ARTIFICIAL INTELLIGENCE IN MEDICINE

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Medicine in digital age:
disruptive innovation of Artificial Intelligence

- **for clinicians, predominantly via rapid, accurate image interpretation;**
- **for health systems, by improving workflow and the potential for reducing medical errors;**
- **and for patients, by enabling them to process their own data to promote health.**

High-performance medicine:
the convergence of human and artificial intelligence

Limitations: privacy and security, and lack of transparency.

Artificial Intelligence /Cognitive computing

- **Machine learning** (supervised or unsupervised)
  - **Data mining** (used also for Natural Language Process and Images classification)
    - Classification trees (for classifying/predicting discrete outcomes, e.g. bad/good)
    - Regression trees (for continuous outcomes, e.g. cost forecasting)
    - Belief networks (learning of probabilistic models)
    - Support vectors machines (learning of mathematical models)
    - Neural networks (learning of mathematical models)
      - » **Deep learning**
    - Conditional random fields
    - Reinforcement learning
  - **Process mining**
    - temporal pattern discovery
- **Complex Network and emergent behaviour (**cognitive and physiological phenomena result from a complex series of interactions that occur hierarchically)
  - Dynamic interactions
  - Emergence

WHY NOW?

The **time is right** because of:

Sequencing of the human genome

Improved technologies for biomedical analysis

New tools for using large datasets

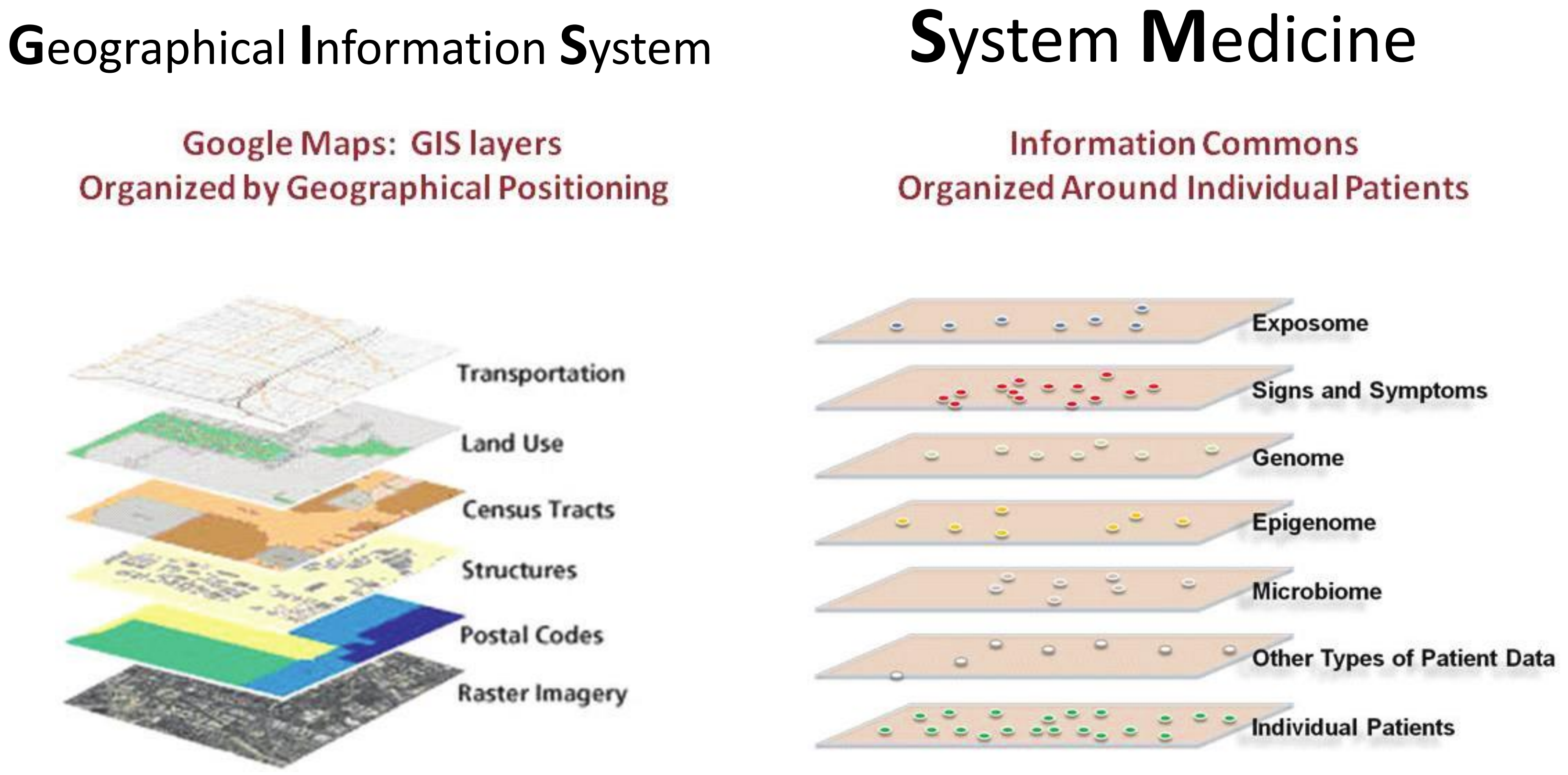
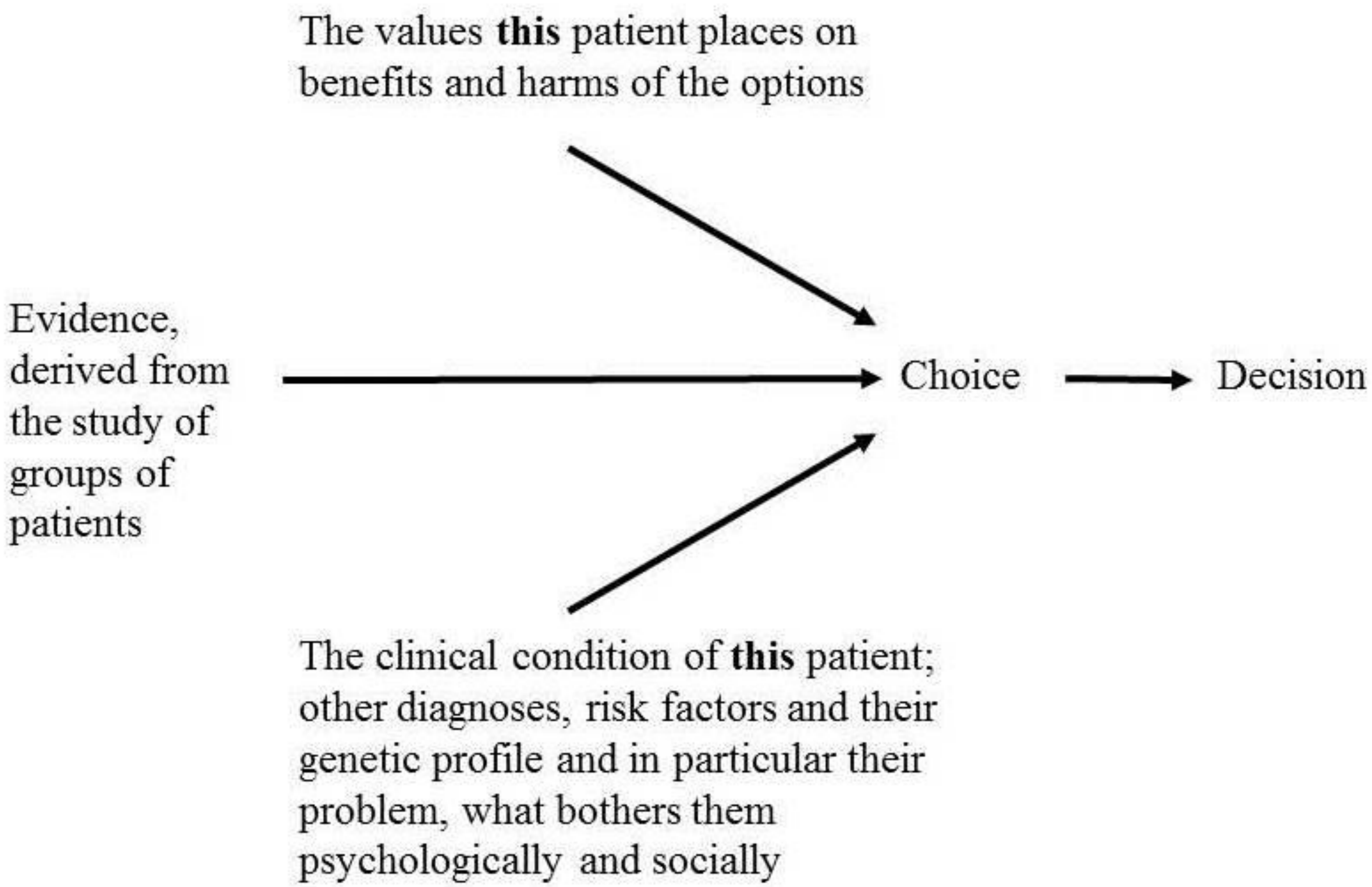


