L'AI nel Medical Imaging: strumenti di analisi quantitativa per approcci personalizzati e di precisione

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A^{2}VI Lab

Step procedurali nel Medical Imaging

- Acquisizione
- Pre-processamento
- Ricostruzione Immagini
- Rimozione di Rumore ed Artefatti
- Segmentazione, Analisi Quantitativa ed Interpretazione

L'AI interviene in ogni step!

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Department of Life, Health & Enironmental Sciences

A²VI Lab

Acquisition, Analysis, Visualization & Imaging Laboratory

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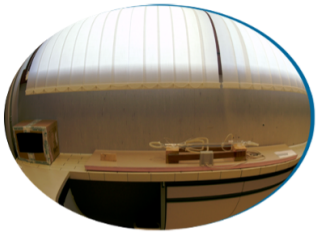
Location

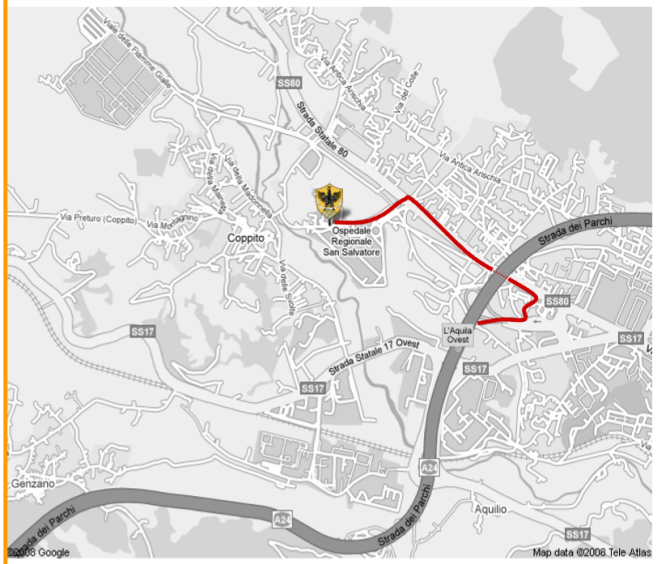


A²VI Lab is situated in the Coppito 2 building, level 3, rooms B4.24, B4.31, B4.32, and B4.33.

The research is on the following themes:

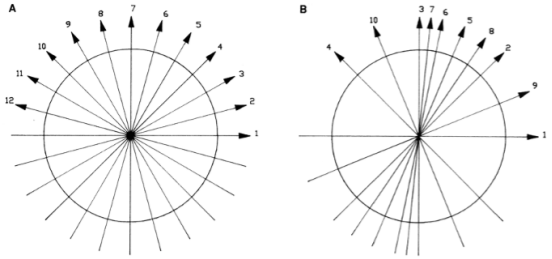
- Coding/decoding schemes and sparse sampling & reconstruction for medical tomography;
- Classification strategies for weak and non stationary signals;
- Image analysis and interpretation;
- Simulation and optimization of magnetic and electromagnetic fields;
- Artificial intelligence.

Road map

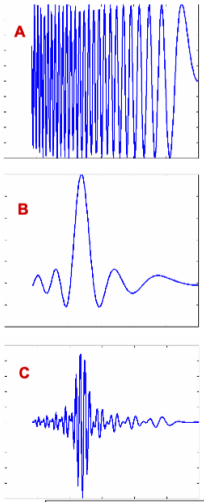


Building map

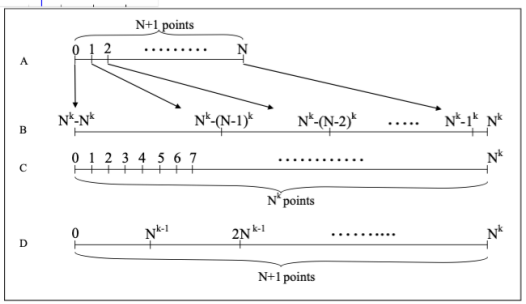
Smart Acquisition Schemes for Tomography



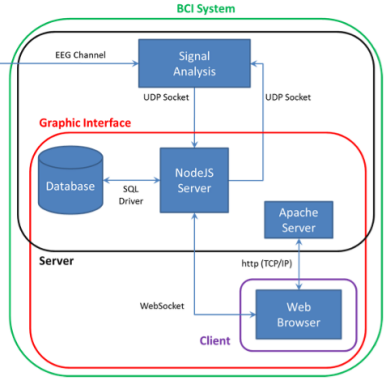
Adaptive acquisition techniques from radial projections have been studied and tested for medical tomography. They are based on the calculation of the information content of an initial, reduced, set of projections, followed by the selection of new angles where the information content is maximum, during the acquisition process. An entropy function is used to evaluate the information content of each projection. The methods allow the reduction of the acquisition time and accurate reconstruction.



