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Abstract:	This Deliverable describes SP10's progress in implementing its Platform Specifications (D10.4.1) in the period M1-M12.
Keywords:	Neurorobotics Platform, SCRUM, Milestones

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1. Introduction

1.1 The Human Brain Project

The Human Brain Project (HBP) is a major international scientific research project, involving over 100 academic and corporate entities in more than 20 countries. Funded by the European Commission (EC), the ten-year, EUR 1 billion Project was launched in 2013 with the goal "to build a completely new ICT infrastructure for neuroscience, and for brain-related research in medicine and computing, catalysing a global collaborative effort to understand the human brain and its diseases and ultimately to emulate its computational capabilities."

The fields of neuroscience, medicine and information technology each have important roles to play in addressing this challenge, but the knowledge and data that each is generating have been very fragmented. The HBP is driving integration of these different contributions.

During the Ramp-Up Phase, the HBP will collect strategic data, develop theoretical frameworks, and perform technical work necessary for the development of six Information and Communication Technology (ICT) Platforms during the Operational Phase. The ICT Platforms, offering services to neuroscientists, clinical researchers and technology developers, comprise Neuroinformatics (a data repository, including brain atlases and analysing tools); Brain Simulation (building ICT models and multi-scale simulations of brains and brain components); Medical Informatics (bringing together information on brain diseases); Neuromorphic Computing (ICT that mimics the functioning of the brain); and Neurorobotics (allowing testing of brain models and simulations in virtual environments). A High Performance Computing Platform will support these Platforms.

1.2 HBP Subproject 10: Neurorobotics Platform

The Neurorobotics Platform's objective is to allow non-robotics researchers, such as cognitive neuroscientists, to perform experiments *in silico*. In such experiments, a brain model would typically be coupled to a simulated robot (body), and these then interact within a simulated environment. The level of abstraction of the brain models will range from micro via meso to macro scale connectomes: it could be a model of a particular neuronal circuit, a region like a Brodmann area or even the whole brain.

Using a simulation approach with a variable degree of model abstraction will allow us to replicate classical experimental paradigms, and eventually develop new ones. Our goal is to gain new insights into the causal relationships linking basic neural constituents to perception, cognition and behaviour.

Simulating an experiment also implies simulating a robot's brain. After running a brain simulation on a dedicated computer node, it is only a small step to transfer this software from a simulated robot to a real robot.

The Neurorobotics Platform aims to develop and establish a sustainable and open source software solution. Software modules will be derived from established tools with a strong developer community, and from software already developed in the Blue Brain Project. Developers from the robotics community and the open source community are invited and encouraged to take part in this continuous effort.

1.3 Purpose of this Document

This report describes the progress in the development of the Platform during the period from Month 1 to Month 12.

1.4 Structure of this Document

The remainder of this chapter provides an SP-level overview, highlighting the SP's main accomplishments and issues encountered in the period M1-M12. Subsequent chapters look at accomplishments and in issues within individual Work Packages and Tasks of the Neurorobotics Subproject.

The Neurorobotics Subproject was divided into the following components:

- The Neurorobotics Platform software including:
  - Robot Designer and Brain Interface & Body Integrator (T10.1.1 and WP10.5)
  - Environment Designer and Experiment Designer (T10.1.2 and WP10.6)
  - Closed-loop Engine, World Simulation and Experiment Simulation Viewer (T10.1.3 and WP10.7)
- Integration and Operation (WP10.2)
- User Support and Community Collaboration (WP10.3)
- Scientific coordination (WP10.4)

In M6, three new Partners with substantial resources joined the Subproject via the Competitive Calls, which suggested an effective realignment of the WP structure to optimally exploit the competencies of the different Partners.

It is assumed that the reader is familiar with Subproject 10's first Deliverable: the specification document (Deliverable 10.4.1), which is referred to in this document.

The Annexes present in tabular form what the Subproject planned to achieve in this period and what it actually achieved.

1.5 Overview of Subproject 10: Organisation and implementation

The organisation of the Subproject has changed since the beginning of the year. The winners of the Competitive Call have been integrated in the Subproject. New Work Packages and tasks have been accordingly added.

The organisation of the Subproject as for today is the following:

- The project is led by Prof. Alois Knoll and Dr. Marc-Oliver Gewaltig.
- PD Dr. Florian Röhrbein coordinates the project.
- Prof. Gudrun Klinker oversees the visualisation related developments.
- Prof. Patrick van der Smagt leads WP 10.2 and fortiss members.
- Daniel Peppicelli (EPFL), Axel von Arnim (fortiss) and Florian Kuhnt (FZI) are or have been Scrum Masters.
- The SP10 engineering team of six software engineers contributes to the development of the Platform and ensure that the Competitive Call winners and the rest of the HBP communicates and work together.

- The VINERO SP consortium, winner of the Competitive Call, takes care of the development of the Platform. It is divided in two groups: four persons at Scuola Superiore Sant'Anna (SSSA) in Pisa and fourteen persons at Forschungzentrum Informatik (FZI) in Karlsruhe. The VINERO-SP consortium is led by Prof. Paul Levi and Prof. Cecilia Laschi.

As stated in the Subproject 10 Specification document (Deliverable D10.4.1), Chapter 10, SP10 follows the so-called *Scrum* methodology. This Agile programming method has proven to be more efficient and productive than traditional software development methods, such as the Waterfall model and its derivatives, and is becoming a standard within the software industry. Scrum is based on very short interaction cycles between the software stakeholders (the "product owners") and the development teams. Each cycle, or "sprint", lasts only two weeks during which a new set of features is implemented and demonstrated to the Project leaders, the Science and Technology Officer, and everyone who is interested. During each sprint, the development team meets regularly:

- The daily stand-up meeting where everyone communicates his/her daily progresses.
- The planning meeting, two weeks before a sprint, where the team decides on the features to be delivered during the next sprint.
- The review meeting, every two weeks after a sprint, where the team demonstrates the new features that were implemented during the last sprint.
- The retrospective meetings, where the team reviews everything that happened during the previous sprint and proposes improvements to the process.

The Scrum process allows progress of a software project to be monitored closely, tracking the number of completed features and the effort needed to implement them. The Scrum software engineering processes is detailed and discussed in 2.4.1 Scientific Coordination: Internal Meetings.

1.6 Overview of Subproject 10: Achievements

During the last six months, SP 10 faced the big challenge of integrating the new Partners into the existing team. The new Partners, in turn, faced the challenge of recruiting a substantial number of qualified software researchers within a very short time. Recruiting started in M7 and is now almost finished, with a current team size of 23 persons.

The Subproject was very successful in integrating the new Partners, probably due to the large number of virtual and in-person meetings. The entire team works in close collaboration, using a common toolset for development and quality assurance. This includes source code control, automated and peer code reviews, automated builds and a developer wiki.

Six months ago, the core HBP team within SP10 delivered the Neurorobotics Platform Specification document. It sets out the requirements that drive the development effort. It also includes a set of Key Performance Indicators that are used to monitor the progresses made on the Platform (See Annex B: Scientific Key Performance Indicators (SKPIs).