FIGURE 1-2 An Information Commons might use a GIS-type structure.
The proposed, individual-centric Information Commons (right panel) is somewhat analogous to a layered GIS (left panel). In both cases, the bottom layer defines the organization of all the overlays. However, in a GIS, any vertical line through the layers connects related snippets of information since all the layers are organized by geographical position. In contrast, data in each of the higher layers of the Information Commons will overlay on the patient layer in complex ways (e.g., patients with similar microbiomes and symptoms may have very different genome sequences).
SOURCE: FPA 2011 (left panel).

The model for personalised decision making



The Analogy between self-driving cars and medicine

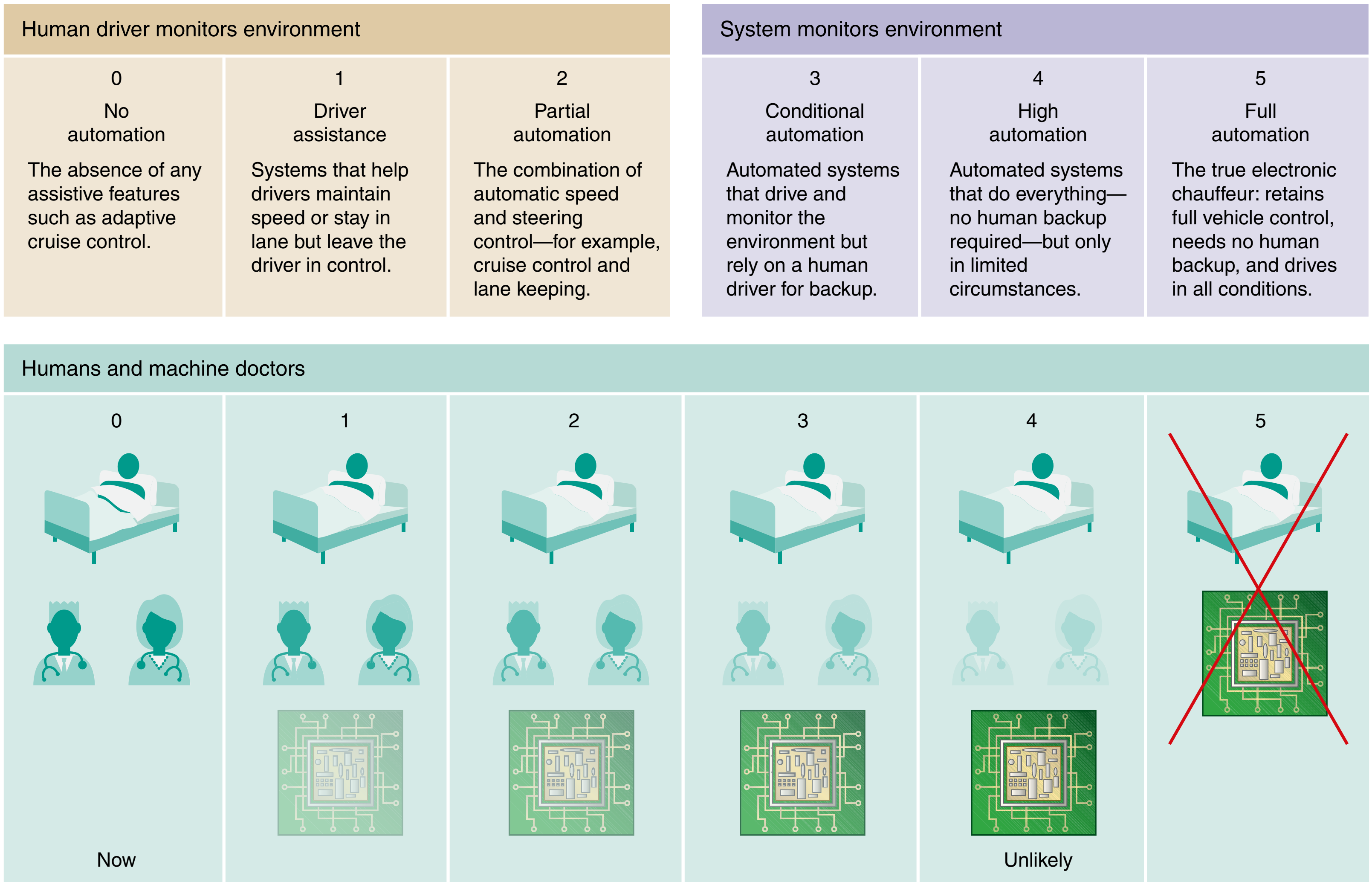


Fig. 5 | The analogy between self-driving cars and medicine. Level 5, full automation with no potential for human backup of clinicians, is not the objective. Nor is Level 4, with human backup in very limited conditions. The goal is for synergy, offsetting functions that machines do best combined with those that are best suited for clinicians. Credit: Debbie Maizels/Springer Nature

Artificial Intelligence for clinicians

- synergy of the combined pathologist and algorithm interpretation
- 2018- US Food and Drug Administration (FDA) granted approval to an artificial intelligence–based device to detect certain diabetes-related eye problems

