The EU's Human Brain Project (HBP) Flagship – Accelerating brain science discovery and collaboration

(Extended Abstract)

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Abstract. The human brain has a multi-level organisation and high complexity. New approaches are necessary to decode the brain with its 86 billion nerve cells, which form extensive networks. Ultra-high resolution models of the brain pose massive challenges in terms of data processing, visualisation and analysis. The Human Brain Project creates a cutting-edge European infrastructure to enable cloud-based collaboration among researchers from different disciplines around the world. The infrastructure includes development platforms with databases, workflow systems, petabyte storage. New technologies, including neuromorphic computing and robotics are being developed. Neuroscientists and ICT-specialists collaborate in a co-design process, based on neuroscientific use cases, to develop such infrastructure, thus opening new perspective to decode the human brain.

Keywords: data analytics, data management, future computing, neuroinformatics, neuroscience.

1 Introduction

The human brain has a highly complex, multi-level organisation. New approaches are necessary to decode the brain with its 86 billion nerve cells, which form complex networks – a challenge that is addressed by the Human Brain Project (1). E.g., 3D Polarized Light Imaging (2) elucidates the connectional architecture of the brain at the level of axons, while keeping the topography of the whole organ; it results in data sets of several Petabytes per brain, which should be actively accessible while minimizing their transport. Thus, ultra-high-resolution models pose massive challenges in terms of data processing, visualisation and analysis.

High-resolution data obtained in post-mortem brains supplement information about structural and functional connectivity as obtained, e.g., by Magnetic Resonance imaging, acquired from the living human brain, but with lower spatial resolution. By bringing together different aspects of connectivity in one and the same atlas, it is feasible to combine the advantages of the different approaches, and to address the different spatial (and temporal) scales.

2 The Human Brain Project

The Human Brain Project is developing a new European research infrastructure. Part of it is the HBP atlas. It integrates information from multiple levels of brain organisation including cellular architecture, connectivity, molecular and genetic maps, as well results from neuroimaging and physiological studies. This atlas is a resource for empirical research, but also modeling and simulation. To represent microscopical data, it includes the Big Brain as one of its templates (3).

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The HBP infrastructure will enable cloud-based collaboration among researchers coming from different disciplines around the world. To achieve this, research platforms include databases, workflow systems, petabyte storage, and supercomputers, to address the requirements of the different users.

3 Project Structure

The core project involves 117 institutions and 500 researchers from 19 countries. It is organized in 12 Subprojects. Neuroscience Subprojects include: Mouse Brain Organization, Human Brain Organization, Systems and Cognitive Neuroscience and Theoretical Neuroscience. Activities in these Subprojects provide insights across all levels of brain organization: They will be more and more linked and integrated into comprehensive models, and tested by simulation.

Big data analytics and simulation are highly challenging and data intensive. Therefore, the Human Brain Project embraces ICT solutions. These include cloud-based collaboration and development platforms, with databases for metadata and provenance tracking, as well as data analytics and compute services, right up to leading-edge supercomputers, neuromorphic systems (4), and virtual robots (5). Research and development in these areas is organized in six Subprojects, forming research platforms: Neuroinformatics, Simulation, High Performance Analytics and Computing, Medical Informatics, Neuromorphic Computing, and Robotics. In addition, Management and Ethics & Society form two Subprojects.

The main IT service infrastructures is represented by the Neuroinformatics Platform (NIP) and the High-Performance Analytics and Computing Platform (HPAC). Data from patients are being collected and analysed in the Medical Informatics Platform (6). The

so-called COLLAB provides a connection between the Platforms, and a uniform entrance point. As a part of the NIP it serves as the main collaboration infrastructure.

The development of the platforms is guided by co-design projects where neuroscientific investigators and IT specialists collaborate. After the Ramp-up phase of the HBP from 2013 to 2016, the platforms were released in March 2016, can be accessed by test-users: https://www.humanbrainproject.eu/en/.

The NIP is conceptualized in such a way, that researchers from other countries can share their data, tools and expertise, to decode the human brain. This includes also collaboration with other brain initiatives (7).

