CSS/ITALY
ITALIAN CHAPTER OF COMPLEX SYSTEMS SOCIETY

Contribution ID: **154** Type: **not specified**

Machine-enhanced reconstruction of functional connectomes unravels discriminative brain sub-systems in health and disease

Tuesday 16 September 2025 10:50 (20 minutes)

The human brain is a complex system of 100 billion neurons, each one connected on average to 10,000 other neurons to exchange
electrochemical information. It is possible to coarse-grain this system by considering the average activity of large neuronal aggregates
into Regions of Interest (ROIs), acting as fundamental areas in functional Magnetic Resonance Imaging (fMRI), and their co-activation
patterns, providing a map of the underlying functional connectivity. The main difficulties with this approach relate to the choice of the
statistical technique and arbitrary thresholds for pruning the correlation network obtained from fMRI signals. Here we tackle this challenge
by switching the focus from statistical to functional pruning: instead of considering the significance of co-activation signals separately, we
consider the collective co-activation patterns of whole sub-networks to choose which links to drop. Being a hard combinatorial problem,
we boost the search for solutions by means of geometric deep learning coupled to a suitable explainer. Using fMRI data from healthy and
ASD subjects, we build multilayer network representations from a multi-frequency decomposition of the signals and provide robust evidence
that the machine-learned sub-systemic co-activation patterns significantly improve the identification of affected individuals. Our results
demonstrate how functional pruning —which is based on collective, rather than individual, co-activation patterns —provides mechanistic
insights that can be reliably used to characterize brain disorders, at variance with statistical pruning. Our approach —depicted in Figure 1
—is general and can be applied to find task-based biomarkers, as we demonstrate in panel H, where ASD-affected subject show, for
instance, a significant increase in the connectivity of the sub-systems related to the default mode network, which is known to be involved
in the pathophysiology of the disease.

References

[1] Manlio De Domenico, Shuntaro Sasai, and Alex Arenas. Mapping multiplex hubs in human functional brain networks. Frontiers in
Neuroscience, 10, 2016.

[2] Jared A Nielsen, Brandon A Zielinski, P Thomas Fletcher, Andrew L Alexander, Nicholas Lange, Erin D Bigler, Janet E Lainhart,
and Jeffrey S Anderson. Multisite functional connectivity mri classification of autism: Abide results. Frontiers in human neuroscience,
7:599, 2013.

Presenter: GRASSIA, S.

Session Classification: Session 5