IA: tecnologie, applicazioni e prospettive in campo biomedicale

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The AI & robotics revolution

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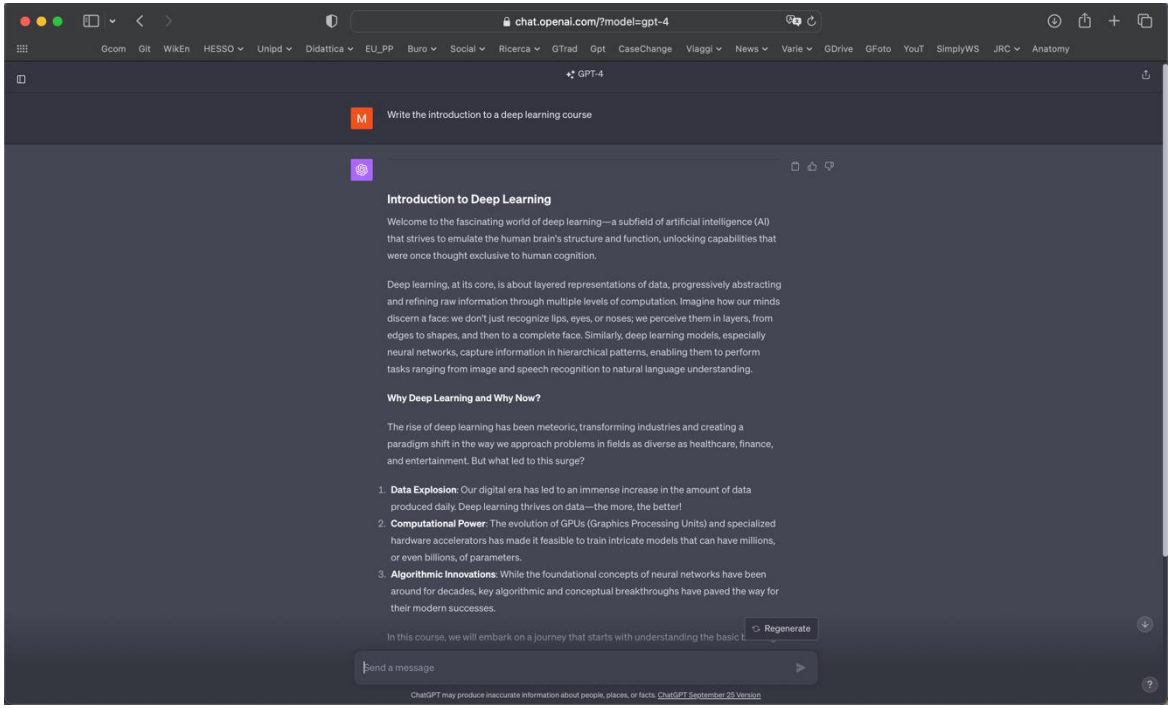
AI tools for everyone

- How many of you played a bit with ChatGPT?



AI tools for everyone

- How many of you played a bit with MidJourney?

21st Century: will it be the century of AI & robotics revolution?

- For science fiction? Sure.

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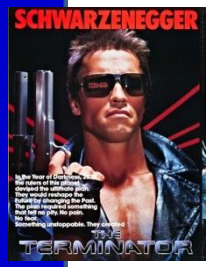
- For science fiction? Sure.
- According to some results? Probably.

21st Century: will it be the century of AI & robotics revolution?

- For science fiction? Sure.
- According to some results? Probably.
- According to some other results… maybe not.



The rehabilitation revolution

- It there will be an AI & robotics revolution, it will extend to medical applications


Prosthetics


Rehabilitation

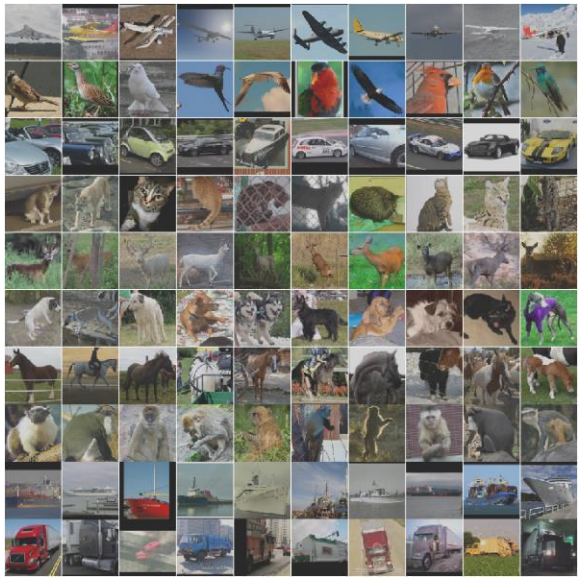

Assistive Robotics

What is artificial intelligence?