For Month 12, the SP had the following Milestones:

- **MS193**: Implementation specification for Neurorobotics Toolkit and for the Neurorobotics Cockpit.
- **MS296**: Robot Designer and Brain Interfaces & Body Integrator: Implementation Specification
- **MS300**: Environment Designer and Experiment Designer: Implementation Specification

- **MS304**: Closed-Loop Engine, World Simulation and Experiment Simulation Viewer: Implementation Specification

MS193 was an original SP 10 Milestone that existed prior to the Competitive Call. MS296, MS300, MS304 were then added as a result of the work plan proposed by VINERO-SP.

Milestone MS296, "Robot Designer: Implementation Specification" has been reached. The Subproject development team agreed on the design of the Robot Designer based on existing open source tools. The team also decided to use the open URDF format to describe robots. URDF is one of the most widely used robot description formats and gives the Neurorobotics Platform access to a large range of well-tested robot models.

Milestone MS300, "Environment Designer and Experiment Designer: Implementation Specification" has been reached. One of the main decisions that had to be taken as part of this Milestone was the choice of a description format for virtual environments. We decided to use the SDF format that allowed us to use the existing Gazebo software to build virtual environments. Here again, we can benefit from a wide range of existing environment models from the robotics community. For the experiment designer, we decided to develop a Web-based user interface. As of Month 12, the Experiment Designer architecture is fully defined, including an implementation plan. The main developments of the Experiment Designer are scheduled between Month 12 and Month 15.

Milestone MS304, "World Simulation Engine: Implementation Specification" is reached. Most of the development between Month 6 and Month 12 has been put on this Milestone, since the World Simulation Engine is the core of the Platform and its usefulness decides foremost whether the goals of the specification document are reached. A functional World Simulation Engine is also the prerequisite to attract early adopters from within and from outside the HBP, starting with researchers from WP11.1 ("Future Neuroscience").

1.6.1 Cross-SP Collaboration

During Month 6 to 12, the team also started collaborations with other Subprojects. The main collaboration areas are outlined in chapter 2.8 of the specification document.

From the start, the SP10 development team has collaborated with the visualisation team from SP7. This collaboration was very important in defining the direction of the Neurorobotics team with respect to high-fidelity rendering. Moreover, common code interfaces and codes have been identified and are shared between the Subprojects.

The team took a great care to use the same libraries and frameworks as the Unified Portal team from SPs 13 and 6. Next month, the first version of the Unified Portal will be released and the Neurorobotics Platform will already be able to use it.

Currently, the Neurorobotics Platform uses the neural simulation tool NEST (aka NETSIM from SP6) to implement simple neural controllers for the robots provided by SP10. At the same time, SP6 and SP10 are defining the required interfaces so that brain models from SP6 can be used from within the Neurorobotics Platform.

Collaboration with the Neuromorphic Computing Subproject (SP9) started early in the Project. Two SpiNNaker boards were provided by an SP9 Partner, the University of Manchester, for evaluation by SP10. The Partners at FORTISS and TUM, together with the team from University of Granada (SP11) are exploring the use of the SpiNNaker system for real-time control of a robot arm with artificial muscle actuators in simulation and in reality. First results were presented in poster form during the HBP Summit.

The SP10 team at the EPFL also received a SpiNNaker board and explored its use for real-time control of a simple ball-balancing robot, using a neural network derived from a detailed reconstruction of a neocortical microcircuit that was developed at the EPFL.

Preliminary results were presented at the first HBP Summit in 2013 and recent work has focussed on training the controller through reinforcement learning.

1.6.2 Quality control measures

The team has successfully put in place most of the software engineering tools needed to ensure quality:

- Common guidelines on writing code for each used programming language
- Automated build for each part of the Platform
- Code review process, each piece of code needs the approval of at least two developers.
- Zero warnings compiler policy.

The output of these tools is monitored using S-KPIs (see Annex B: Scientific Key Performance Indicators (SKPIs)).

Every two weeks, during the scrum demo meetings, the project leaders are invited to witness the progress made on the Platform. At that point, the team double-checks that all quality standards have been respected.

The team also sets aside a brief, dedicated period after each demo meeting to deliberately reflect on progress and find ways to improve its performance. This exercise was performed 10 times during Month 6 to 12. The resulting process-improvement decisions included:

- Wherever possible, features are co-developed by all the developing teams (Munich, Karlsruhe, Lausanne and Pisa), rather than dedicating assigning the whole of an individual feature to a single team.
- Involving all development teams in reviews of the code and the architecture documents.
- Setting up a development environment using virtual machines and provisioning software, which shortens the learning time for newcomers to the SP.
- Splitting the team in two subteams, because it had grown too large to be managed by one scrum master. A coordination committee synchronises the work of the 2 teams.
- To focus heavily on software architecture, which we did by introducing an architectural committee that supervises the architectural choices taken by the team.

1.7 Overview of Subproject 10: Problems

The biggest challenge so far was the extremely tight timeline for the integration of the VINERO-SP Partners inducted via the Competitive Call project and the recruitment of the necessary new scientists and engineers. Considering that this had to be done in parallel to the planned research and development work, we were highly relieved that the SP10 Milestones and Deliverables due to date have been achieved with little or no delay.

After the summer, it became clear that the SP10 team meetings had become too large and therefore ineffective. As a remedy, the team decided to split into two, while maintaining sufficient overlap to allow all teams to be informed about their mutual progress.

Another challenge has been the integration of modern, Agile-based software development practices into the traditional planning and reporting structures of other parts of the HBP.

SP10 and SP6 are in intensive and constructive discussions with the Science and Technology Office to develop a transparent and sustainable solution to this problem.

1.8 The Next Six Months for Subproject 10

The period from Month 12 to Month 18 includes two important activities. Firstly, the HBP's first Periodic Review in January 2015 and, secondly, the preliminary release of the Neurorobotics Platform to HBP Partners, due in April 2015.

For the HBP Review, SP10 is preparing an interactive demonstration of the Neurorobotics Platform to highlight key-features of its functionality. The demonstration will show the interactive real-time simulation of a "virtual laboratory". The virtual laboratory is a faithfully modelled room with lamps, furniture and computer screens. Inside the laboratory, the user can see and interact with a mobile robot that is controlled by a simple neural network model and that reacts to stimuli shown on the simulated computer screens. Preliminary results for this demonstration were shown at the HBP Summit 2014 in Heidelberg.

For the internal SP10 Platform release, work will focus on developing and refining the web-based user interfaces to the Neurorobotics Platform.

2. Neurorobotics Platform Software

The following sections present an overview of the technical choices and progress made for each of the components of the Neurorobotics Platform as they were described in the Specification Deliverable. The Neurorobotics Platform has 8 parts: 4 designers (Robot, Environment, Experiment, Brain Interfaces & Body Integrator), 3 simulation engines (World Simulation, Closed Loop and Neural Simulation) and an Experiment Simulation Viewer, designed for two scenarios (web and high-fidelity immersive visualisation).

In some documents, the term "neurorobotics cockpit" has been used. The cockpit consists of all the web interfaces of the design tools and the Experiment Simulation Viewer. All of them will be accessed through the Unified Portal. The broader term "neurorobotics toolkit" consists of all the software delivered and used for the Platform (the cockpit software plus the different simulation engines and the closed loop engine).