Table 2 | FDA AI approvals are accelerating

Company	FDA Approval	Indication
Apple	September 2018	Atrial fibrillation detection
Aidoc	August 2018	CT brain bleed diagnosis
iCAD	August 2018	Breast density via mammography
Zebra Medical	July 2018	Coronary calcium scoring
Bay Labs	June 2018	Echocardiogram EF determination
Neural Analytics	May 2018	Device for paramedic stroke diagnosis
IDx	April 2018	Diabetic retinopathy diagnosis
Icometrix	April 2018	MRI brain interpretation
Imagen	March 2018	X-ray wrist fracture diagnosis
Viz.ai	February 2018	CT stroke diagnosis
Arterys	February 2018	Liver and lung cancer (MRI, CT) diagnosis
MaxQ-AI	January 2018	CT brain bleed diagnosis
Alivecor	November 2017	Atrial fibrillation detection via Apple Watch
Arterys	January 2017	MRI heart interpretation

Table 1 | Peer-reviewed publications of AI algorithms compared with doctors

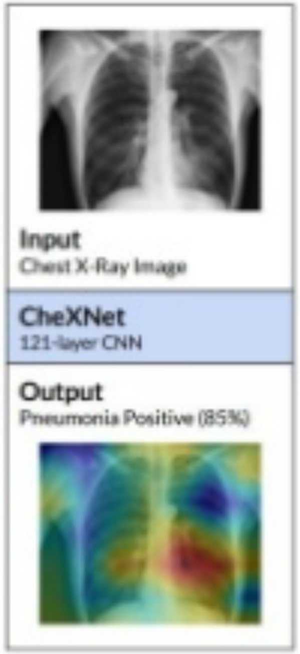
Specialty	Images	Publication
Radiology/ neurology	CT head, acute neurological events	Titano et al. [27]
	CT head for brain hemorrhage	Arbabshirani et al.[19]
	CT head for trauma	Chilamkurthy et al.[20]
	CXR for metastatic lung nodules	Nam et al.[8]
	CXR for multiple findings	Singh et al.[7]
	Mammography for breast density	Lehman et al.[26]
	Wrist X-ray*	Lindsey et al.[9]
Pathology	Breast cancer	Ehteshami Bejnordi et al.[41]
	Lung cancer (+driver mutation)	Coudray et al.[33]
	Brain tumors (+methylation)	Capper et al.[45]
	Breast cancer metastases*	Steiner et al.[35]
	Breast cancer metastases	Liu et al.[34]
Dermatology	Skin cancers	Esteva et al.[47]
	Melanoma	Haenssle et al.[48]
	Skin lesions	Han et al.[49]
Ophthalmology	Diabetic retinopathy	Gulshan et al.[51]
	Diabetic retinopathy*	Abramoff et al.[31]
	Diabetic retinopathy*	Kanagasingam et al.[32]
	Congenital cataracts	Long et al.[38]
	Retinal diseases (OCT)	De Fauw et al.[56]
	Macular degeneration	Burlina et al.[52]
	Retinopathy of prematurity	Brown et al.[60]
	AMD and diabetic retinopathy	Kermany et al.[53]
Gastroenterology	Polyps at colonoscopy*	Mori et al.[36]
	Polyps at colonoscopy	Wang et al.[37]
Cardiology	Echocardiography	Madani et al.[23]
	Echocardiography	Zhang et al.[24]

Prospective studies are denoted with an asterisk.

Pneumonia Detection on Chest X-Rays with Deep Learning

2017

Pathology
Atelectasis
Cardiomegaly
Effusion
Infiltration
Mass
Nodule
Pneumonia
Pneumothorax
Consolidation
Edema
Emphysema
Fibrosis
Pleural Thickening
Hernia

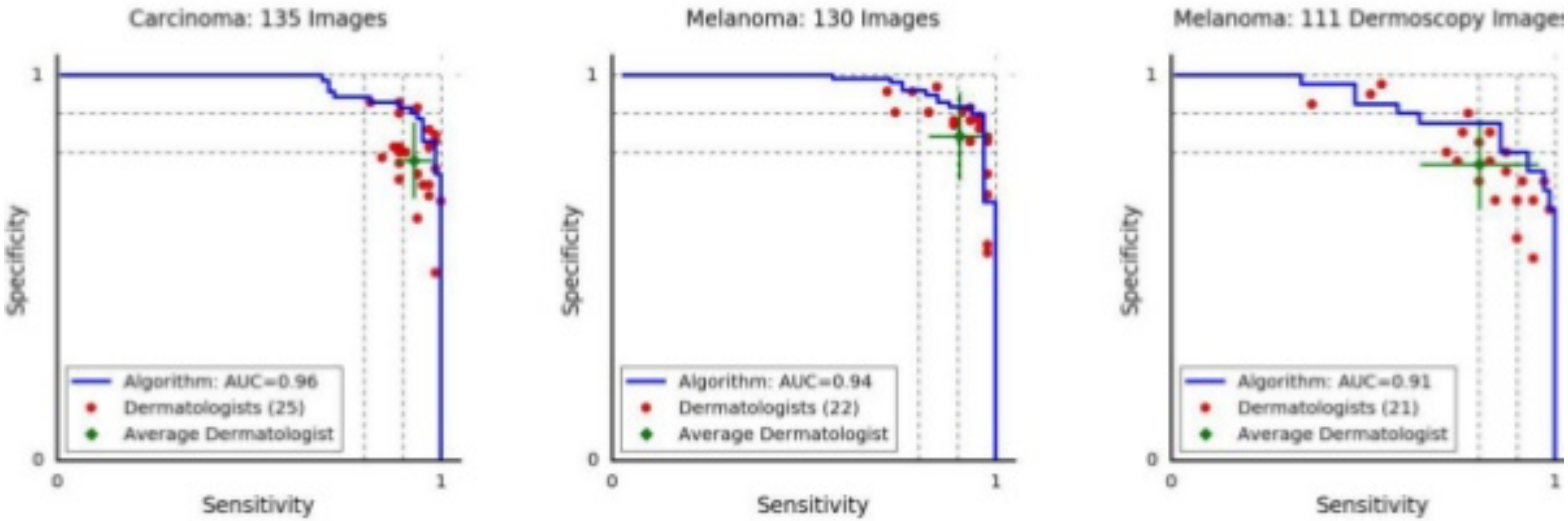


	F1 Score (95% CI)
Radiologist 1	0.383 (0.309, 0.453)
Radiologist 2	0.356 (0.282, 0.428)
Radiologist 3	0.365 (0.291, 0.435)
Radiologist 4	0.442 (0.390, 0.492)
Radiologist Avg.	0.387 (0.330, 0.442)
CheXNet	0.435 (0.387, 0.481)

Source: Rajpurkar, Pranav, et al. "CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning." (2017