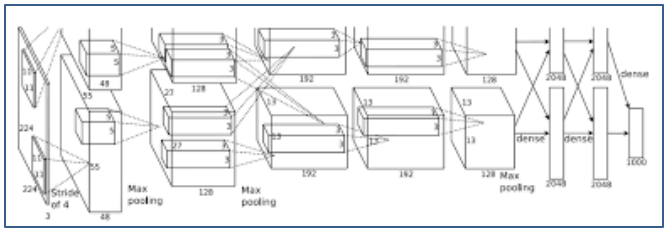
- Oxford dictionary definition:
  - Theory and development of computer systems capable of performing tasks that normally require human intelligence, such as:
    - visual perception
    - voice recognition
    - translation between languages
    - decision making
    - tactile perception
    - interaction with the surrounding environment
      - choice of a path
      - manipulation of objects
    - understanding of complex events linked by cause-effect relationships abstraction

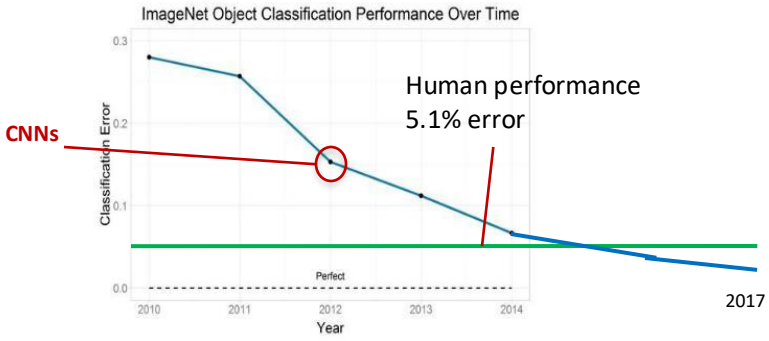
Can machines see?

Convolutional NNs: AlexNet (2012): trained on 200 GB of ImageNet Data

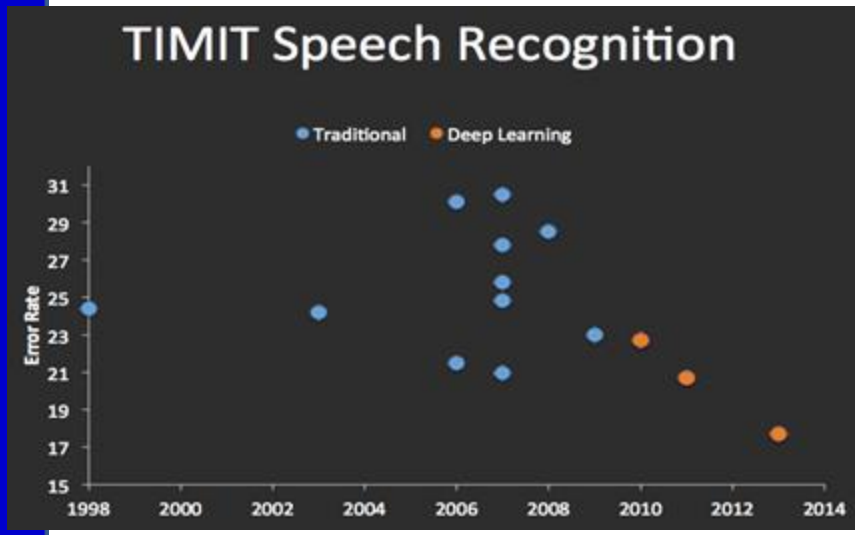


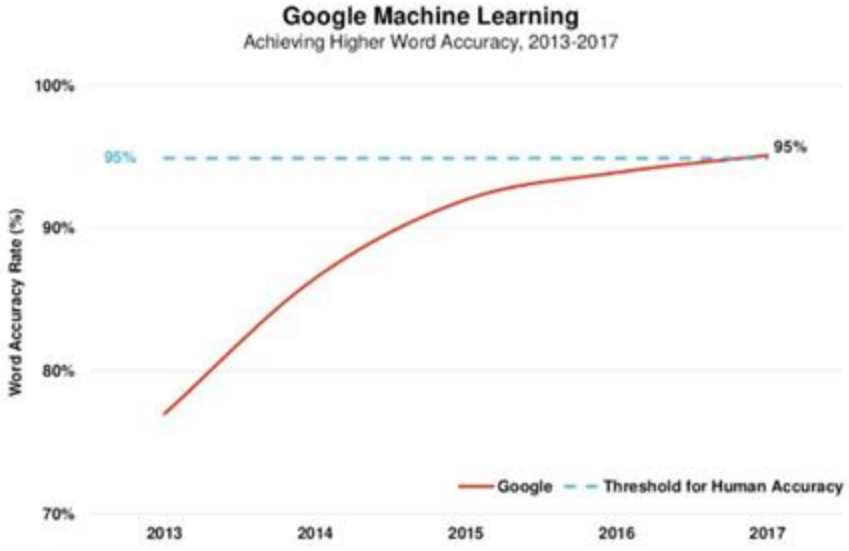
Almost a LeNet !





Can machines hear?