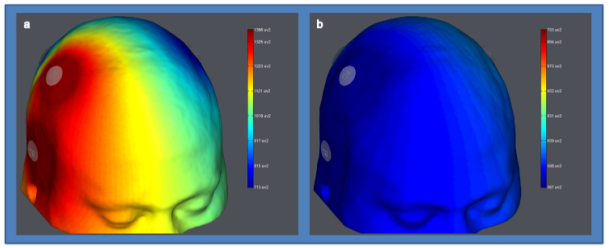
In MRI, magnetic field spatial variations are used to spatially codify the signal. The presence of static magnetic field in-homogeneities introduces distortions and artefacts in the images. An innovative coding/reconstruction algorithm for MRI, based on the assignment of different time varying frequencies (accelerations) to different spatial positions, has been proposed. The technique is used both for coding and decoding the signal. The algorithm reduces the costs of magnet construction and shimming and allows the construction of more accessible magnets.



BCI driven by emotions

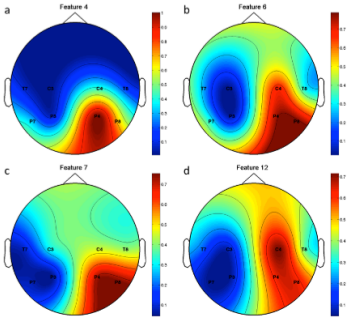


A BCI is able to give a new output channel to the brain. A BCI driven by self-induced emotions for severely disabled people has been proposed. The subject, thinking at an intention, generates voluntary brain signals to be translated into commands for an output device.



The brain activity is measured by EEG and the BCI explores, through classification algorithms, these signals to recognize and translate the subject's will.

One of the proposed classification method is based on the analysis of the EEG signals through Short-time Fourier Transform. The method is very effective but too specific (only binary classification is considered).

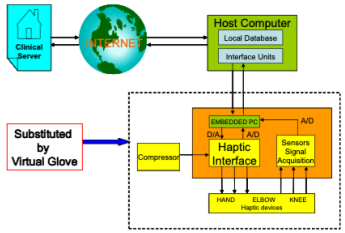


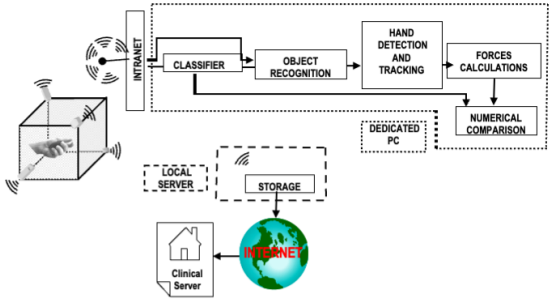
Another classification method is in the framework of machine learning. A set of 12 features is calculated. PCA is applied to reduce feature redundancy and the most effective features are classified through SVM. The classification accuracy is above 90%.

The implemented BCI has been also tested on a minimally conscious state subjects to reveal covert consciousness: the results are very promising.

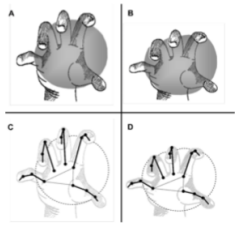
Virtual Glove for the Hand Tele-rehabilitation

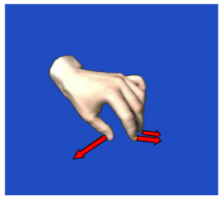
A virtual glove, to be used for hand rehabilitation, has been studied and realised. It tracks hand and fingers movements by using the images collected by synchronous webcams.





Finger forces are calculated from the deformations impressed to some objects (of known elastic coefficient) grasped by the patient hand.