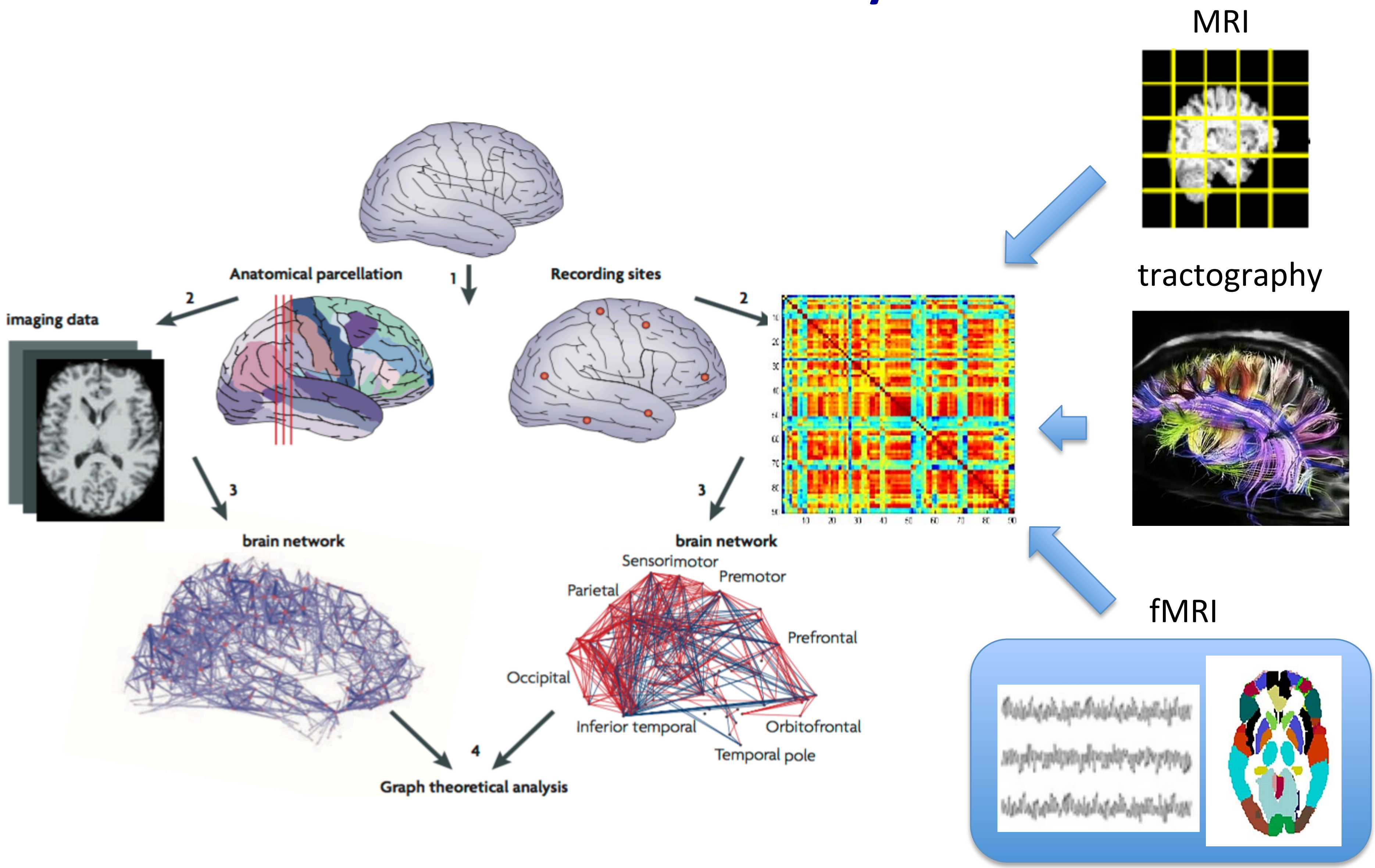
Classification of Skin Cancer with Deep Neural Networks

2017



Source: Esteva, Andre, et al. "Dermatologist-level classification of skin cancer with deep neural networks." Nature (2017)