Risk & opportunities

- Opportunities
  - Science, engineering, entertainment, transportation, **medicine**
  - Semplification & creation of new jobs
- Risks
  - High, in several domains
    - Displacing jobs
    - Security

Multimodal learning from biomedical data

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Main research projects

• ProHand	Hasler Stiftung	1 partner	2019 - 2020
• ExaMode	EU Horizon 2020	7 partners	2019 - 2023
• MedMax	STARS@UNIPD	1 partner	2022 - 2025
• PNRR	MIUR DM 351	1 partner	2022 – 2025
• Hereditary	EU Horizon Europe	18 partners	2024 - 2027

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Funded by the European Union

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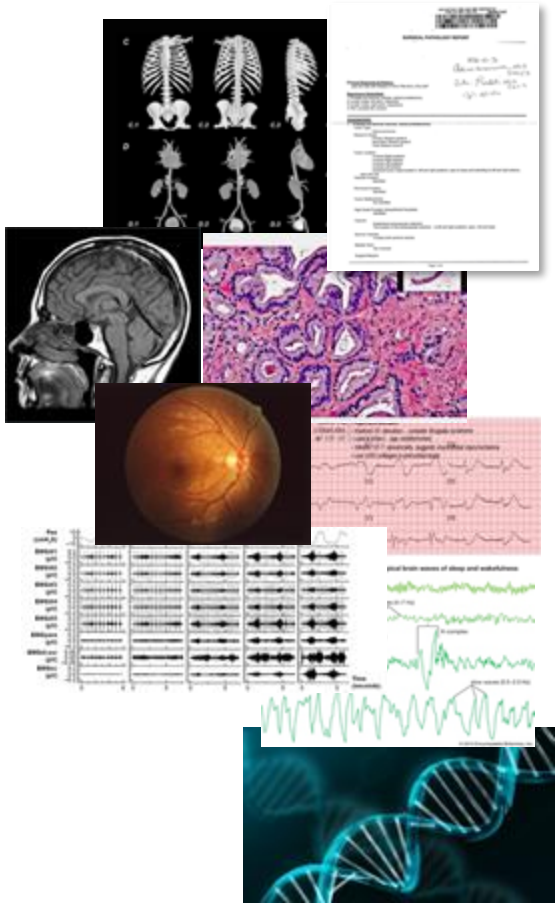
The potential of biomedical data

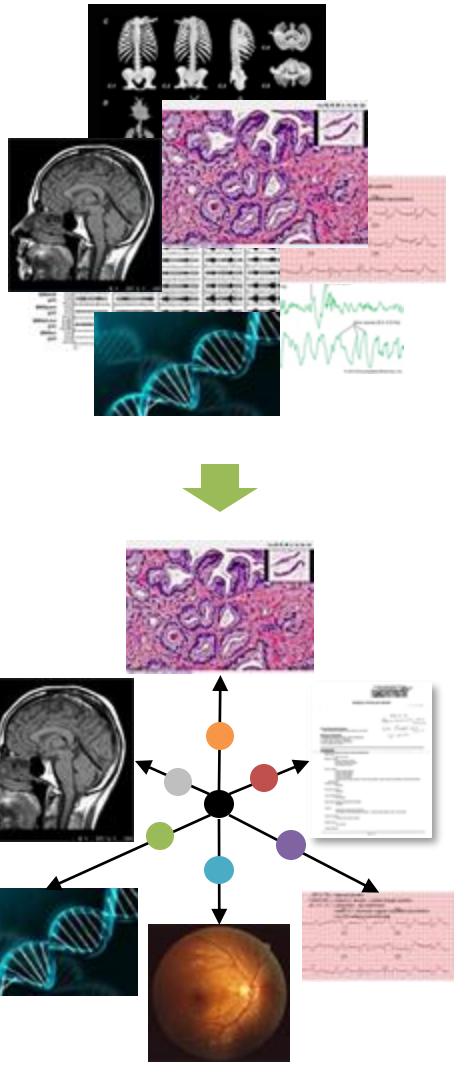
- Biomedical big data
  - Production: over 2’000’000’000 Terabytes / year
  - Included knowledge: diagnoses
  - Potential: to improve clinical practice
- Machine learning application to biomedical data
  - Reduction of diagnosis time
  - Improvement of diagnosis reliability
  - Precision medicine



Challenges

- Medical data are usually easy to understand by experts
- Medical data include unique challenges
  - Heterogeneity
  - Complexity

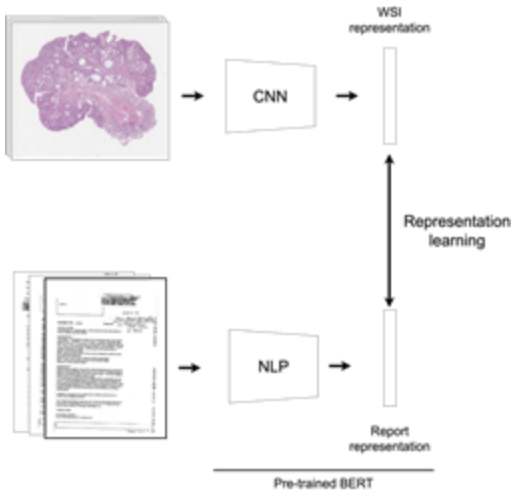
- Ambition
  - Unsupervised knowledge extraction from inter-disciplinary, heterogeneous medical data, targeting precision medicine