4 Supercomputing

To obtain the means needed to address the incredible complexity of the brain, the neuroscience community will need to become a competitive player on high-end supercomputers and systems for big-data analytics. The HPAC aims to provide the Human Brain Project and in extension the neuroscience community with High Performance Computing systems geared towards the particular needs of neuroscientists.

Four European Tier 0 supercomputer centers currently are members of the consortium of the HBP: the Barcelona Supercomputing Centre (BSC) in Spain, the Consorzio Interuniversitario per le Applicazioni di Supercalcolo per Università e Ricerca (CINECA) in Italy, the Centro Svizzero di Calcolo Scientifico (CSCS) in Lugano, Switzerland, and the Jülich Supercomputing Centre (JSC) in Germany.

At the JSC, two new pilot systems for an interactive supercomputer have been obtained as the result of the "Pre-Commercial Procurement": JULIA, developed by Cray, and JURON from IBM and NVIDIA. These systems are specifically designed for data-intensive analytics and simulation applications in the neurosciences.

5 Teaching

The convergence of neuroscience and ICT that the Human Brain Project envisions in the long run depends on training a new generation of young researchers to be fluent in both areas. To this end, the HBP Education Programme offers online courses, advanced HBP Schools, an annual HBP Student Conference and Young Researchers Events.

All educational offers are made available through its website: https://education.humanbrainproject.eu/web/hbp-education-portal

References

[1] Amunts K, Ebell C, Muller J, Telefont M, Knoll A, Lippert T.: The Human Brain Project: Creating a European research infrastructure to decode the human brain. Neuron 2016; 92 (3): 574–81 doi: 10.1016/j.neuron.2016.10.046

[2] Axer M, Amunts K, Grässel D, Palm C, Dammers J, Axer H, Pietrzyk U, Zilles K.: A novel approach to the human connectome: Ultra-high resolution mapping of fiber tracts in the brain. Neuroimage 2011; 54: 1091–101. doi: 10.1016/j.neuroimage.2010.08.075

[3] Amunts K, Lepage C, Borgeat L, Mohlberg H, Dickscheid T, Rousseau MÉ, Bludau S, Bazin PL, Lewis LB, Oros-Peusquens AM, Shah NJ, Lippert T, Zilles K, Evans AC.: BigBrain – an ultra-high resolution 3D human brain model. Science 2013; 340: 1472–5 doi: 10.1126/science.1235381

[4] Friedmann S, Schemmel J, Grubel A, HArteil A, Hock M, Meier K.: Demonstrating hyrid learning in a flexible neuromorphic hardware system. IEEE Trans Biomed Circuits Syst 2017; 11 (1):128-142 doi: 10.1109/TBCAS.2016.2579164. Epub 2016 Sep 9

[5] Falotico E, Vannucci L, Ambrosano A, Albanese U, Ulbrich S, Vasquez Tieck JC, Hinkel G, Kaiser J, Peric I, Denninger O, Cauli N, Kirtay M, Roennau A, Klinker G, Von Arnim A, Guyot L, Peppicelli D, Martínez-Cañada P, Ros E, Maier P, Weber S, Huber M, Plecher D, Röhrbein F, Deser S, Roitberg A, van der Smagt P, Dillman R, Levi P, Laschi C, Knoll AC, Gewaltig MO.: Connecting artificial brains to robots in a comprehensive simulation framework: The Neurorobotics Platform. Front Neurorobot. 2017 Jan 25;11:2. doi: 10.3389/fnbot.2017.00002. eCollection 2017

[6] Frackowiak, R, Markram, H: The future of human cerebral cartography: a novel approach. Philos Trans R Soc Lond B Biol Sci. 2015 May 19; 370(1668): 20140171. doi: 10.1098/rstb.2014.0171

[7] Vogelstein, J. T. & Neuro Cloud Consortium: To the Cloud! A Grassroots Proposal to Accelerate Brain Science Discovery. Neuron. 2016 Nov 2;92(3):622-627. doi: 10.1016/j.neuron.2016.10.033