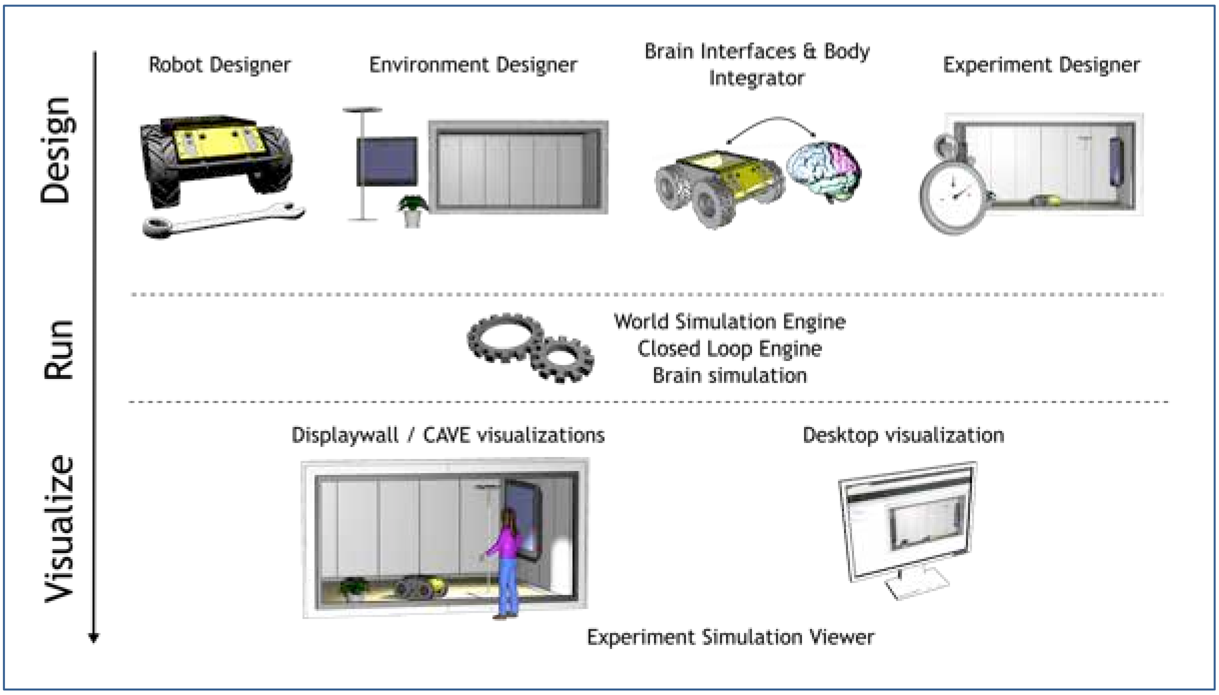


Figure 1: Components of the Neurorobotics Platform

2.1 Design and Specification (WP10.1)

The first task of the SP10 development team was to select the software foundation for the Neurorobotics Platform. This process started with an in-depth survey of the available open source software for robotics and high fidelity, real-time rendering. The various tools were evaluated on the basis of the criteria outlined in the Specification document and the most promising tools were selected. The next sections will describe each selected software components in mode details.

As it turned out, most of the selected software foundations had designer tools, which could be used as foundations for the design tools envisioned for the Neurorobotics Platform, even though they do not fulfil all of our requirements. This allowed the development team to focus on the core components of the Neurorobotics Platform, such as the Closed Loop Engine, the Experiment Simulation Viewer and the Brain Interfaces & Body Integrator.

In order to develop core components that satisfy realistic needs, SP10 defined a neurorobotics simulation scenario (or use case) that will be available for the internal release Milestone (MS194). Note that, even though we describe the scenario on the basis of a large monitor wall (power wall), the same scenario can be executed and visualised using one or more standard computers.

The user is standing in front of a Display Wall and sees a continuation of the room into the monitor(s). In the centre of the virtual room is a Clearpath *Husky* robot. Two computer screens are mounted to the sidewalls of the virtual room. To control the simulation, the user has a mobile computing device, such as a tablet or notebook computer. To start the experiment, the user changes the images shown on the simulated computer screens. Depending on the selected image, the robot will move towards or away from the respective screen. The logic for this simple control is provided by a neural network running within the NETSIM simulator. The network model processes the visual images coming from the robot's camera and generates motor commands for the robot's wheels.

Figure 2: Scenario targeted for the next Milestone, "the virtual room"

This initial scenario not only uses all required parts and features of the Neurorobotics Toolkit, it also poses a number of challenges to the development team:

- High-fidelity real-time rendering is a difficult requirement and the team wanted to gather experience in this field before other user interface decisions for the Platform had to be taken.
- The web-based user interaction needs to be seamlessly integrated into the HBP Unified Portal. By adding a mobile, web-based simulation control to the scenario, the development team was forced to tackle this challenge early in the Project. SP6 has just released a beta version of the Unified Portal and the development of the neurorobotics component of the portal will start in the following months.
- Since the Display Wall is composed of multiple displays, each controlled by a separate computer or GPY, the development team had to support real-time rendering on multiple monitors from the beginning. For the standard user, this technology brings the benefit of multiple observation perspectives during an experiment.

For the foundation of the Neurorobotics simulation tools, the SP10 team decided to use the open source simulator GAZEBO. Gazebo is well established in the robotics community and has a modular design that met many of our requirements. For example, rendering is decoupled from the physics simulation, which enabled us to develop our own rendering module on top of Gazebo (more on this in Chapter 3.3.3 Experiment Simulation Viewer). Physics simulation in Gazebo is also modular and supports different physics engine such as bullet, DART or ODE. This modularity eases the development of the World Simulation Engine (in Chapter 3.3.2). Finally, Gazebo already has various graphical user interfaces that can be used as starting point for the various designers of the Neurorobotics Platform.

2.2 Integration and Operation (WP10.2)

2.2.1 Quality Assurance

Since the start of the project, the development team has paid particular attention to producing high-quality code. This was achieved by using the following software development process:

1) Developers write code according to "stories" written in the SCRUM format (More about that in 2.4.1 Scientific Coordination: Internal Meetings).
2) Developers are required accompany their code with so-called "unit" tests. These are automated tests that must cover at least 80% of the code.
3) Once the code is ready, it's committed to a "reviewing system", called Gerrit, where the code is then reviewed and commented by another developer.
4) Then, the code enters a continuous integration system, called Jenkins, which checks that the software can be compiled and run without any problems. It then executes the unit tests to ensure that all parts of the software run according to specification (Fig. 3).
5) Only then, when the software has been reviewed, when it builds successfully and has passed all tests, does the code enter the central code repository where it is available to everyone in the project.

This process is monitored through KPIs defined with the STO office.