Brain connectivity

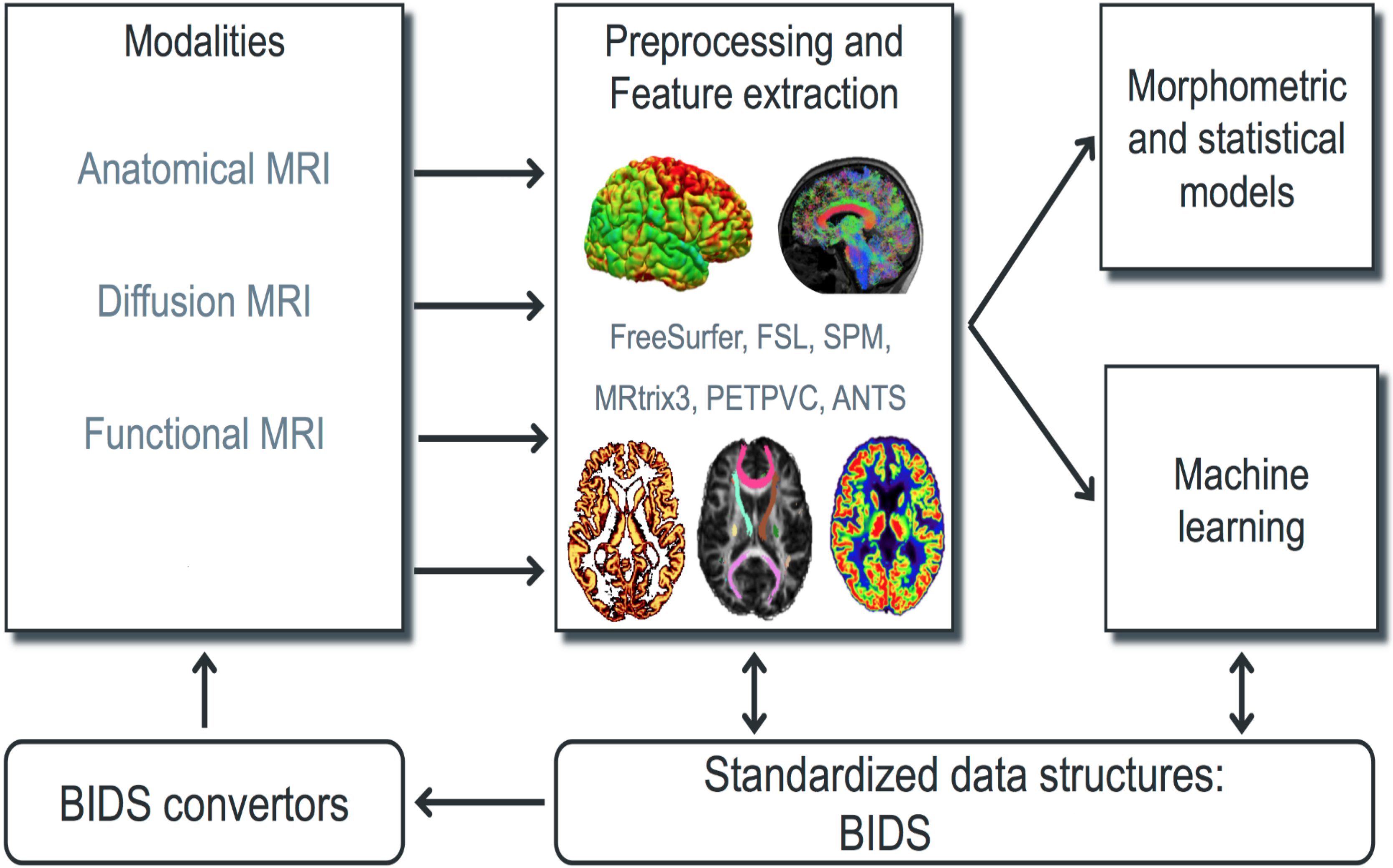


Multidimensional neuroimaging processing in ReCaS

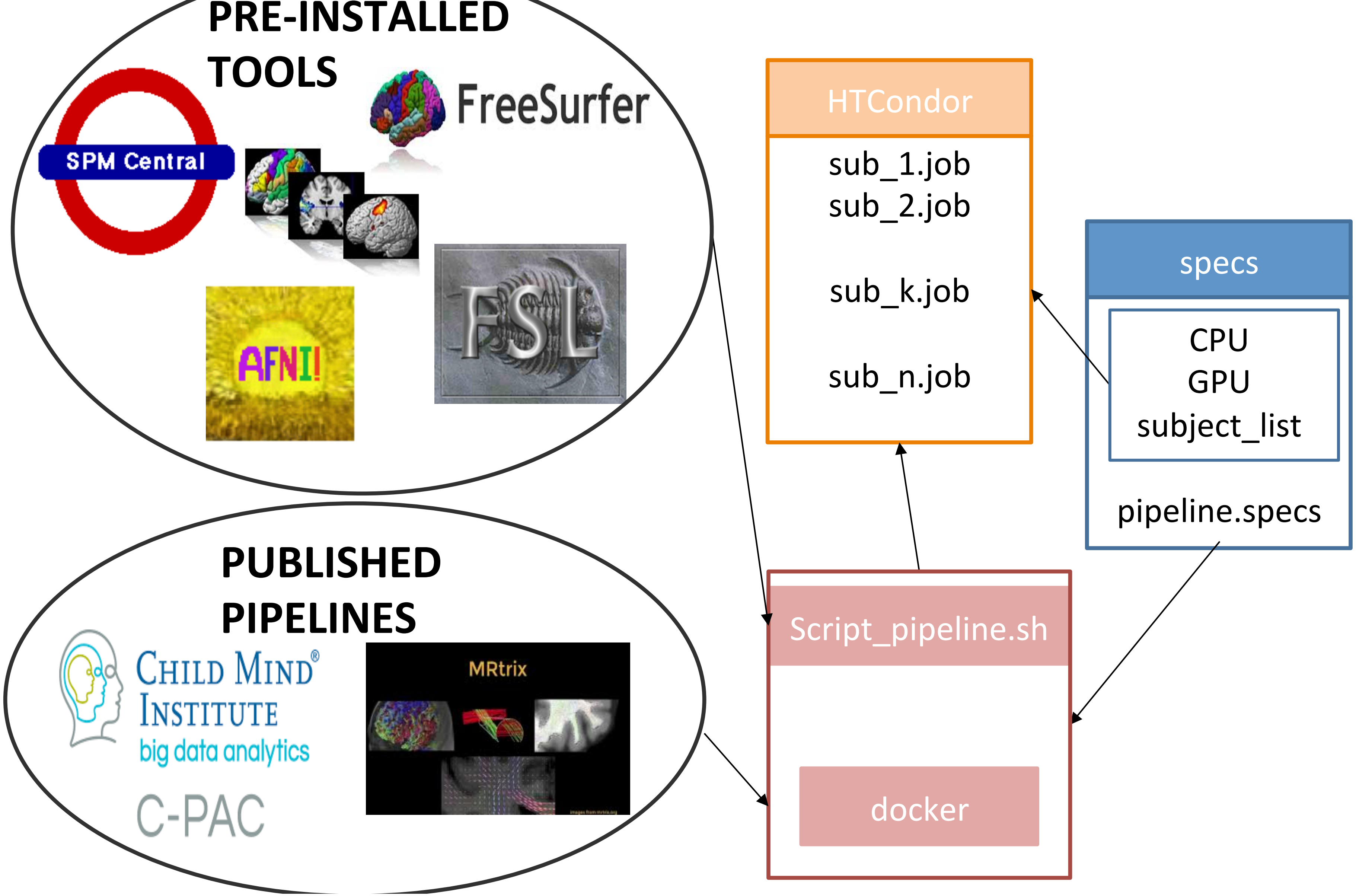
- In ReCaS datacenter it is possible to create a **custom pipeline** for preprocessing and analysis of structural and functional neuroimaging data by efficiently combining different tools or by running **open-source already published software pipelines** such us C-PAC (for fMRI data) or MRtrix (for DTI imaging).

- In addition, existing **pipelines can be integrated** with new tools, thus resulting in a highly scalable and flexible system.

Multidimensional neuroimaging processing in ReCaS



Multidimensional neuroimaging processing



Modelling cognitive loads in schizophrenia by means of new functional dynamic indexes

Angela Lombardi [a,b], Cataldo Guaragnella [c], Nicola Amoroso [b,a], Alfonso Monaco [a], Leonardo Fazio [f], Paolo Taurisano [d], Giulio Pergola [d], Giuseppe Blasi [d,e], Alessandro Bertolino [d,e], Roberto Bellotti [b,a], Sabina Tangaro [a,*]

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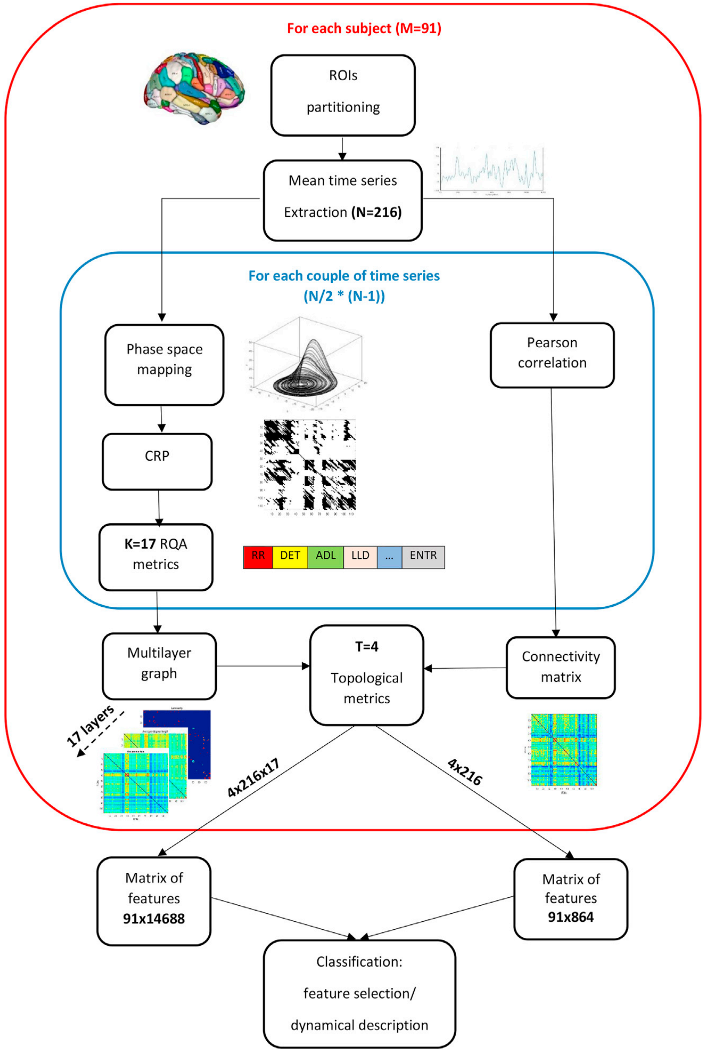


Fig. 1. Flow-chart showing the multi-recurrence framework and the comparison with the Pearson-based functional connectivity.