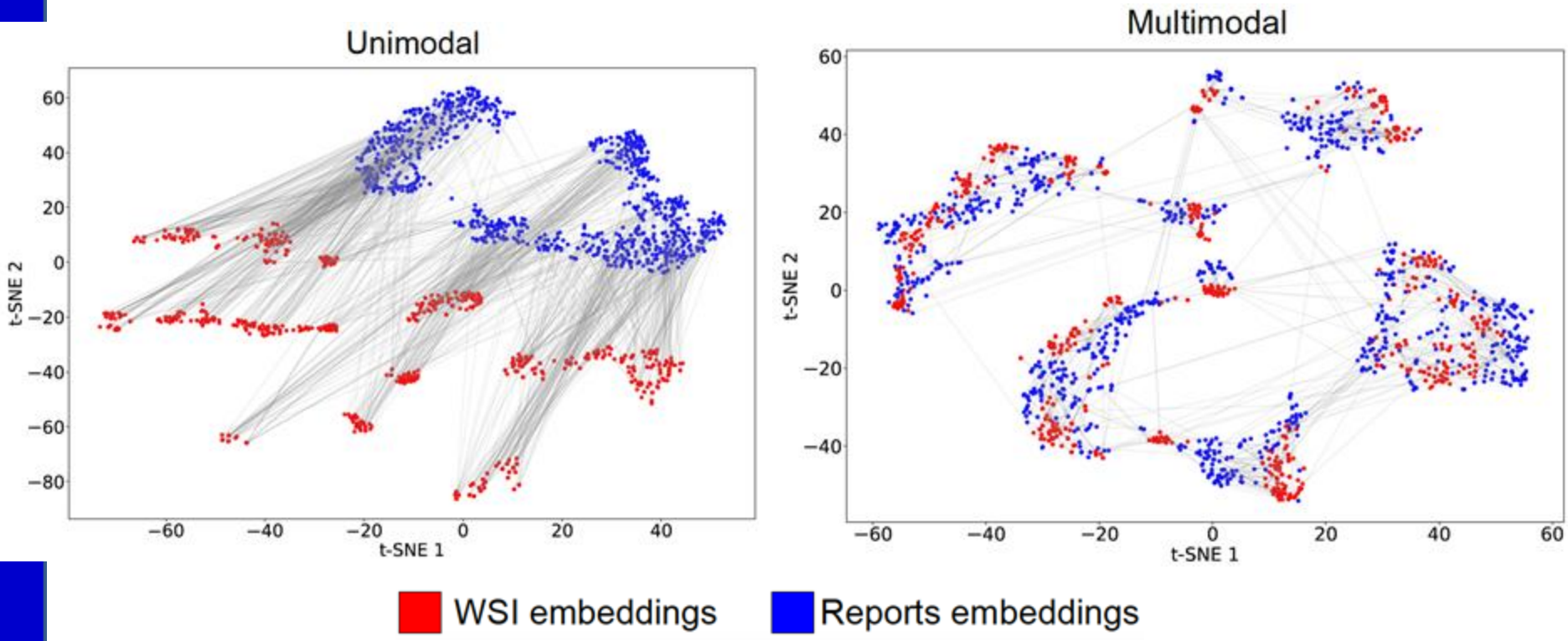
Multimodal learning

- Challenge
  - Medical experts combine multimodal data seamlessly on the basis of their experience
  - Still, this is not straightforward for machine learning algorithms

- How can multimodal learning help?
  - More robust data representations
  - Downstream tasks of different kinds
  - Visual ontologies