Code Coverages(Cobertura)

Job	Packages	Files	Classes	Methods	Lines	Conditionals
neurorobotics.BIBIRobotControl #3	100%	100%	100%	N/A	90%	100%
neurorobotics.BIBIRobotControl.gerrit #27	100%	100%	100%	N/A	90%	100%
neurorobotics.ESVRender #55	100%	97%	97%	100%	83%	100%
neurorobotics.ESVRender.gerrit #251	100%	94%	94%	100%	81%	100%
neurorobotics.ESVWebCockpitClient #8	100%	100%	100%	100%	100%	100%
neurorobotics.ESVWebCockpitClient.gerrit #27	100%	100%	100%	100%	100%	100%
neurorobotics.ESVWebCockpitServer #12	100%	100%	100%	N/A	84%	100%
neurorobotics.ESVWebCockpitServer.gerrit #25	100%	100%	100%	N/A	84%	100%
neurorobotics.nestify #44	100%	100%	100%	N/A	90%	100%
neurorobotics.WSLib #7	100%	100%	100%	100%	94%	100%
neurorobotics.WSLib.gerrit #143	100%	100%	100%	100%	100%	100%
Total:	**100%**	**96%**	**96%**	**100%**	**83%**	**100%**

Figure 3: Code coverage report in Jenkins (build manager) for the Neurorobotics Platform projects

2.2.2 Integration and Operation: Deployment

Work Package 10.2 is led by Prof. Patrick van der Smagt of the company fortiss, which is working under contract to the Technische Universitaet Muenchen. It concentrates on creating a brain-body-like closed-loop system by real-time cerebellar motor control of robotic hardware. For this, the Work Package is working with the neuromorphic SpiNNaker board (developed by the University of Manchester in WP9.2) as a suitable, energy-efficient computing platform for simulating spiking neural networks in real time. WP10.2 collaborates with the Universidad de Granada (UGR) on cerebellar modelling. It has completed ported specific implementations of these real-time cerebellar-learning models capable of closed-loop conditions to PyNN, a unified Python front-end for several neuronal simulators including the SpiNNaker board.

The musculoskeletal robot arm used by SP10 is based on the latest Myorobotics toolkit, which features intrinsically compliant actuators and a modular design. In collaboration with the Neuroscientific System Theory (NST, Prof. Jörg Conradt) group at TU Muenchen, we have established a CAN-enabled communication between the robot and the SpiNNaker board. We integrated the closed loop in real-time in hardware and software as a proof of concept, and have designed an initial setup for the emulated cerebellum to correctively control a single joint robot following a simple trajectory being able to cope with unforeseen payloads and dynamics.

2.3 User Support and Community Building (WP10.3)

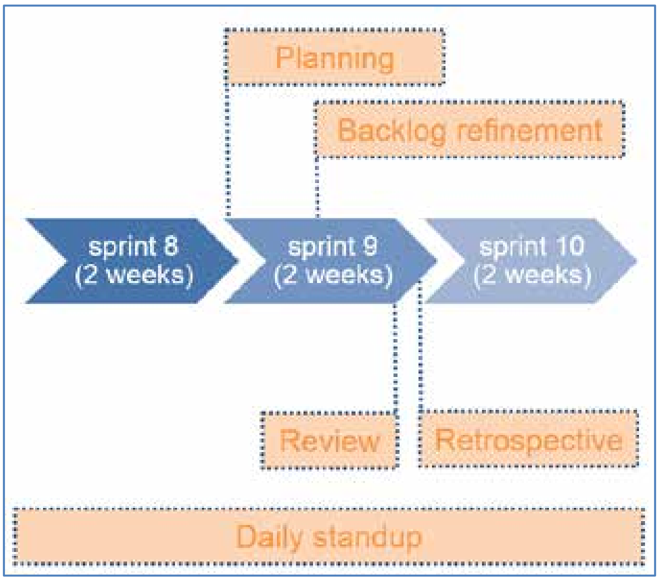
The first users of the Neurorobotics Platform are expected for the next Milestone (MS194 Internal release). The team will start to work on the user documentation in the following months. The user training will start after the internal release Milestone.

2.4 Scientific Coordination (WP10.4)

2.4.1 Scientific Coordination: Internal Meetings

As already stated, the team follows the Scrum methodology. Scrum defines a set of well-structured meetings that enclose the Sprints (units of two weeks of uninterrupted work).

The following schema shows how these meetings are organised.



Each Sprint starts with a Planning meeting, where all developers and the Product Owner (the project leader, not a developer) decide on which User Stories (features) will be implemented in the coming Sprint. The review meeting closes the sprint where the team demonstrates the successfully implemented features to the Product Owner. He then decides if the features are acceptable. Just after the Review, the team (without the Product Owner) has a 1.5 hour long Retrospective meeting (described above). In this meeting, we analyse what went right and wrong and take decisions accordingly.

Figure 4: Sprint 5 retrospective output. The team used three columns to express their views about the sprint and drive discussion about how to improve

In the middle of the sprint, a Backlog Refinement meeting can take place where the Product Owner and interested members of the team redefine priorities for the next Sprint.

This is a kind of pre-Planning which is useful for keeping the developers synchronised with the Product Owner's views.

Every day at 10h30, the team has a Daily Stand Up meeting, lasting only 15 minutes, where everyone states his/her progress.

This may seem like too many meetings, but as all Scrum meetings conform to a well-defined format and are subject to rigid time limits, they have proved to be efficient.

On top of Scrum, some SP10 Partners have arranged extra meetings that are listed below. Among them are three internal workshops that were held in Munich and Karlsruhe (this type of meeting is now called a "performance show"). During these workshops, all the developers met and discussed with the various Subproject stakeholders.

The table below lists physical meetings between SP staff, where people from more than one HBP Partner institution were present.

Date	Description	Location
9.10.2013	SP10 meeting during the HBP summit	Lausanne
12.12.2013	Software specification meeting	Lausanne
8-9.1.2014	1st Neurorobotics workshop	Munich
12-13.02.2014	1st developer internal workshop	Lausanne
3.3.2014	Neurorobotics SW meeting	Lausanne
18.3.2014	Neurorobotics meeting with Call winners	Munich
25-26.3.2014	2nd Neurorobotics workshop	Munich
6-8.05.1014	2nd developer internal workshop (including FZI, SSSUP)	Lausanne
27-29.8.2014	1st performance show	Karlsruhe
29.9.2014	SP10 meeting during the HBP summit	Heidelberg

2.4.2 Scientific Coordination: HBP Meetings

The development teams in Lausanne meet once a week, for fifteen minutes. This meeting is called the Scrum of Scrums. Usually, one member from each team participates and quickly describes what are the progresses made by his/her team, what they will work on during the following week and if they have any issues that another team could address. For the Subproject 10, this meeting did lead to (among other things)

- Collaboration with the visualisation (SP7) helping us identifying the building blocks of the Experiment Simulation Viewer.
- Collaboration with the Unified Portal team helping us applying the state of the art good practices with languages we are not familiar with such as Javascript and Python.

On top of that, members of the neurorobotics team are participating to the sprint demos of the visualisation team (SP7) and the portal team (SP6).

This table lists additional meetings that took place between this SP and other SPs.

Date	Description	Location	Participants	Comments
8.10.2013	Parallel meeting during HBP summit	Lausanne	All SPs	
8.-9.1.2014	Cross-SP meeting during 1st SP10	Munich	SP10 and SP11	

	workshop			
25.-26.3.2014	Cross-SP meeting during 2nd SP10 workshop	Munich	SP10 and SP11	
17.7.2014	Cross-Platform meeting on data, SW and service streams	TelCo	Representatives of all Platforms	
28.8.2014	Introduction to the unified portal from SP6	Karlsruhe	SP6 portal team, SP10 team	
30.9.2014	Parallel meeting during HBP summit	Heidelberg	SP4 and SP10	
01.10.2014	Parallel meeting during HBP summit	Heidelberg	SP7, SP9 and SP10	

2.4.3 Scientific Coordination: External Meetings

This table lists meetings between this SP and Partners outside the HBP.

