishing and streaming of the vision sensor's data:  
topicName=simExtROS_enablePublisher('visionSensorData',1,  
    simros_strmcmd_get_vision_sensor_image,visionSensorHandle,0,'')  
  
-- Retrieve the handle of the passive vision sensor. We will use  
-- the passive vision sensor to visualize received data:  
passiveSensorHandle=simGetObjectHandle('PassiveVision_sensor')  
  
-- Now enable a topic subscription:  
simExtROS_enableSubscriber(topicName,1,  
    simros_strmcmd_set_vision_sensor_image,passiveSensorHandle,0,'')
```

Enable image streaming to ROS

Enable image streaming from ROS

Embedded  
script



# Control Mechanisms – Feature Overview



	Embedded script	Add-on	Plugin	Remote API client	ROS node	Custom client/server
Control entity is external (i.e. can be located on a robot, different machine, etc.)	No	No	No	Yes	Yes	Yes
Difficulty to implement	Easiest	Easiest	Relatively easy	Easy	Relatively difficult	Relatively difficult
Supported programming language	Lua	Lua	C/C++	C/C++, Python, Java, Matlab, Octave, Urbi	Any <sup>1</sup>	Any
Simulator functionality access (available API functions)	>280 functions, extendable	>270 functions, extendable	>400 functions	>100 functions, extendable	>100 services, >30 publisher types, >25 subscriber types, extendable	custom implementation (up to 300 func.)
The control entity can control the simulation and simulation objects (models, robots, etc.)	Yes	Yes, but not recommended	Yes	Yes	Yes	Yes
The control entity can start, stop, pause and step a simulation	Stop, pause	Start, stop, pause	Start, stop, pause, step	Start, stop, pause, step	Start, stop, pause, step	Start, stop, pause, step
The control entity can customize the simulator	No	Yes	Yes	No	No	No