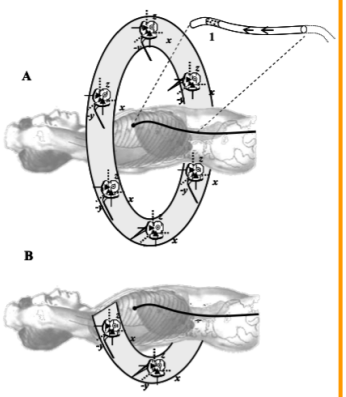




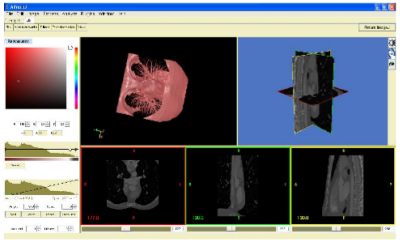
The presented system is notable for simplicity, generality, low cost and can be used for tele-rehabilitation.

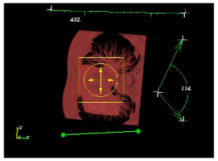
Magnetic endovascular position/orientation indicator

An innovative magnetic position/orientation indicator for endovascular *in-vivo* medical procedures has been realised and tested. It uses the magnetic field produced by a thin permanent magnet installed on the probe and magnetic field sensors positioned outside the body of the patient. It is capable of reducing X-Ray exposure.



The patient vascular tree, reconstructed with data collected before the intervention, is used as a guide map instead of fluoroscopic scans. The spatial correspondence between the body of the patient and the 3D reconstructed vascular model is established by means of the above position indicator.

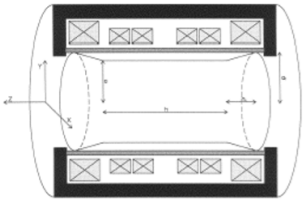


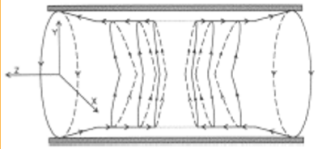


Accurate segmentation and reconstruction algorithms ensure that the 3D vascular tree is correctly selected and properly reconstructed.

Magnetic Field Coils Optimization

MRI requires magnetic field gradients, one for each axis, to encode spatial information. These are produced by a set of three coils and have to be linear and efficient.





An innovative algorithm for the optimization of gradient coil systems for MRI has been developed. The method eliminates restrictions on coil geometry and provides an approach for modelling any shape, including cylindrical and planar systems.

Design constraints can be easily enforced, such as the length of the cylinder in a cylindrical system, the size of the plane in a planar system, or the presence of current-free slots or holes.

The method can deal with the eddy currents induced in conducting objects, and with shielded or double-shielded coil systems.

Planar coil assemblies were simulated and designed for two commercial MRI open apparati (Paramed MrJ and Mr Open systems).

Patents

1. M.Alecci, J.Brivati, G.Placidi, L.Testa, D.J.Lurie, and A.Sotgiu
   "Magnetic resonance apparatus having reduced 'dead time' "
   UK Patent No 9622183.3 Magnetic Resonance Imaging (1996).

2. G.Placidi, M.Alecci, A.Sotgiu
   "Metodo perfezionato di acquisizione di dati nel dominio della frequenza spaziale per la ricostruzione di immagini bidimensionali, in particolare di risonanza magnetica nucleare, e relativo apparato"
   Italian Patent No RM98A000217 (1998).

3. C.A.Curto, G.Placidi, A.Sotgiu, M.Alecci
   "Disposizione di rilevamento per una apparecchiatura per risonanza magnetica di tipo perfezionato, ed apparecchiatura per risonanza magnetica comprendente una tale disposizione"
   Italian Patent No TO2003A000465 (2003).

4. M.Alfonsetti, G.Placidi, A.Sotgiu, V.Clementi, S.Iotti, R.Lodi, B.Barbiroli, M.Alecci
   "Configurazioni di bobina di superficie a radiofrequenza per apparecchiatura MRI con migliorata sensibilita e selettività spaziale, ed apparecchiatura comprendente una tale bobina"
   Italian Patent No TO2004A000378 (2004).