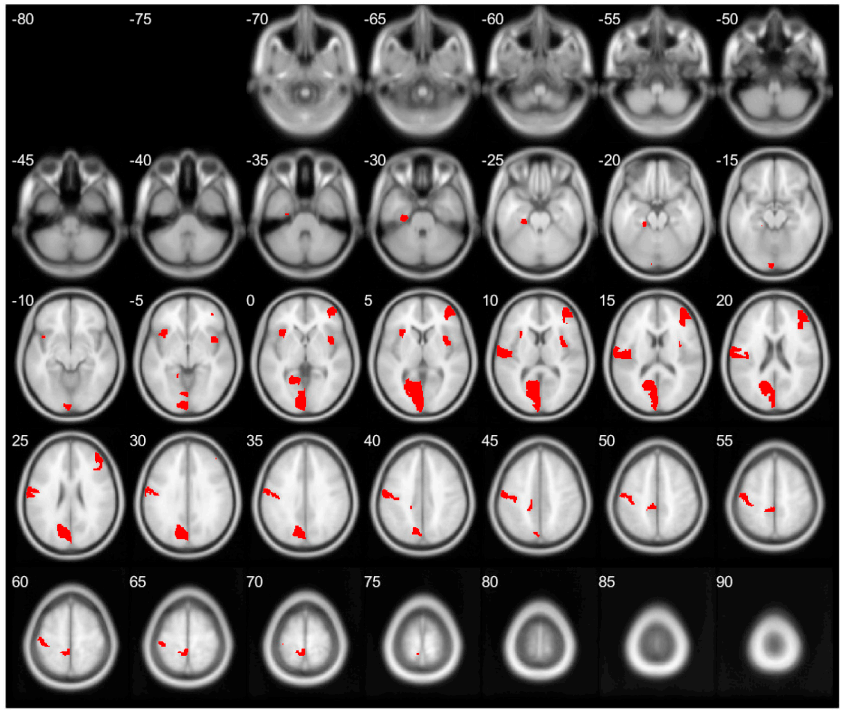
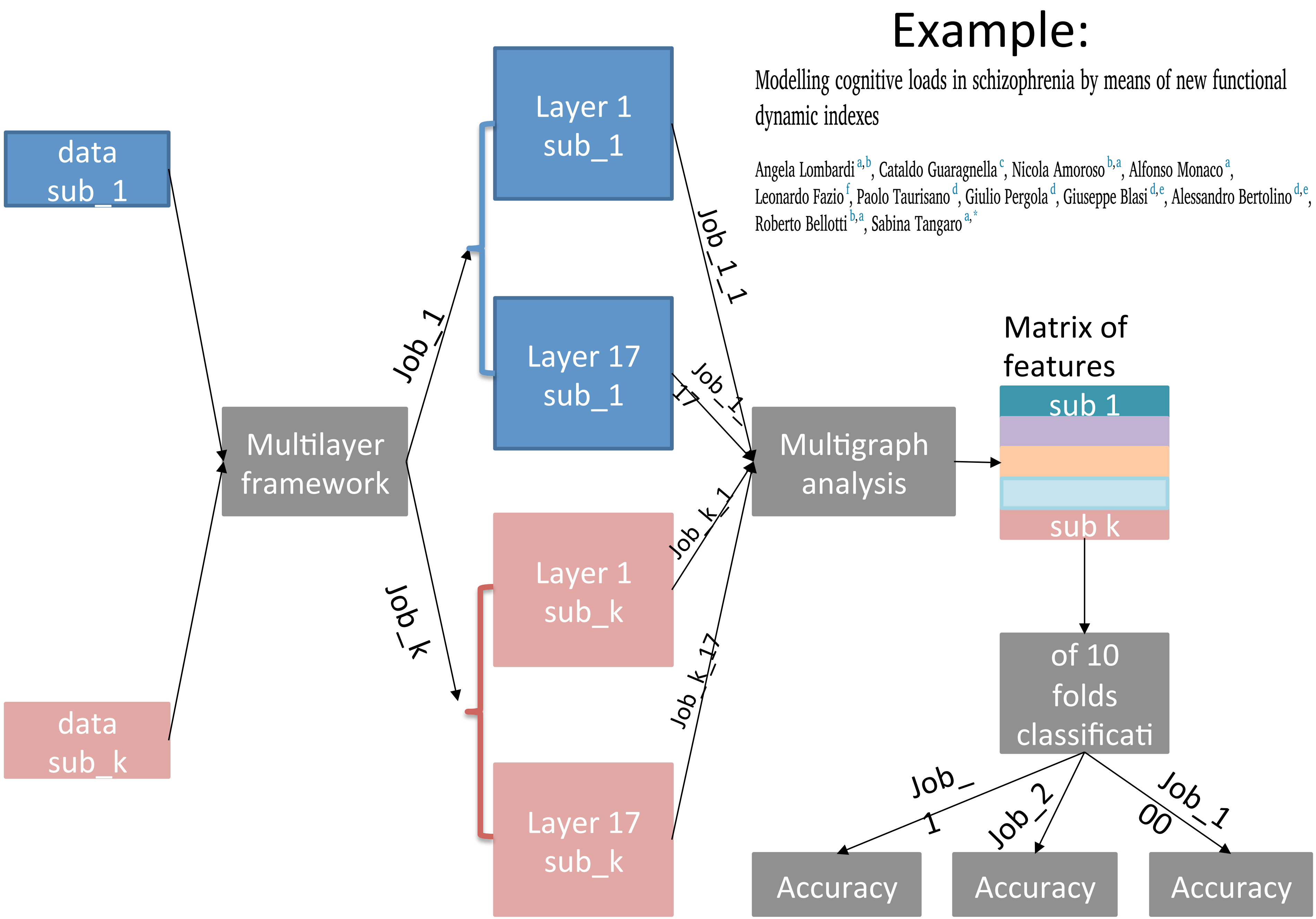


Fig. 7. Slice view of the most significant ROIs for the classification of the control/schizophrenic subjects during the 0-back condition.