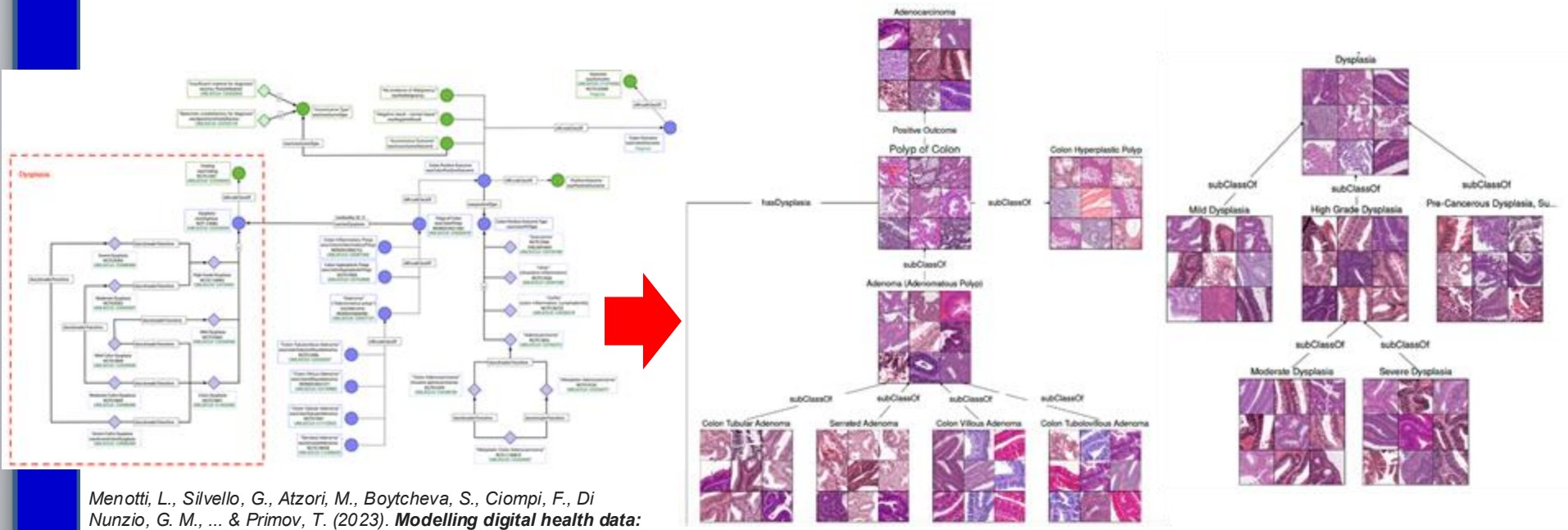


Data representation - multimodal



Marini, N., Marchesin, S., Wodzinski, M., Caputo, A., Podareanu, D., Guevara, B.C., Boytcheva, S., Vatrano, S., Fraggetta, F., Ciompi, F., Silvello, G., Müller, H. and Atzori, M. 2024. ***Multimodal representations of biomedical knowledge from limited training whole slide images and reports using deep learning****. Medical Image Analysis, 97, p.103303.*

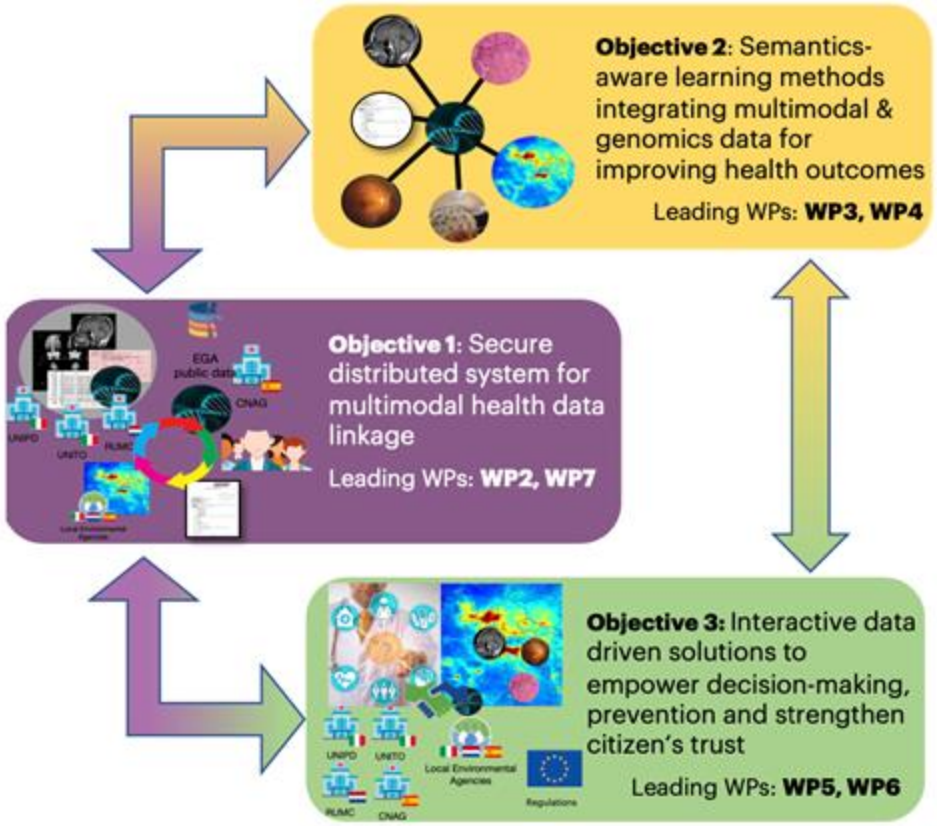
Multimodal ontologies – ExaMode EU Horizon 2020 Project



Menotti, L., Silvello, G., Atzori, M., Boytcheva, S., Ciompi, F., Di Nunzio, G. M., ... & Primov, T. (2023). ***Modelling digital health data: The ExaMode ontology for computational pathology.*** *Journal of Pathology Informatics, 14, 100332.*