Code execution speed	Relatively slow <sup>2</sup>	Relatively slow <sup>2</sup>	Fast	Depends on programming language	Depends on programming language	Depends on programming language
Communication lag	None	None	None	Yes, reduced <sup>3</sup>	Yes, reduced	Yes, can be reduced
Control entity is fully contained in a scene or model, and is highly portable	Yes	No	No	No	No	No
API mechanism	Regular API	Regular API	Regular API	Remote API	ROS	Custom communication + regular API
API can be extended	Yes, with custom Lua functions	Yes, with custom Lua functions	Yes, V-REP is open source	Yes, Remote API is open source	Yes, ROS plugin is open source	N/A
Control entity relies on	Nothing	Nothing	Nothing	Sockets + Remote API plugin	Sockets + ROS plugin + ROS framework	Custom communication + script/plugin
Synchronous operation <sup>4</sup>	Yes, inherent. No delays	Yes, inherent. No delays	Yes, inherent. No delays	Yes. Slower due to comm. Lag	Yes. Slower due to comm. Lag	Yes. Slower due to comm. Lag
Asynchronous operation <sup>4</sup>	Yes, via threaded scripts	No	No (threads available, but API access forbidden)	Yes, default operation mode	Yes, default operation mode	Yes

<sup>1</sup>) Depends on what ROS currently supports

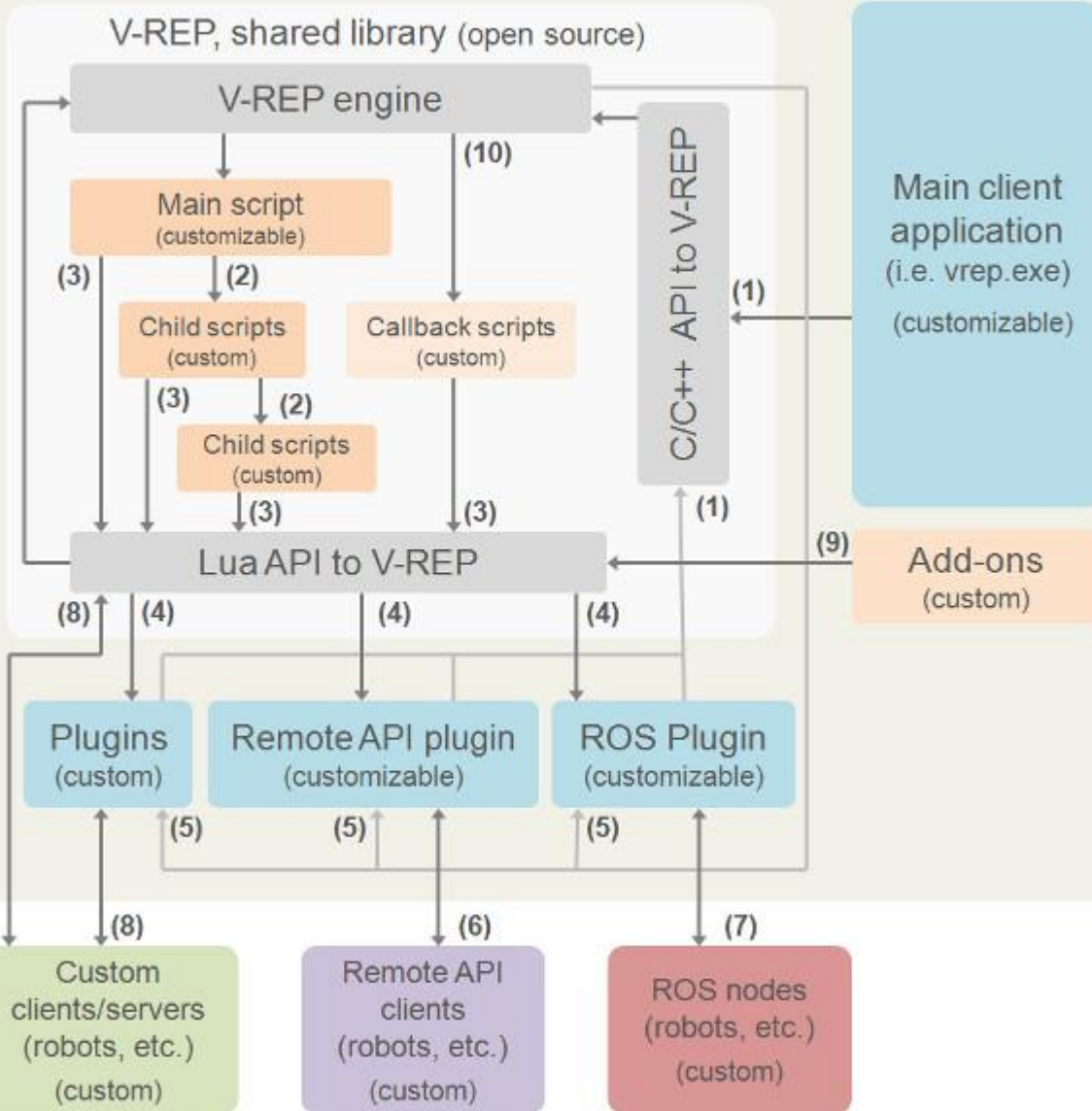
<sup>2</sup>) The execution of API functions is however very fast

<sup>3</sup>) Lag reduced via streaming and data partitioning modes

<sup>4</sup>) *Synchronous* in the sense that each simulation pass runs synchronously with the control entity, i.e. simulation step by step

# Architecture Overview

## V-REP framework

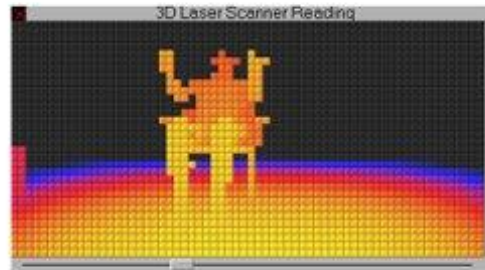


- (1) C/C++ API calls
- (2) cascaded *child script* execution
- (3) Lua API calls
- (4) custom Lua API callbacks
- (5) V-REP event callbacks
- (6) remote API function calls
- (7) ROS transit
- (8) custom communication (socket, serial, pipes, etc.)