Example:
Modelling cognitive loads in schizophrenia by means of new functional dynamic indexes
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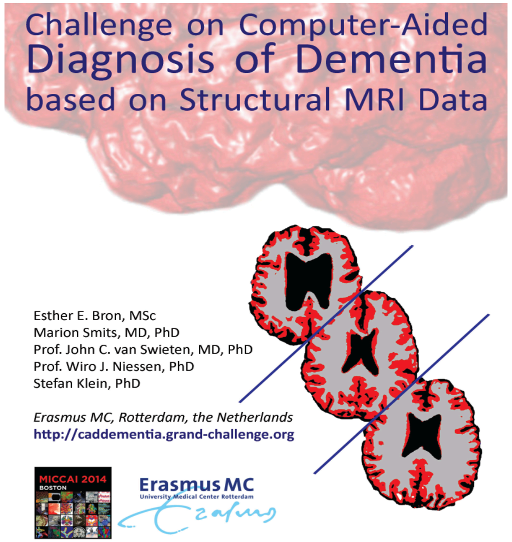
data sub_1
data sub_k
Multilayer framework
Job_1
Job_k
Layer 1 sub_1
Layer 17 sub_1
Layer 1 sub_k
Layer 17 sub_k
Job_1_1
Job_1_17
Job_k_1
Job_k_17
Multigraph analysis
Matrix of features
sub 1
sub k
of 10 folds classificati
Job_1
Job_2
Job_100
Accuracy
Accuracy
Accuracy

Public large-scale validation studies

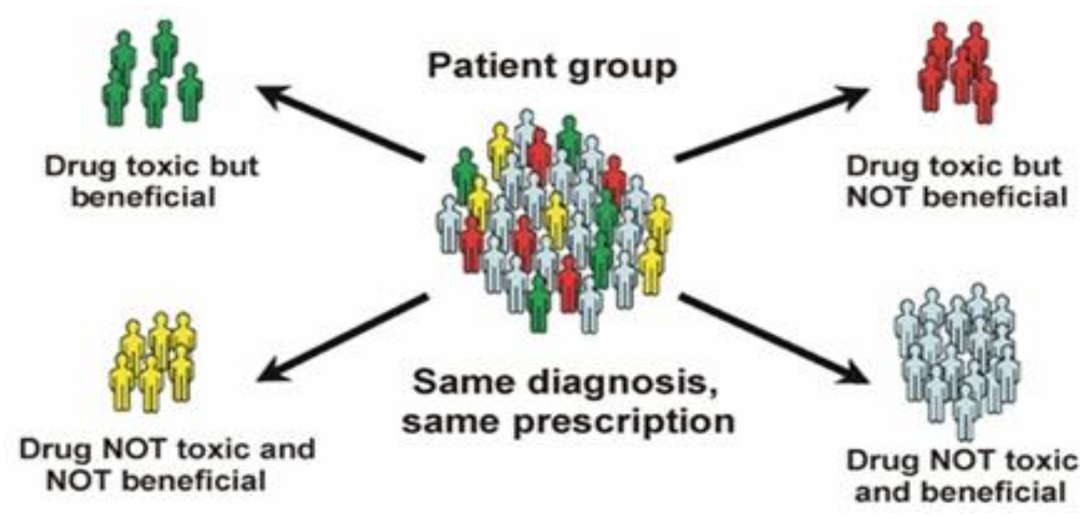
Segmentation and classification results can be exploited to design computer aided detection systems.

The lack of an unbiased comparison among different studies has motivated in recent years a number of international challenges have been promoted to compare algorithms and methodologies within a common framework.



A Machine learning neuroimaging challenge for automated diagnosis of Mild Cognitive Impairment

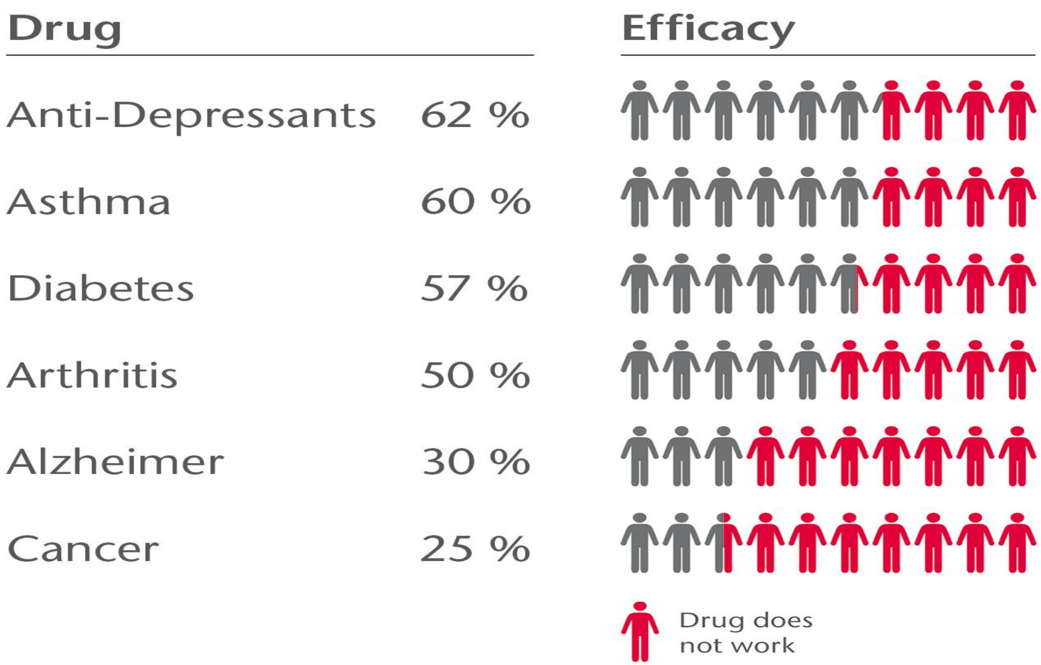
International challenge for automated prediction of MCI from MRI data.



Now it is possible, using molecular analysis of the genome of each patient, to divide the patients (stratify) into subgroups:
those that respond to the treatment or that do not respond, or those for which the treatment is toxic or well tolerated.

The overcoming of paradigm ‘one drug fits for all’

In fields like oncology, Alzheimer's,
arthritis and diabetes, to date the percentage of patients for whom a certain drug is effective
can vary from 25% to 60% depending on the pathology and therapy assigned.



Conclusions

- **Artificial Intelligence is here to stay**
- **Cross area collaboration is essential**
- **Data creation and sharing is a cornerstone for the success of Artificial Intelligence in healthcare**