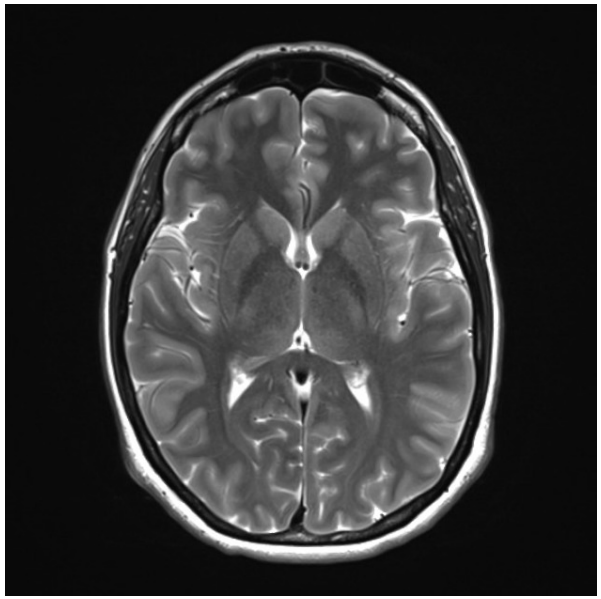
5. G. Placidi, D. Franchi, G. Gualtieri, P. Gallo, L. Marsili, C. Marinelli, R. Passariello, L. Rosa, A. Sotgiu
   "Sistema ausiliario per l'effettuazione di procedure mediche diagnostiche o interventistiche endocorporee in vivo con uso ridotto di scansioni RX"
   Italian Patent No AQ2006A000020 (2006).

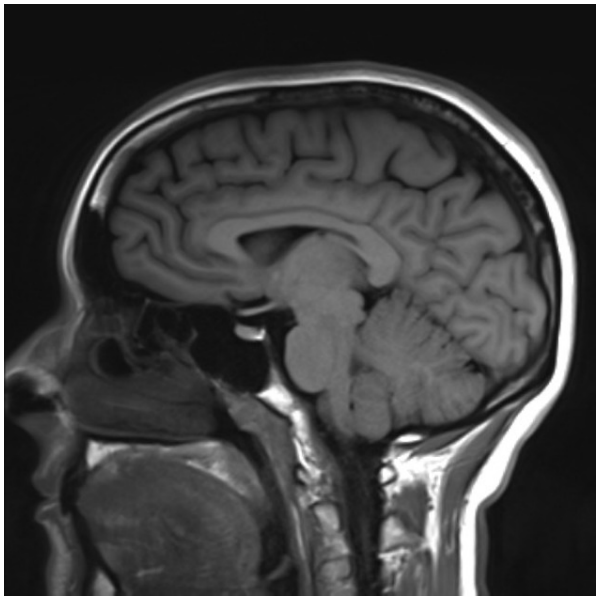
6. G. Placidi, F. Manasseri, A. Mancini, F. Politi, M. Proietti
   "Sistema integrato per la tempestiva localizzazione, verifica della presenza in vita e conteggio di persone investite dai crolli di edifici causati dal terremoto"
   Italian Patent No AQ2006A000021 (2006).

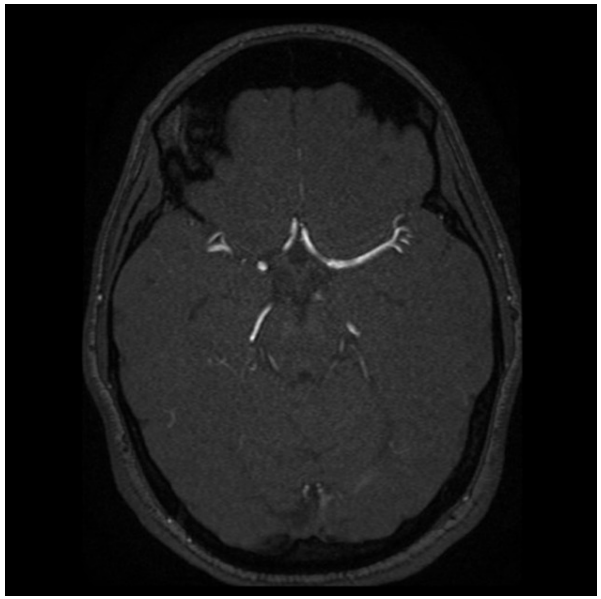
7. G. Placidi
   "Metodi di Codifica e Decodifica dei Segnali e Ricostruzione di Immagini nel Dominio delle Accelerazioni Spaziali per Imaging e Spettroscopia di Risonanza Magnetica e Relativo Apparato"
   Italian Patent No AQ2007A000017 (2007).