- (9) Add-on calls to Lua API
- (10) Script callback calls

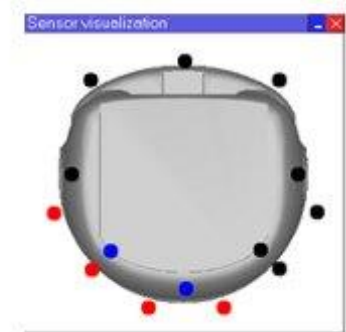
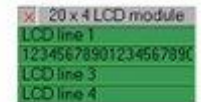
# Other Feature: Custom User Interfaces

## Custom User Interfaces

- Buttons, sliders, edit boxes and labels
- Can be textured or animated (e.g. via video stream)
- Can be attached (i.e. embedded) to scene objects
- Extremely portable
- Integrated edit mode



Joints	
All parameters to 0	
Store parameters	
Restore parameters	
Test all joints	
Test "test" joints	
Axis1	120.0
029.5	136.0
Axis2	119.3
013.0	023.2
Axis3	145.3
122.0	125.6
Axis4	078.2
097.2	063.4
Axis5	147.2
046.5	033.3
Axis6	119.9
135.5	086.4
Axis7	044.2
073.1	170.0
Axis8	069.1
000.0	017.0



## Mesh Edit Modes

- Triangle, vertex or edge edit mode
- Modify meshes (adjust vertices, add/remove triangles)
- Semi-automatic primitive shape extraction function
- Triangle, vertex or edge extraction
- Mesh decomposition
- Convex decomposition
- Convex hull extraction



# More Features



- Headless mode support (i.e. via command line)
- Import formats: OBJ, STL, 3DS, DXF, COLLADA & URDF
- Integrated Reflexxes motion library: [www.reflexxes.com](http://www.reflexxes.com)
- Model browser and scene hierarchy
- Multilevel undo / redo
- Movie recorder
- Simulation of wireless communication
- Simulation of paint or welding seams
- Static & dynamic textures
- Exhaustive documentation
- Etc.

## State-of-the-art distributed control architecture

- Embedded scripts
- Remote API
- ROS interface

## Extremely fine-grained and large amount of features

- >400 different API function
- 12 types of simulation objects (force/torque sensor, joint, camera, etc.)
- Integrated physics, kinematics, collision/distance calculation & path planning

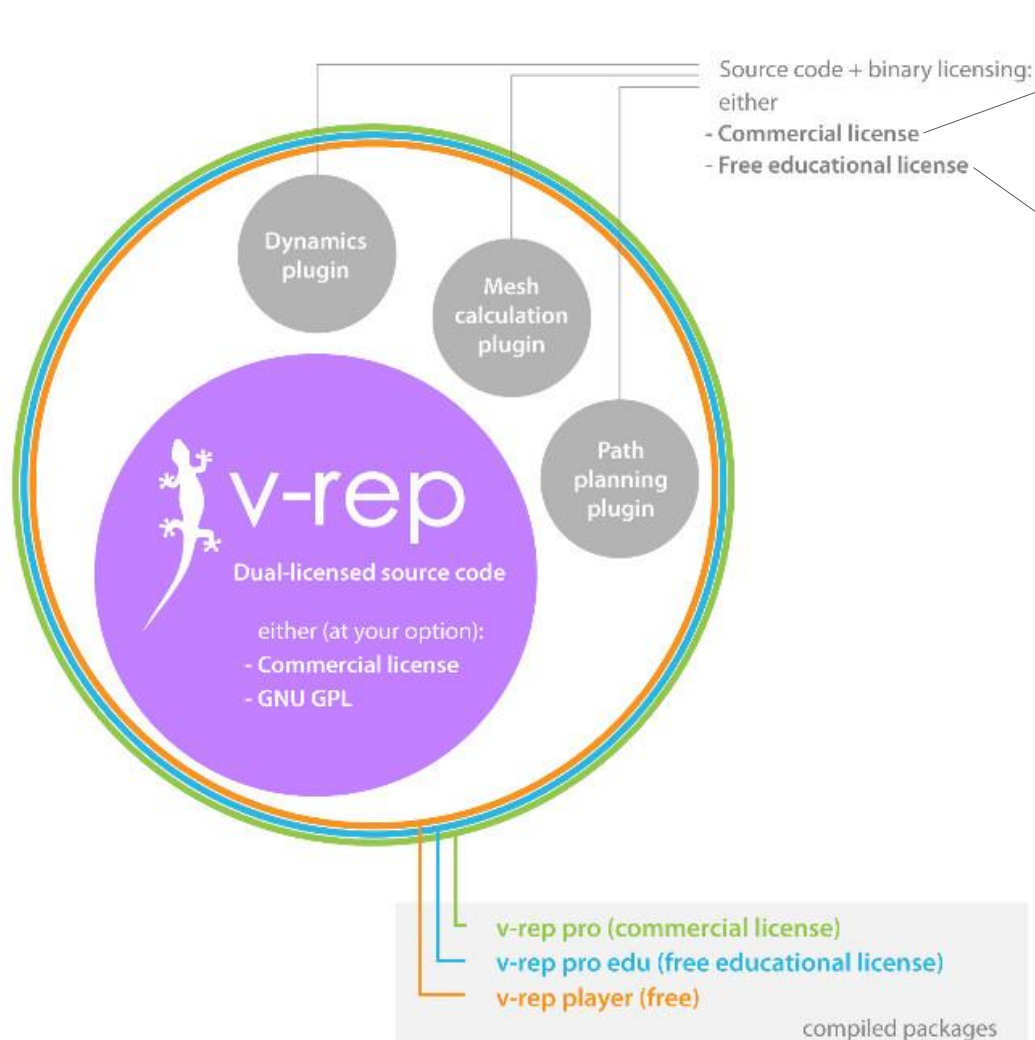
## V-REP sets on several horses

- Interfaces (plugins, embedded scripts, add-ons, Remote API, ROS)
- Languages (C/C++, Java, Python, Lua, Matlab, Octave, Urbi)
- Physics engines (Bullet, ODE, Vortex)
- Platforms (Windows, MacOS, Linux)

- V-REP PRO EDU**
  - For hobbyists, students, teachers, professors, schools and universities
  - Free
  - No limitations (i.e. fully functional)
  - No registration
  - Not for commercial applications