Date	Description	Location	Participants	Comments
8.-9.1.2014	Invited talks and discussions with guests during 1st SP10 workshop	Munich	Aaron Sloman, Leslie Smith, Murray Shanahan and SP10	
25.-26.3.2014	Invited talks and discussions with guests during 2nd SP10 workshop	Munich	Mel Slater, Robert Trappl and SP10	
26.6.2014	Meeting with members of the German parliament	Berlin	Amunts, Ebell, Lippert, Meier, Röhrbein	

2.4.4 Scientific Coordination: Monitoring and Quality Control

The monitoring of progress is performed using three sets of indicators:

- The SCRUM monitoring: The stakeholders attend all the important SCRUM meetings. They use the SCRUM metrics to monitor the progresses such as the burndown chart (see Figure).
- The quality metrics: The team did put in place some quality metrics and their implementation made it impossible for the developers to submit code that is not compliant with the standards defined in the specification document (see also Figure). These metrics are discussed in 1.6 Overview of Subproject 10: Achievements.
- Regular performances show where the development team demonstrate to the stakeholders the latest developments.

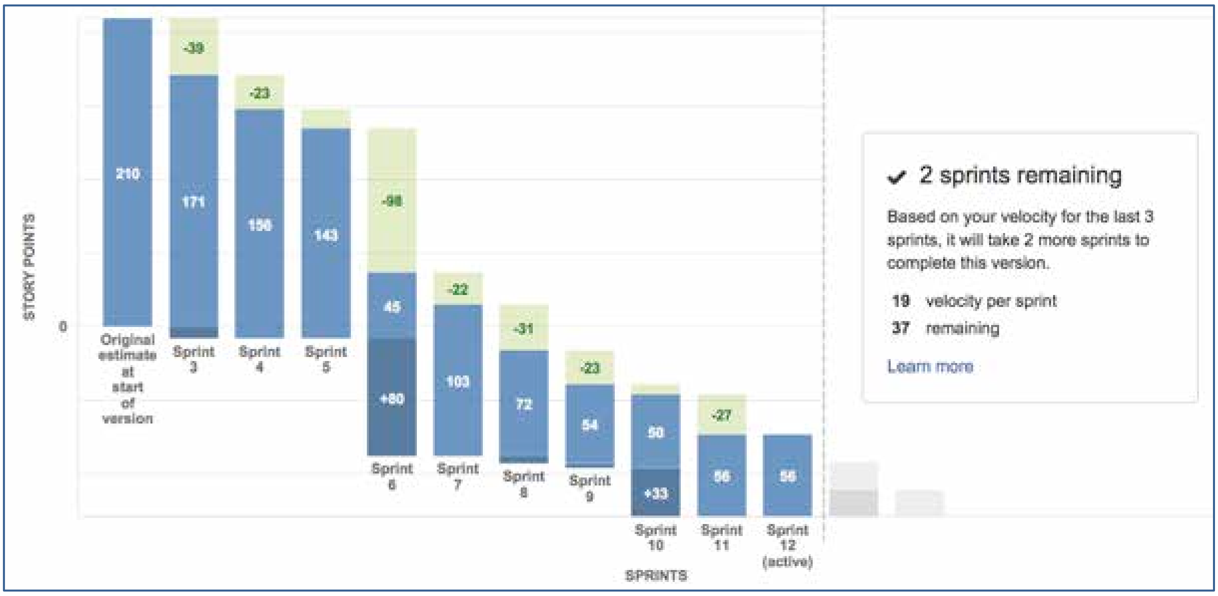
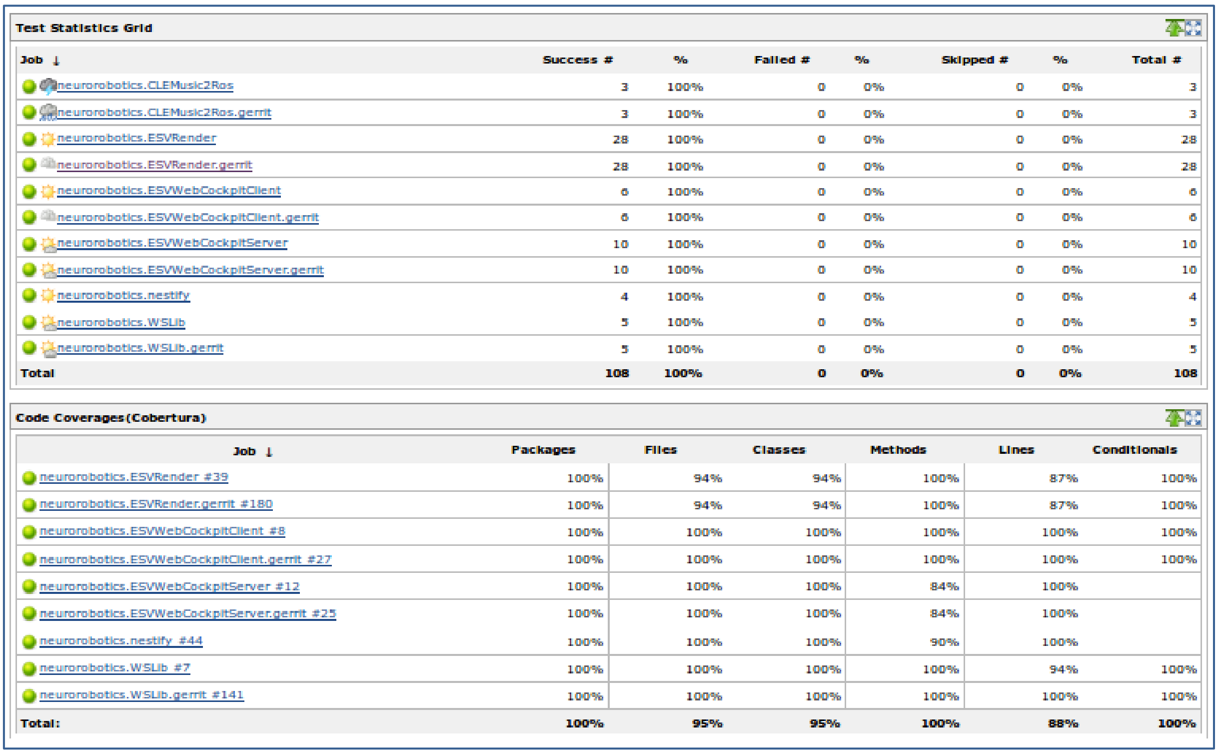


Figure 5: Burndown chart for the target of the development team: a minimum viable product. This chart shows the speed of development, the amount of unforeseen work and the estimation of the release date



Test Statistics Grid

Job ↓	Success #	%	Failed #	%	Skipped #	%	Total #
neurorobotics.CLEMusic2Ros	3	100%	0	0%	0	0%	3
neurorobotics.CLEMusic2Ros.gerrit	3	100%	0	0%	0	0%	3
neurorobotics.ESVRender	28	100%	0	0%	0	0%	28
neurorobotics.ESVRender.gerrit	28	100%	0	0%	0	0%	28
neurorobotics.ESVWebCockpitClient	6	100%	0	0%	0	0%	6
neurorobotics.ESVWebCockpitClient.gerrit	6	100%	0	0%	0	0%	6
neurorobotics.ESVWebCockpitServer	10	100%	0	0%	0	0%	10
neurorobotics.ESVWebCockpitServer.gerrit	10	100%	0	0%	0	0%	10
neurorobotics.nestify	4	100%	0	0%	0	0%	4
neurorobotics.WSLib	5	100%	0	0%	0	0%	5
neurorobotics.WSLib.gerrit	5	100%	0	0%	0	0%	5
Total	108	100%	0	0%	0	0%	108