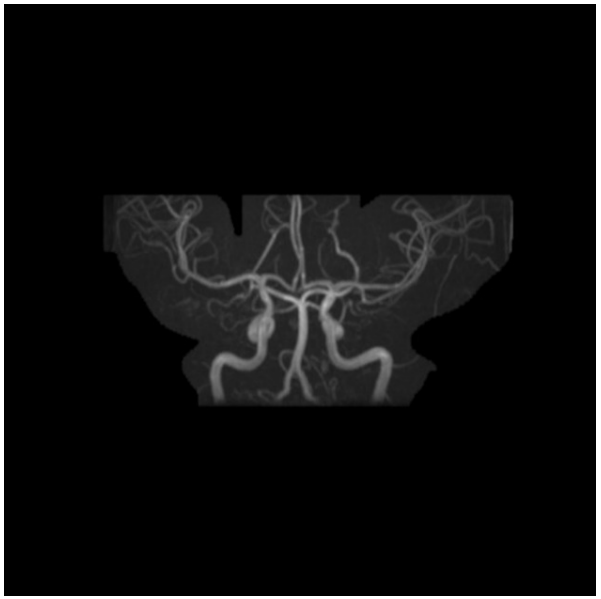
8. A. Galante, G. Placidi
   "Metodo ed Apparato per il Monitoraggio dell'Esposizione Individuale a Campi Magnetici Statici o Quasi Statici"
   Italian Patent No RM2013A000189 (2013). UnivAQ Financed PCT extension.

AI in Segmentazione, Analisi Quantitativa ed Interpretazione





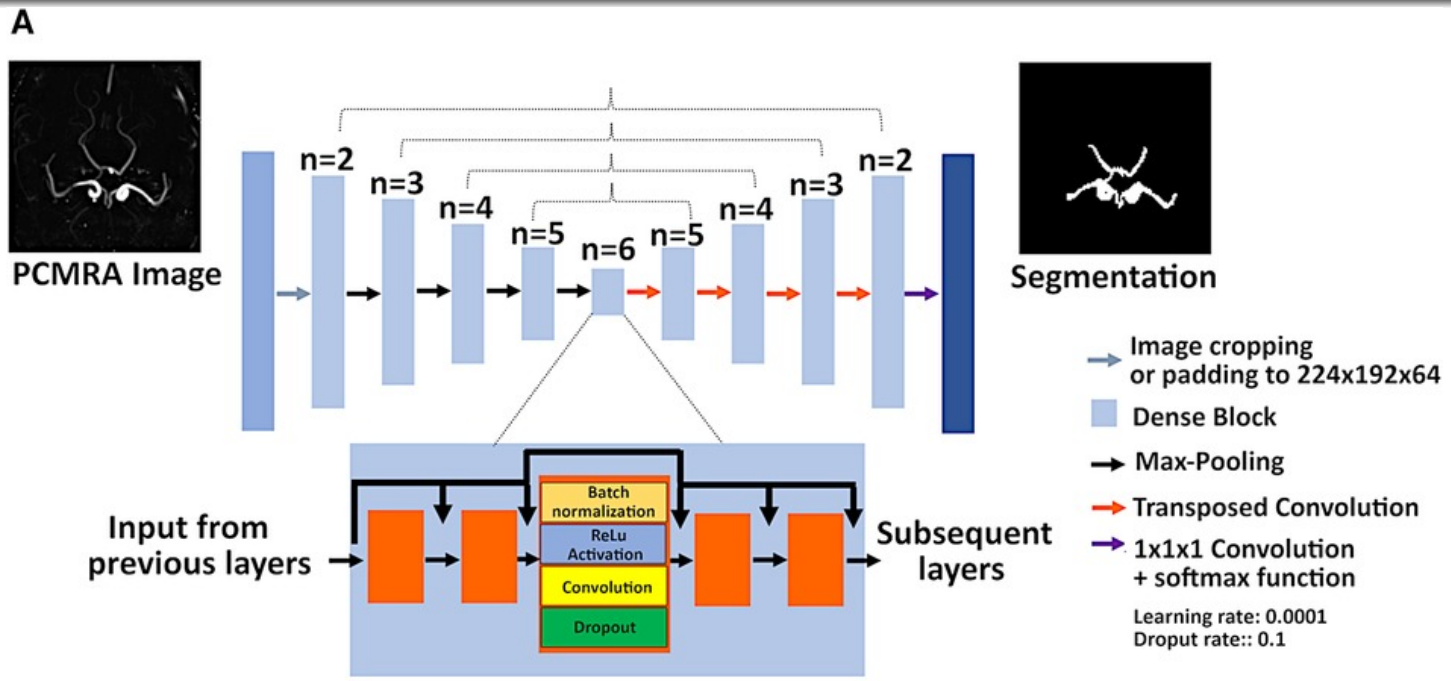




Winter P, et al.