  - Not for companies, research institutions, non-profit organizations, etc.
  
- V-REP PRO**
  - For companies, research institutions, non-profit organizations, etc.
  - Not free
  - No limitations (i.e. fully functional)
  - For commercial applications
  
- V-REP PLAYER**
  - For everyone
  - Free, can be distributed
  - Limited editing capability, saving is disabled
  - For any application



# V-REP Source Code Licensing



contact Coppelia Robotics for details

PLUGIN educational license  
(where 'PLUGIN' may refer to 'DYNAMICS PLUGIN', 'MESH CALCULATION PLUGIN' or 'PATH PLANNING PLUGIN'):

The PLUGIN educational license applies ONLY to EDUCATIONAL ENTITIES composed by following people and institutions:

1. Hobbyists, students, teachers and professors
2. Schools and universities

EDUCATIONAL ENTITIES do NOT include companies, research institutions, non-profit organisations, foundations, etc.

An EDUCATIONAL ENTITY may use, modify, compile and distribute the modified/unmodified PLUGIN under following conditions:

1. Distribution should be free of charge.
2. Distribution should be to EDUCATIONAL ENTITIES only.
3. Usage should be non-commercial.
4. Altered source versions must be plainly marked as such and distributed along with any compiled code.
5. When using the PLUGIN in conjunction with V-REP, the "EDU" watermark in the V-REP scene view should not be removed.
6. The origin of the PLUGIN must not be misrepresented. you must not claim that you wrote the original software.

The PLUGIN is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. In no event will the original author be held liable for any damages arising from the use of this software.

The PLUGIN is copyrighted by Dr. Marc Andreas Freese (the original author). All rights reserved.

# Resources



V-REP website: [www.coppeliarobotics.com](http://www.coppeliarobotics.com)

V-REP user manual: [www.coppeliarobotics.com/helpFiles/](http://www.coppeliarobotics.com/helpFiles/)

V-REP forum: [www.forum.coppeliarobotics.com](http://www.forum.coppeliarobotics.com)

V-REP YouTube channel: [VirtualRobotPlatform](https://www.youtube.com/VirtualRobotPlatform)

V-REP contact: [info\\_at\\_coppeliarobotics\\_dot\\_com](mailto:info_at_coppeliarobotics_dot_com)