Code Coverages(Cobertura)

Job ↓	Packages	Files	Classes	Methods	Lines	Conditionals
neurorobotics.ESVRender #39	100%	94%	94%	100%	87%	100%
neurorobotics.ESVRender.gerrit #180	100%	94%	94%	100%	87%	100%
neurorobotics.ESVWebCockpitClient #8	100%	100%	100%	100%	100%	100%
neurorobotics.ESVWebCockpitClient.gerrit #27	100%	100%	100%	100%	100%	100%
neurorobotics.ESVWebCockpitServer #12	100%	100%	100%	84%	100%	
neurorobotics.ESVWebCockpitServer.gerrit #25	100%	100%	100%	84%	100%	
neurorobotics.nestify #44	100%	100%	100%	90%	100%	
neurorobotics.WSLib #7	100%	100%	100%	100%	94%	100%
neurorobotics.WSLib.gerrit #141	100%	100%	100%	100%	100%	100%
Total:	100%	95%	95%	100%	88%	100%

Figure 6: Dashboards used to control quality metrics

2.4.5 *Scientific Coordination: Additional Comments*

From Month 9 onwards, regular biweekly PI teleconferences were held to ensure quick information dissemination and synchronisation between TUM, EPFL, FZI and SSSA. Monthly seminars for all people at TUM who are involved in HBP Neurorobotics have been organised since April 2014. This meeting is open to colleagues from outside the HBP.

We have set up two newsletters, one for communication within SP10 and one for the larger community interested in neurorobotics and related fields. We maintain our own website which went online in Month 3 and is currently being refurbished.

2.4.6 Scientific Coordination: The Next Six Months

In the next few months, we will further increase our community-building effort by organising international workshops and special tracks at major robotic conferences, e.g., ICRA May 2015 (Seattle, USA) and IROS October 2015 (Hamburg, Germany).

We will target the international neurorobotics community, but also HBP Partners from other SPs. Additional projects with HBP Partners are under discussion as result of cross-SP meetings at the 2014 HBP Summit in Heidelberg. For the internal release in M18, we will install statistics tools to measure usage of the NR Platform.

The 2nd SP10 performance show will take place 17-19 December in Lausanne, while the 3rd will take place in March in Munich.

3. Neurorobotics Platform Components

3.1 Robot Designer, Brain Interfaces and Body Integrator (WP10.5)

3.1.1 Robot Designer

The Robot Designer will allow a user to easily set up a virtual robot for a given simulated experiment. The word "easily" is here very important, since the user may be a neuroscientist who is unfamiliar with robotics. The robot will be integrated into an environment at a later stage.

In the first version of the Robot Designer, scheduled to be completed at the end of the Ramp-Up Phase, the Designer will provide the user with pre-assembled robots from a "robot library," or from imported files for quick customisation.

The team is currently implementing two robots for the Platform: The Clearpath Husky robot and a biologically inspired mouse model. The Husky is a realistic model of a mobile robot produced by a company called Clearpath. It will therefore be a good demonstrator for the transition from simulated to physical robotics experiments, which are planned for the FPA Phase of HBP. The mouse model caters to the needs of neuroscientists and the plans to run behavioural experiments in simulation.

Figure 7: Clearpath Husky robot and Mouse robot models

While designing the two first robot models, the team investigated how to integrate new or existing robots into Gazebo. For inexperienced users, Gazebo provides a large choice of pre-configured robot models, for example the Husky or the PR2. Experienced users can use one of the many existing 3D modelling tools such as Blender. For example, the mouse model has been created with Blender. The Gazebo development roadmap also includes a dedicated robot designer, announced for version 6.0, to be released around July 2015.

Figure 8: Virtual room model with the Husky robot running in the Gazebo simulator

3.1.2 *Brain Interfaces and Body Integrator*

One of the biggest challenges for neurorobotics experiments is the coupling between brain models and the various sensors and effectors of a robot. In the Neurorobotics Platform, this task will be performed by the Brain Interfaces and Body Integrator (BIBI). BIBI lets the user choose a brain simulator and a brain model to run on it, and then it lets the user connect it to a virtual robot.

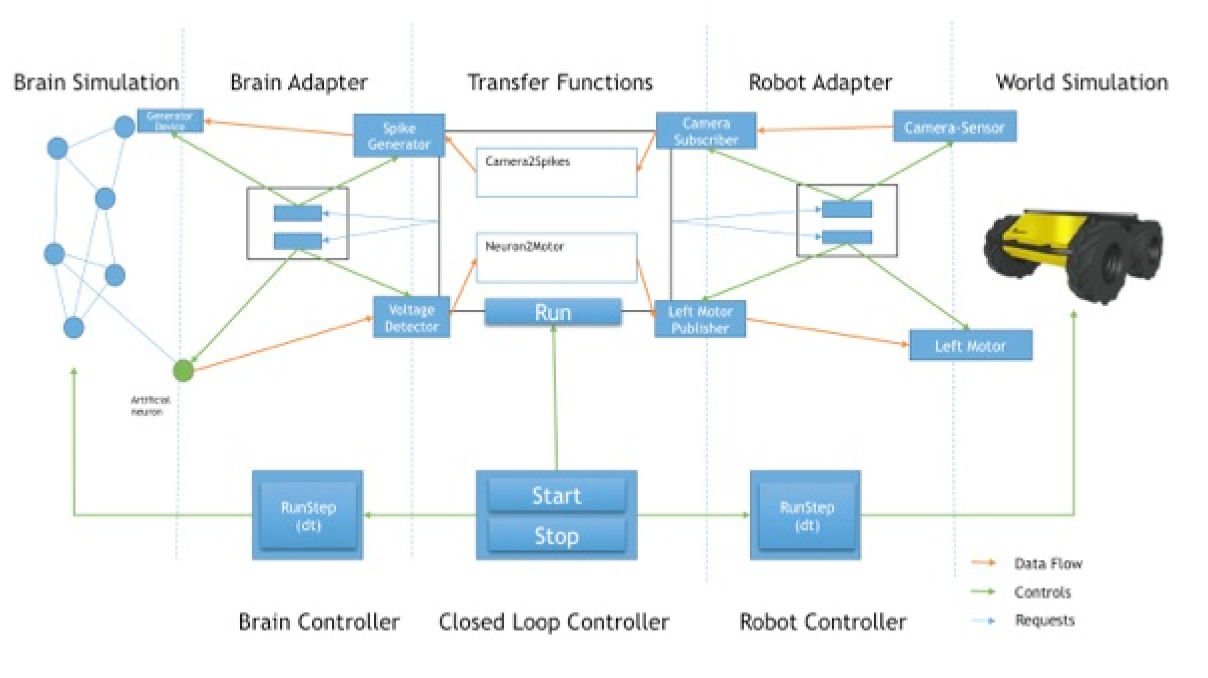


Figure 9: Transfer function architecture. The transfer functions make the link between the neural simulator (on the left) and the world simulator (on the right)

These connections are then used during the simulation to transfer data from the sensors of the virtual robot to the desired parts of the brain model and from the brain model back to the actuators of the virtual robot. When the experiment is being designed, BIBI is used to specify the connections between the brain model and the robot's actuators and sensors. During the simulation, the Closed-Loop Engine will transfer the appropriate data between the Brain Simulation Engine (e.g. NETSIM) and the World Simulation Engine. So-called "transfer functions" offer the user a programmatic framework to transform the data that is exchanged between brain and robot model (see SP 10 Specification Document). For example, transfer functions are a way to translate spikes and current coming from a neural simulation into the physical signals for robot servo-motors or activation signals for abstract muscle models. Since this framework presented many conceptual challenges to the Neurorobotics team, it was a focus of the team's work during the first few months.