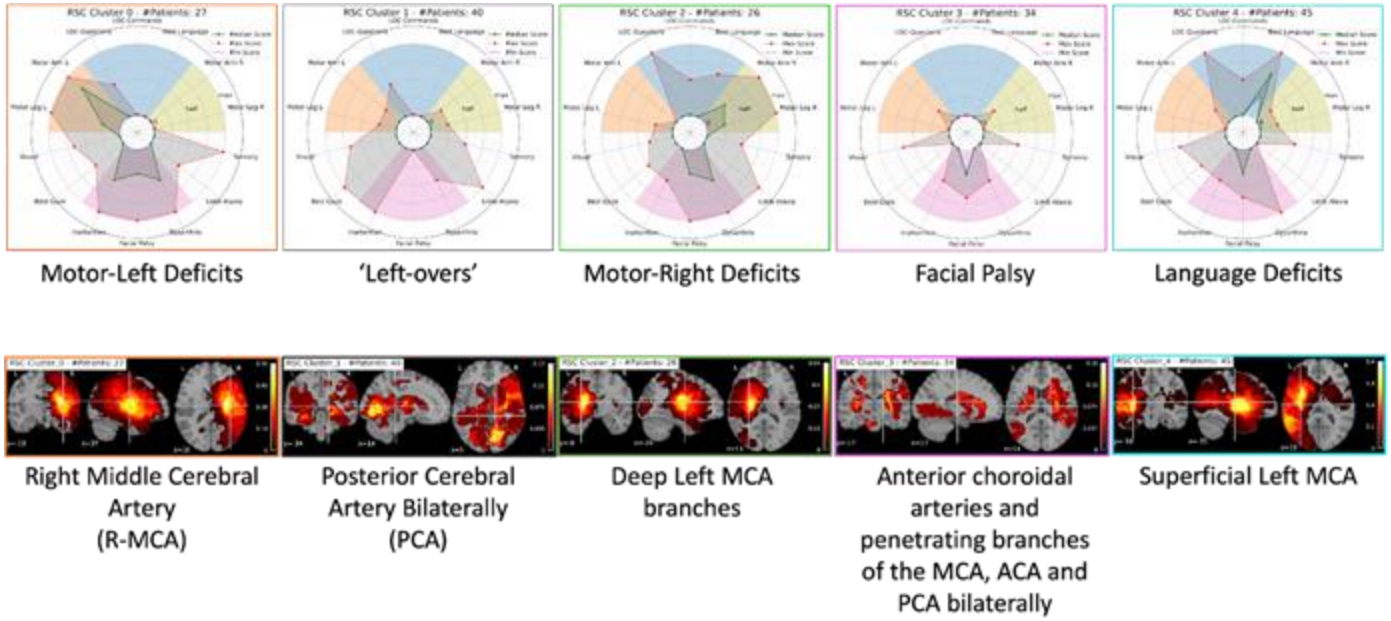
Marini, N., Marchesin, S., Wodzinski, M., Caputo, A., Podareanu, D., Guevara, B.C., Boytcheva, S., Vatrano, S., Fraggetta, F., Ciompi, F., Silvello, G., Müller, H. and Atzori, M. 2024. ***Multimodal representations of biomedical knowledge from limited training whole slide images and reports using deep learning****. Medical Image Analysis, 97, p.103303.*

HEREDITARY – Horizon Europe Project



Unsupervised learning from biomedical data: the importance of methods

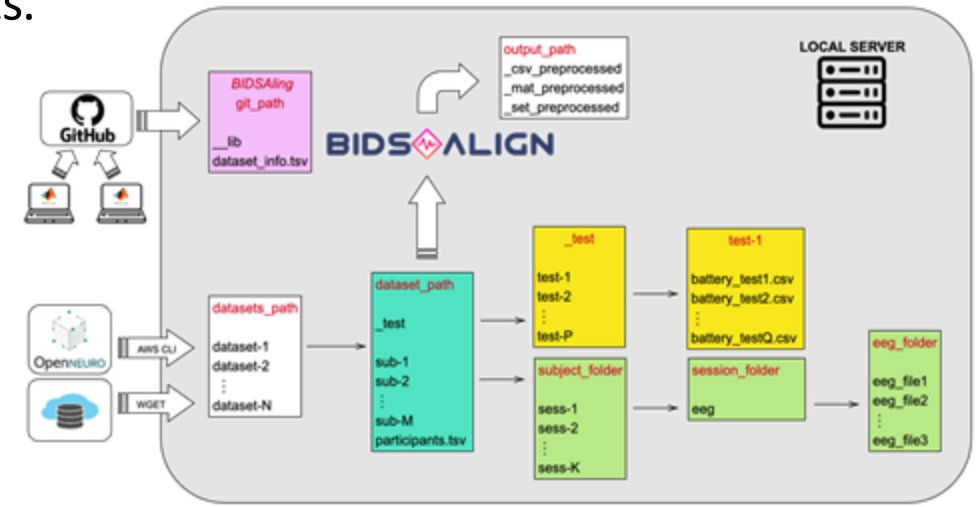
- Stroke clustering based on NIHSS



Tshimanga, L. F., Zanola, A., Porcaro, Facchini, S., Bisogno, A. L., Pini, L., Atzori, M. , Corbetta, M. (2024). Behavioral Clusters and Lesion Distributions in Ischemic Stroke, based on NIHSS Similarity Network. *Journal of Healthcare Informatics Research (under review)*.

BIDSAlign: align multiple EEG dataset

- Functionalities
  - Automatic preprocessing, with a customizable pipeline, assisted by an user-friendly GUI.
  - Unification of EEG data to a common template (IFCN 10-10 standard).
  - Data visualization for group analyses.
  - Parallel processing of datasets.
- Where
  - Open source. Source code available on GitHub.
  - Easy installation with a simple download.

