

A 3D Atlas of Brain Connections

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BraDiPho is an innovative tool for the study of white matter connections in the human brain. A realistic map developed by a group of researchers from the University of Trento, the Provincial Healthcare Service of Trento, Fondazione Bruno Kessler and the Universities of Bordeaux and Sherbrooke. Their study was published today in Nature Communications

The published paper reports on the results of more than 5 years of collaboration and introduces a new instrument that the scientific community can use to accurately integrate ex-vivo dissection and in-vivo tractography data. These two complementary techniques had never been integrated so far into the study of human white matter connections, and this confirms a new research trend, where multidisciplinary competencies converge, in this case clinical neuroscience and artificial intelligence. The study opens new frontiers for Neurosurgery in the treatment of brain tumors and the approach to degenerative neurological disorders, and in Neuro-rehabilitation to harness the potential of brain plasticity. The new instrument, called BraDiPho (Brain Dissection Photogrammetry), is the result of the joint effort of the University of Trento, the Provincial Healthcare Services of Trento (Apss) and Fondazione Bruno Kessler, in collaboration with the University of Bordeaux (France) and the University of Sherbrooke (Canada).

BraDiPho was presented in a paper published in [Nature Communications](#), with Laura Vavassori as first author. She is a doctoral student at the Center for Brain/Mind Sciences (**Cimec**) of the University of Trento with a grant funded by **Apss** through the NeuSurPlan project of the Autonomous Province of Trento, which is co-funded by Apss. Adopting an interdisciplinary approach that combines clinical neuroscience, artificial intelligence and neuroanatomy, the research work was coordinated by Silvio Sarubbo, professor at the Center for Medical Sciences (**Cismed**), **Cimec** and the Department of Cellular, Computational and Integrative Biology (**Cibio**) of UniTrento and director of the Neurosurgery Operating Unit of Santa Chiara Hospital in Trento; **Paolo Avesani**, head of the Neuroinformatics Laboratory (**NI Lab**) of the Center for [Augmented Intelligence](#) of Fondazione Bruno Kessler; and Laurent Petit, researcher at the **University of Bordeaux**. The collaboration between the Neurosurgery and Anatomical Pathology Operative Units, the latter led by Mattia Barbareschi, a professor at Cismed and the Cibio Department, played a crucial role, in particular for the laboratories and anatomical specimens that they made available.

Silvio Sarubbo explains the innovation that positions Trento as a global point of reference with an effective metaphor: the human brain is a world, and BraDiPho is a 3D map that enables professionals to identify the highways of brain functions and orient themselves with precision when preparing neurosurgical procedures or studying and teaching neuronal anatomy. This tool serves as a guide in white matter research, a field in which Italy and Europe are leaders, opening up new therapeutic perspectives both in neuro-oncology and in neuromodulation, “recognized as one of the new frontiers for the treatment of various neurological and psychiatric diseases.”

The starting point

*“Knowledge of the connecting structures of the brain is very important in the clinical setting and the scientific community is working hard to expand this knowledge,” explains **Sarubbo**. “Above all, we are trying to work in the least invasive way possible. In the past twenty years, diffusion MRI tractography has been widely used to reconstruct fiber pathways: this technology calculates the diffusion coefficient in the water within the white matter and returns a derived image. This technology, however, has some limitations and produces many false positives. It is therefore necessary to go back to basic anatomy to validate the results. So far, the only way to do this has been through microdissections, which means dissecting the tissues ex-vivo in the laboratory” (editor’s note: these are the brains donated to research).”*

Thousands of images return a 3D model

As the researchers explain, the problem so far has been the lack of a way to integrate the ex-vivo into the in-vivo space, and this was the starting point of the research. The paper, in fact, is the story of how the teams of Sarubbo and Avesani solved this problem, managing to faithfully reproduce the ex-vivo anatomy in a virtual way. They did it with BraDiPho: *“For the first time, this instrument puts an anatomical specimen in a radiological space,”* says the neurosurgeon. *“Now the ex-vivo and the in-vivo anatomy can merge, and we can make comparisons, intersect them and make quantitative measurements: in simple terms, make an evaluation that is not only qualitative (that is, visual), but also quantitative. For the first time, instead of making a single image of the dissection of the specimen, we make thousands, at different times. We are talking about thousands of photographs, taken by two very high resolution cameras that take one shot every degree across 360 degrees, from different angles, which, thanks also to artificial intelligence, become a 3D model of the anatomical specimen at very high resolution. This model can be combined with magnetic resonance imaging.”*

The role of artificial intelligence

*“Artificial intelligence,” recalls **Avesani**, “makes a decisive contribution to the individual reconstruction of brain connectivity, allowing personalized analysis of fiber networks and their anatomical variations. But we know that, particularly in the clinical setting, its results must be interpretable and explainable. Photogrammetric models of the ex-*

vivo dissection of the brain provide an essential anatomical reference, allowing clinicians to put the tractography into context, and to more consciously integrate the data generated by artificial intelligence.” “If we look at the future of personalized medicine,” continues Avesani, “one of the key challenges is to distinguish between intrinsic inter-individual differences and pathological deviations from the canonical model. Artificial intelligence is an essential tool to address this challenge, thanks to its ability to integrate and analyze multidimensional and highly complex data.”

New frontiers for surgery, clinic and teaching

So far, 12 anatomical specimens have been translated into photogrammetry and are available online free of charge for the entire scientific community at <https://bradipho.eu>. In the article, says Sarubbo, we present *“a new method of validating anatomical information and certifying it: all laboratories in the world will be able to download the anatomical dissections and the tractographic reconstructions that we have used as an example. In any Department of Neurosurgery in the world,”* he continues, *“a neurosurgeon can download the models and superimpose the tumor of the case they are going to operate on, see it in the structural context, learn its anatomy and better plan the treatment strategy.”* A true map that will guide the hands of neurosurgeons through functional systems without the risk of damaging them. *“It is a true atlas of the brain, a resource to compare the ex-vivo and the in-vivo and substantially reconstruct the real anatomy, and it is very useful to plan and study the procedures, but also to teach future doctors and specialists. We have already used the tool for this purpose at the University of Trento for the course of Anatomy of Brain Functions.”*

But knowing exactly how the human brain is made also means being able to act on other fronts: *“This technology goes beyond the academic environment. It also means being able to make surgical decisions; from a clinical point of view, for example in the treatment of some neurological disorders, it is very helpful to know which part of the brain degenerates first and where to intervene to regenerate, stimulate, or neuromodulate. Neuromodulation is the new frontier in the treatment of various neurological diseases, such as movement disorders like Parkinson’s disease. The treatments in these cases involve, for example, the stimulation of deep brain structures. However, many aspects of their connection with the rest of the human brain have yet to be explored in order to further improve therapeutic outcomes. The important thing is to know what needs to be modulated, to be able to intervene in a precise manner. BraDiPho helps us with this.”*

(m.r.)

“Brain dissection photogrammetry: a tool for studying human white matter connections integrating ex vivo and in vivo multimodal datasets” has been published in [Nature Communications](https://doi.org/10.1038/s41467-025-64788-y):
<https://doi.org/10.1038/s41467-025-64788-y>

References: Laura Vavassori, François Rheault, Erica Nocerino, Luciano Annicchiarico, Francesco Corsini, Luca Zigiotto, Alessandro De Benedictis, Mattia Barbareschi, Umberto Rozzanigo, Paolo Avesani, Silvio Sarubbo, Laurent Petit.

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- Link to BraDiPho website - Interactive navigation3D visualisation with BraDiPho: <https://bradipho.eu/>
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