Grazie per l'attenzione

CONTATTI:
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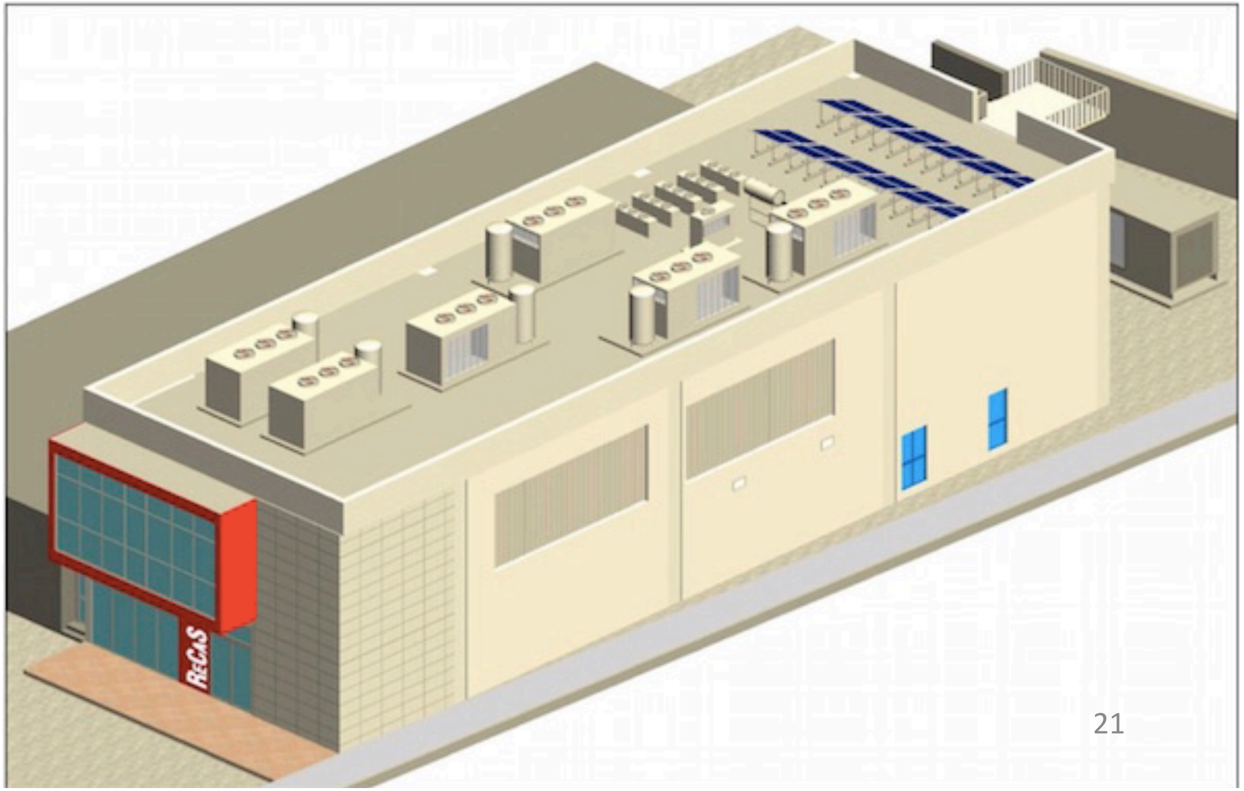
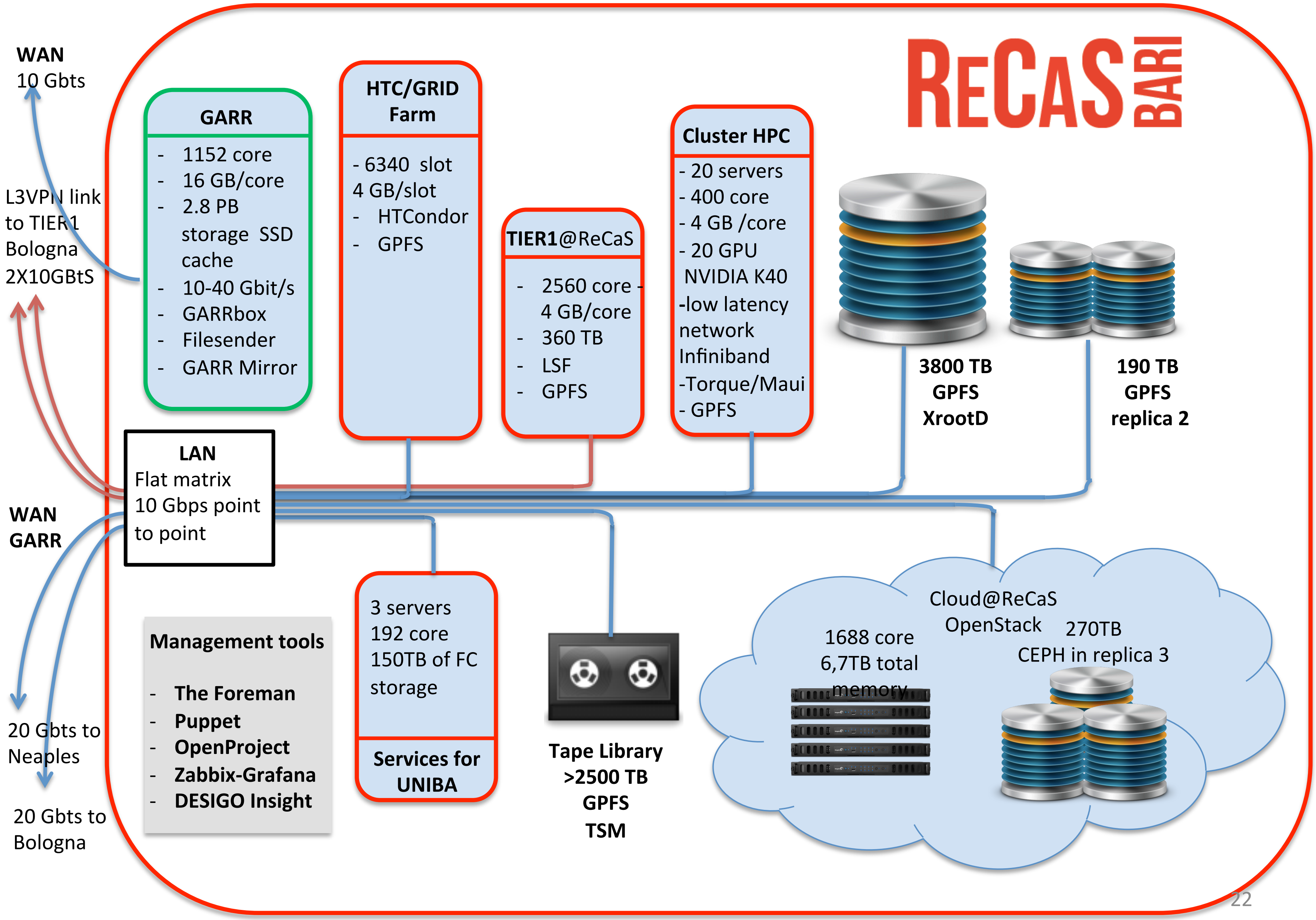
The RECAS computing infrastructure

The DataCenter ReCaS, realized in collaboration with INFN - University of Bari, is housed in a two-storey building, specially built, with an area of 430 square meters per floor.




ReCaS BARI
WAN
10 Gbts
L3VPN link
to TIER1
Bologna
2X10GBtS
GARR
- 1152 core
- 16 GB/core
- 2.8 PB
storage SSD
cache
- 10-40 Gbit/s
- GARRbox
- Filesender
- GARR Mirror
HTC/GRID
Farm
- 6340 slot
4 GB/slot
- HTCondor
- GPFS
TIER1@ReCaS
- 2560 core -
4 GB/core
- 360 TB
- LSF
- GPFS
Cluster HPC
- 20 servers
- 400 core
- 4 GB /core
- 20 GPU
NVIDIA K40
-low latency
network
Infiniband
-Torque/Maui
- GPFS
3800 TB
GPFS
XrootD
190 TB
GPFS
replica 2
LAN
Flat matrix
10 Gbps point
to point
WAN
GARR
20 Gbts to
Neaples
20 Gbts to
Bologna
Management tools
- The Foreman
- Puppet
- OpenProject
- Zabbix-Grafana
- DESIGO Insight
3 servers
192 core
150TB of FC
storage
Services for
UNIBA
Tape Library
>2500 TB
GPFS
TSM
Cloud@ReCaS
OpenStack
1688 core
6,7TB total
memory
270TB
CEPH in replica 3