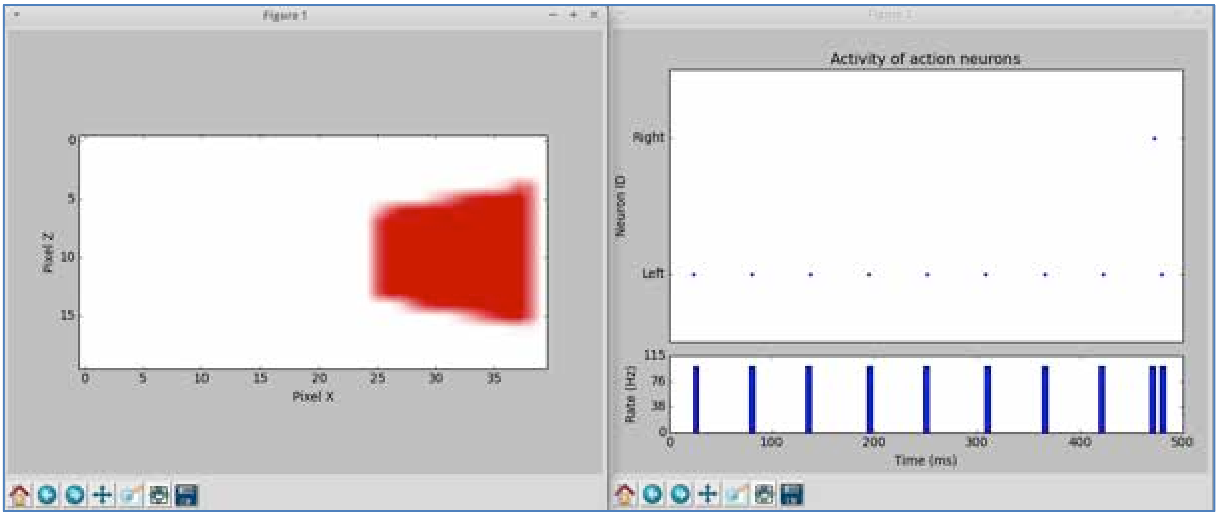


Figure 10: First implemented brain to body and body to brain interface. On the left, the view from the robot camera where the red colour is extracted (representing the virtual screen). On the right, 2 action neurons indicating which robot wheel to action

The next step in advancing the BIBI is to work with SP6 (Brain Simulation) and SP5 (Neuroinformatics) on selection tools for neuron populations or whole brain regions. These tools will allow users to query or select neurons from a given brain model (such as the neocortical microcircuit) and to connect them to transfer functions. BIBI will also be integrated into the Unified Portal.

During prototyping of the virtual room environment, the development team successfully implemented a simple neural controller, able to navigate the Husky robot toward a virtual screen, when it was showing a red image. This prototype also successfully integrated all the tools that are part of the Closed-Loop Engine: Gazebo, ROS (Robot Operating System, more on this in section TODO) and NEST.

3.2 Environment and Experiment Designer (WP10.6)

3.2.1 Environment Designer

The Environment Designer allows users to design virtual environments for interactions with simulated robots in the context of virtual experiments. The user can either refer to a library of pre-build parts and design primitives, or design new objects by specifying their appearance and their physical properties.

With the choice of Gazebo, the SP10 development team also adopted the open Simulation Description Format (SDF) from the Gazebo project. SDF has the advantage of being modular, which allows the different parts of a virtual environment to be stored in separate files. Moreover, the user can construct his environment from existing 3D models, e.g. taken from well-known online resources such as Sketchup Warehouse. In fact, the internal representation of 3D meshes is decoupled from the SDF format and well known formats such as OBJ or Collada can be used. Thus, the Neurorobotics Platform effectively supports different 3D mesh formats, which in turn allow the user to design the parts and assets for his environment using a variety of well-established modelling tools.

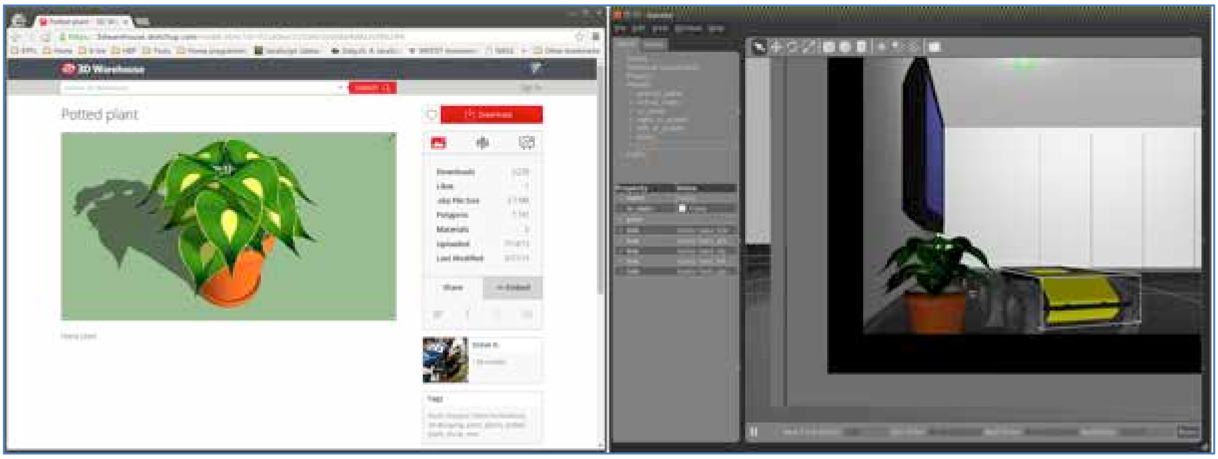


Figure 11: Example of a 3d plant model taken from Sketchup Warehouse and integrated in Gazebo

Blender is a powerful, open-source modelling tool, which the development team used to design the virtual room including the lamp, the screens, and other details inside it. Blender allows experienced users to edit the detailed appearance and properties of objects.

During the next few months, the team will adapt the Environment Designer for inexperienced users. The plan is to implement it as a web application running within the Unified Portal. In parallel, the team will continue to model environments, such as the virtual room, that will be directly available for users.

3.2.2 Experiment Designer

The Experiment Designer will enable users to design neurorobotics experiments. The Experiment Designer therefore links all Neurorobotics Platform design tools together and generates the configuration for the World Simulation Engine.

In recent months, the development team completed the architectural plans for the experiment designer, based on many different use cases. Moreover, mock-ups of the most important user-interface parts have been created. An implementation plan is available and the first version of the designer will be developed between Month 12 and Month 15.