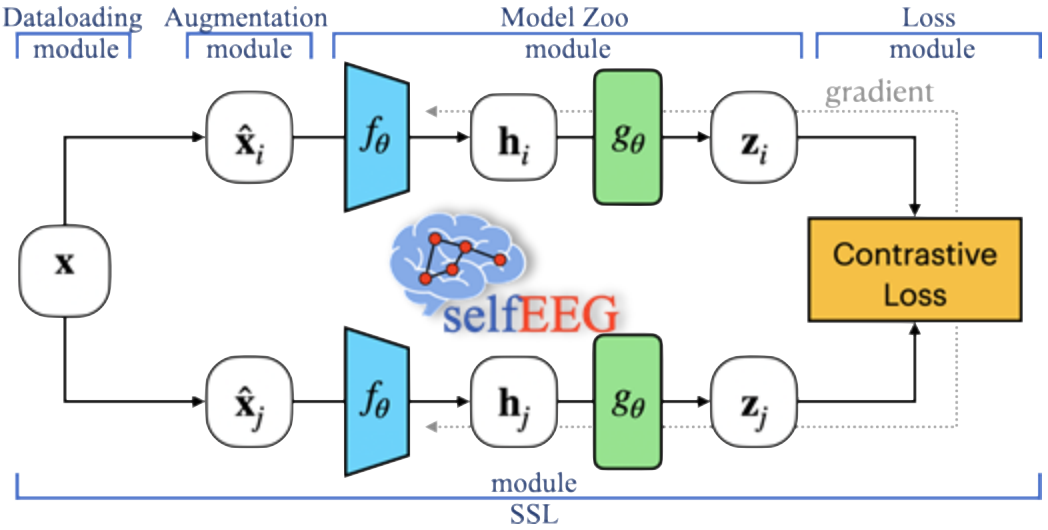


*https://github.com/MedMaxLab/BIDSAlign

Zanola, A., Del Pup, F., Porcaro, C., & Atzori, M. (2024). BIDSAlign: a library for automatic merging and preprocessing of multiple EEG repositories. *Journal of Neural Engineering*.

Self-supervised learning for EEG

- Functionalities
  - Full deployment of SSL pipelines with diverse models and approaches.
  - Record-, session-, subject-, or dataset-based splits with efficient data import.
  - EEG dedicated data augmentations.
  - GPU and MPS support for submodules.
- Where
  - Open source. Source code available on GitHub.
  - Easy installation with conda or pip.



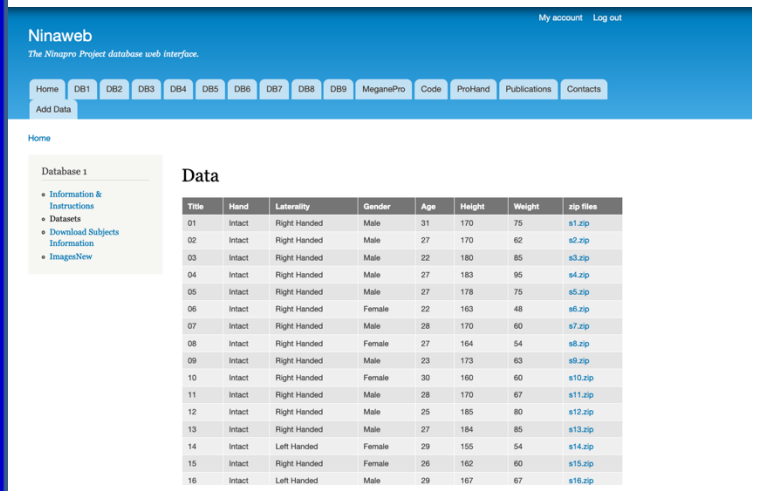
*https://github.com/MedMaxLab/selfEEG

Del Pup, F., Zanola, A., Tshimanga, L. F., Mazzon, P. E., & Atzori, M. (2024). SelfEEG: A Python library for Self-Supervised Learning in Electroencephalography. Journal of Open Source Software, 9(95), 6224.

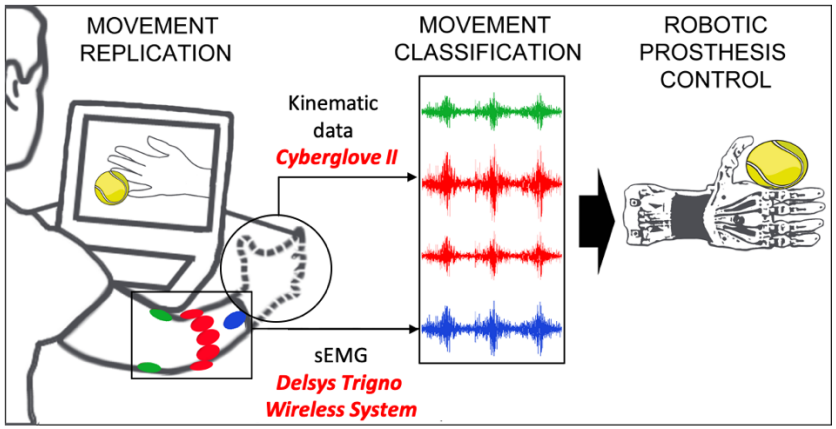
Control of bionic limbs

- Ninapro & MeganePro projects
  - HES-SO (coordinator); Zurich University Hospital; Italian Institute of Technology (IIT); Clinic of Plasti Surgery, University of Padova