In the current plan, the Experiment Designer will offer an interface similar to that of animation and movie editors. A 3D view of the environment helps users to select objects in the virtual scene. A time-line allows users to specify the schedule (protocol) of the experiment. By drag-and-drop operations, the user can combine object properties and connect them to predefined actions. The resulting events are then visible in the timeline, where they can be conveniently scheduled. Interactions with the mouse or the keyboard are set up by dragging objects in a specific work space where connections with buttons and key stroke can be edited in an intuitive way.

The Experiment Designer consists of a backend server and a web front end. The web front end offers the users an intuitive drag-and-drop interface and will be integrated in the Unified Portal.

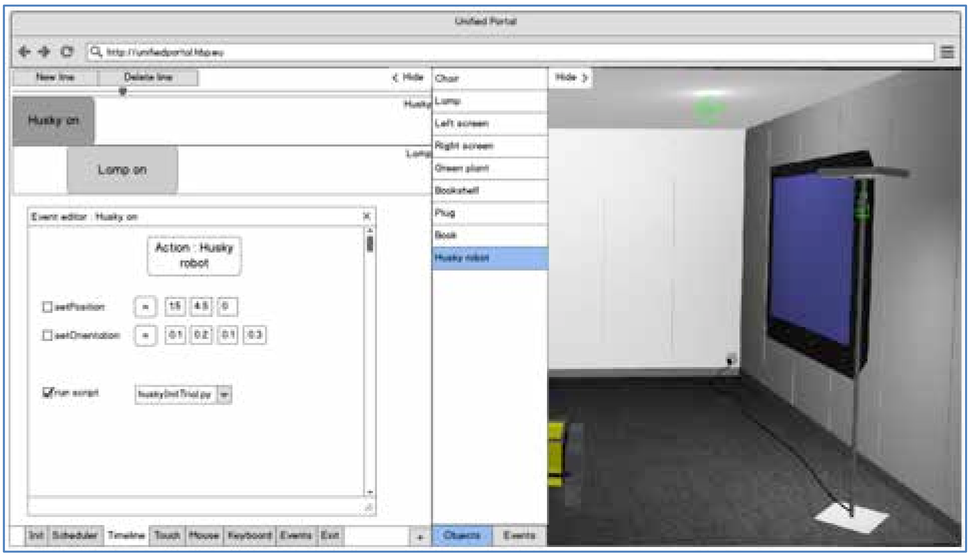


Figure 12: Mock-up of the UI for the Experiment Designer: Editing actions and placing them on a timeline

3.3 Closed-loop Engine, World Simulation and Experiment Simulation Viewer (WP10.7)

3.3.1 Closed-Loop Engine

The Closed Loop Engine (CLE) connects the brain simulation, the world simulation and the Experiment Simulation Viewer during the experiment. The CLE appears when the user pushes the play button and after the experiment has been properly defined in the various designers (Robot Designer, Environment Designer, Experiment Designer and Brain Interfaces and Body Integrator).

In the context of robotics and neural simulations, the tasks of the CLS are solved by middleware. The Neurorobotics team therefore started by evaluating different robotic middleware systems, to find the most appropriate one for the Neurorobotics Platform. Among those evaluated were ROS (Robotic Operating System), YARP (Yet Another Robotic Platform) and Chromosome. The winning middleware was ROS, mainly due to the number of tools that it offers and also its native support for Gazebo.

Connecting the robotic middleware to a neural simulation was the next challenge the team took. A number of parameters make this task difficult:

- The Neurorobotics Platform not only needs to support a wide range of simulators from NEST (point neuron) to NEURON (detailed), but also neuromorphic hardware like the SpiNNaker from SP9.
- The neural simulators will run on distributed, high-performance platforms. The middleware will therefore need to interact with several compute nodes.
- The neural simulation needs to be synchronised with the World Simulation Engine.

In the neural simulation world, the Multi Simulator Coordinator MUSIC, developed in Stockholm, offers part of this functionality and was accordingly evaluated for its applicability to the Neurorobotics Platform. However, MUSIC relies on MPI and its functionality overlaps largely with ROS. Since ROS is needed to interface to physical robots, the Neurorobotics team decided to develop its own interface layer to communicate with the neural simulators.

Development of the CLE will continue over the next few months. To test the CLE, the Neurorobotics team is thinking of employing neural control networks of increasing complexity.

3.3.2 World Simulation

The World Simulation Engine (WSE) is responsible for simulating the virtual environment with the robot, based on its physical properties (e.g. mass, friction, material properties) and its interactions with the environment and the user (for example, robot actions or experimenter interventions). The WSE interprets the specification provided by the Experiment Designer and computes the physical processes in the virtual environment during a desired time interval. The resulting data can then be used by other components to visualise the simulation.

Currently, the WSE is provided by Gazebo, a modular open-source simulation platform for robotics. Its technical capabilities and its user and developer communities made it the best open source candidate for the Neurorobotics Platform. The modularity of Gazebo allowed our development team to choose and use the most appropriate physics engine for our needs. For example, the requirements for the Neurorobotics Platform state that fine tactile sensing should be available for the robots. This is mostly useful for biologically inspired models such as the mouse model. The team successfully extended, in prototype form, one of the physics engines of Gazebo to implement this feature.

The next challenge for the WSE will be to measure how it handles highly complex robot models. Depending on the results, the team will have to make the code base scalable for the High Performance Computing Platform.

3.3.3 Experiment Simulation Viewer

The Experiment Simulation Viewer is the central interface component for the user during the execution phase. It should provide a convenient view and offer a coherent user experience during the simulated experiment.

So far, the Neurorobotics team has focused on the online scenario with high-fidelity rendering on multi-screen displays, such as the EPFL display wall, which has 12 full HD monitors. Once we are able to visualise an experiment using this setup, moving toward a CAVE setup or any other multiple screens setup should be just be a matter of configuration.

The team recently achieved this goal, using the same software stack (Equaliser framework) as the SP7 visualisation team. Compatibility with future HBP visualisation resources is therefore ensured. Moreover, this goal initiated a collaboration between SP10 and SP7 that will extend to other topics in the following months.

Figure 13: The virtual room experiment running on the EPFL display wall. The display wall is composed of twelve full HD monitors

The web viewer for the Experiment Simulation Viewer has also been specified. The technologies that will be used are fully compatible with the unified Common guidelines Common guidelines portal and the development will start soon within the portal. Moreover, both, the web viewer and the high-fidelity viewer use the same rendering system Open Scene Graph (OSG) to describe 3D scenes.

Annex A: Milestones

No.	Milestone Name	WP	Month Due	Month Achieved	See Page
M192	Software requirements for Neurorobotics Toolkit, Neurorobotics Cockpit and Neurorobotics Platform.	10.1	6	6	
M197	Documentation requirements.	10.3	6	6	
M193	Implementation specification for Neurorobotics Toolkit and for the Neurorobotics Cockpit.	10.2	12	12	
MS296	Robot Designer and Brain Interfaces & Body Integrator: Implementation Specification	10.5	12	12	
MS300	Environment Designer and Experiment Designer: Implementation Specification	10.6	12	12	
MS304	Closed-Loop Engine, World Simulation and Experiment Simulation Viewer: Implementation Specification	10.7	12	12	

Annex B: Glossary

CLE	Closed Loop Engine. A software system that orchestrates the different simulation tools involved in a Neurorobotics simulation
WSE	World Simulation Engine. A software system that simulates the physics and user interactions of the virtual robot and its environment