- Ninapro
  - A multimodal database for hand prosthetics.
  - Over 5'000 users worldwide

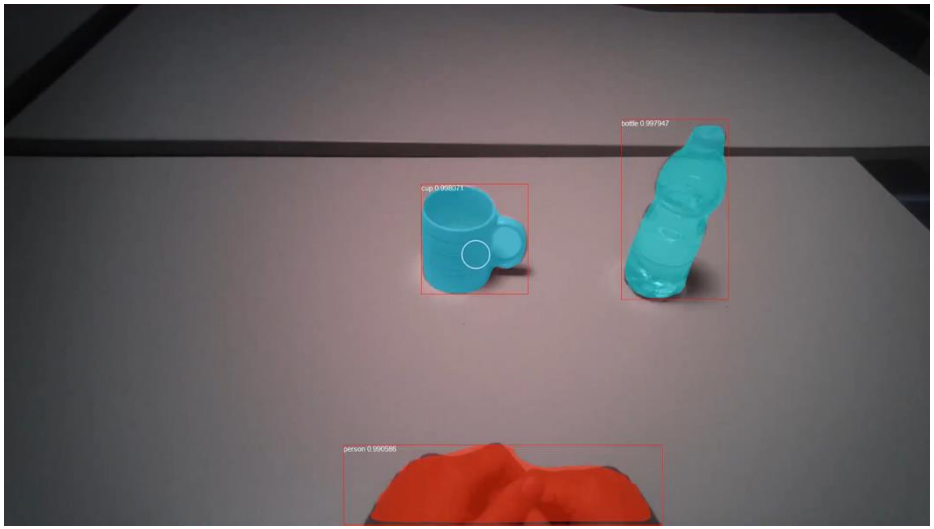


Title	Hand	Laterality	Gender	Age	Height	Weight	zip files
01	Intact	Right Handed	Male	31	170	75	s1.zip
02	Intact	Right Handed	Male	27	170	62	s2.zip
03	Intact	Right Handed	Male	22	180	85	s3.zip
04	Intact	Right Handed	Male	27	183	95	s4.zip
05	Intact	Right Handed	Male	27	178	75	s5.zip
06	Intact	Right Handed	Female	22	163	48	s6.zip
07	Intact	Right Handed	Male	28	170	60	s7.zip
08	Intact	Right Handed	Female	27	164	54	s8.zip
09	Intact	Right Handed	Male	23	173	63	s9.zip
10	Intact	Right Handed	Female	30	160	60	s10.zip
11	Intact	Right Handed	Male	28	170	67	s11.zip
12	Intact	Right Handed	Male	25	185	80	s12.zip
13	Intact	Right Handed	Male	27	184	85	s13.zip
14	Intact	Left Handed	Female	29	155	54	s14.zip
15	Intact	Right Handed	Female	26	162	60	s15.zip
16	Intact	Left Handed	Male	29	167	67	s16.zip



Control of bionic limbs

- Megane Pro
  - Integrating eye-hand coordination in prosthetics



Cognolato et al., Scientific Data, Nature Publishing Group, 2020; Saetta et al., Scientific Data, Nature Publishing Group, 2020

Control of bionic limbs - ProHand

Integration of tools and research achivements

- **Links**
  - https://sites.google.com/view/medmaxproject/
  - https://github.com/MedMaxLab/
- **Publications**
  - Tshimanga, L.F., Del Pup, F., Corbetta, M. and Atzori, M., 2023. **An overview of open source deep learning-based libraries for neuroscience.** Applied Sciences, 13(9), p.5472.
  - Del Pup, F. and Atzori, M., 2023. Applications of self-supervised learning to biomedical signals: A survey. IEEE Access.
  - Del Pup, F., Zanola, A., Tshimanga, L.F., Mazzon, P.E. and Atzori, M., 2023. **SelfEEG: A Python library for Self-Supervised Learning in Electroencephalography.** The Journal of Open Source Software. arXiv preprint arXiv:2401.05405.
  - Tshimanga, L.F., Zanola, A., Facchini, S., Bisogno, A.L., Pini, L., Atzori, M. and Corbetta, M., 2023. **Behavioral Clusters in Ischemic Stroke based on NIHSS Similarity.** Journal of Healthcare Informatics Research (submitted; medRxiv, pp.2023-11.).
  - Zanola, A., Del Pup, F., Porcaro, C. and Atzori, M., 2024. **BIDSAlign: a library for automatic merging and preprocessing of multiple EEG repositories.** Journal of Neural Engineering, 21(4), p.046050.
  - Del Pup, F. and Atzori, M., 2024. **Toward improving reproducibility in neuroimaging deep learning studies.** Frontiers in Neuroscience, 18, p.1509358.
  - Del Pup, F., Zanola, A., Tshimanga, L.F., Bertoldo, A. and Atzori, M., 2024. **The more, the better? Evaluating the role of EEG preprocessing for deep learning applications.** IEEE Transactions on Neural Systems and Rehabilitation Engineering, (submitted; arXiv preprint arXiv:2411.18392.).

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Jacopo Lazzaro
...and many others

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