Front. Radiol. (2024)

10.3389/fradi.2024.1385424



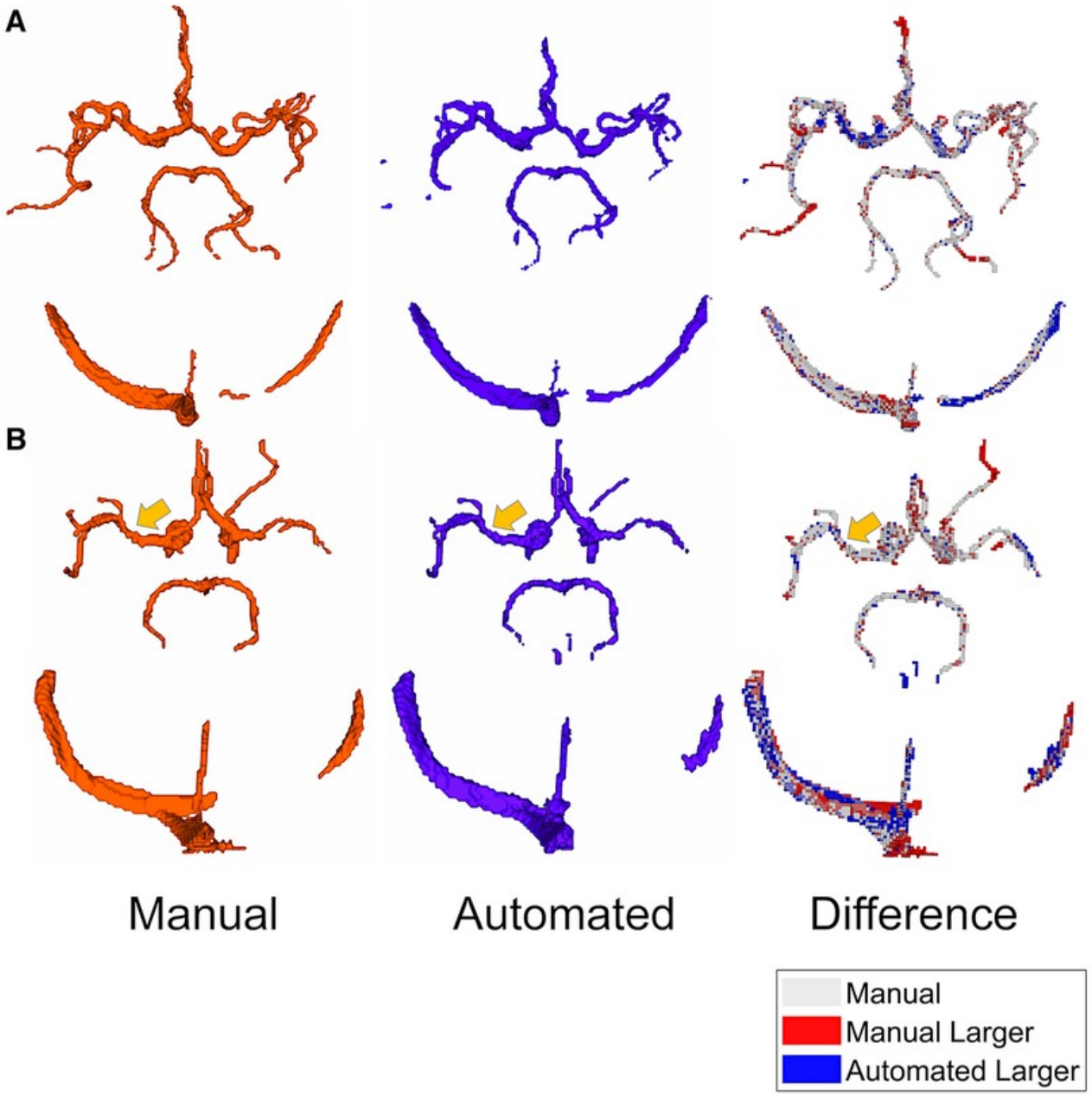
B

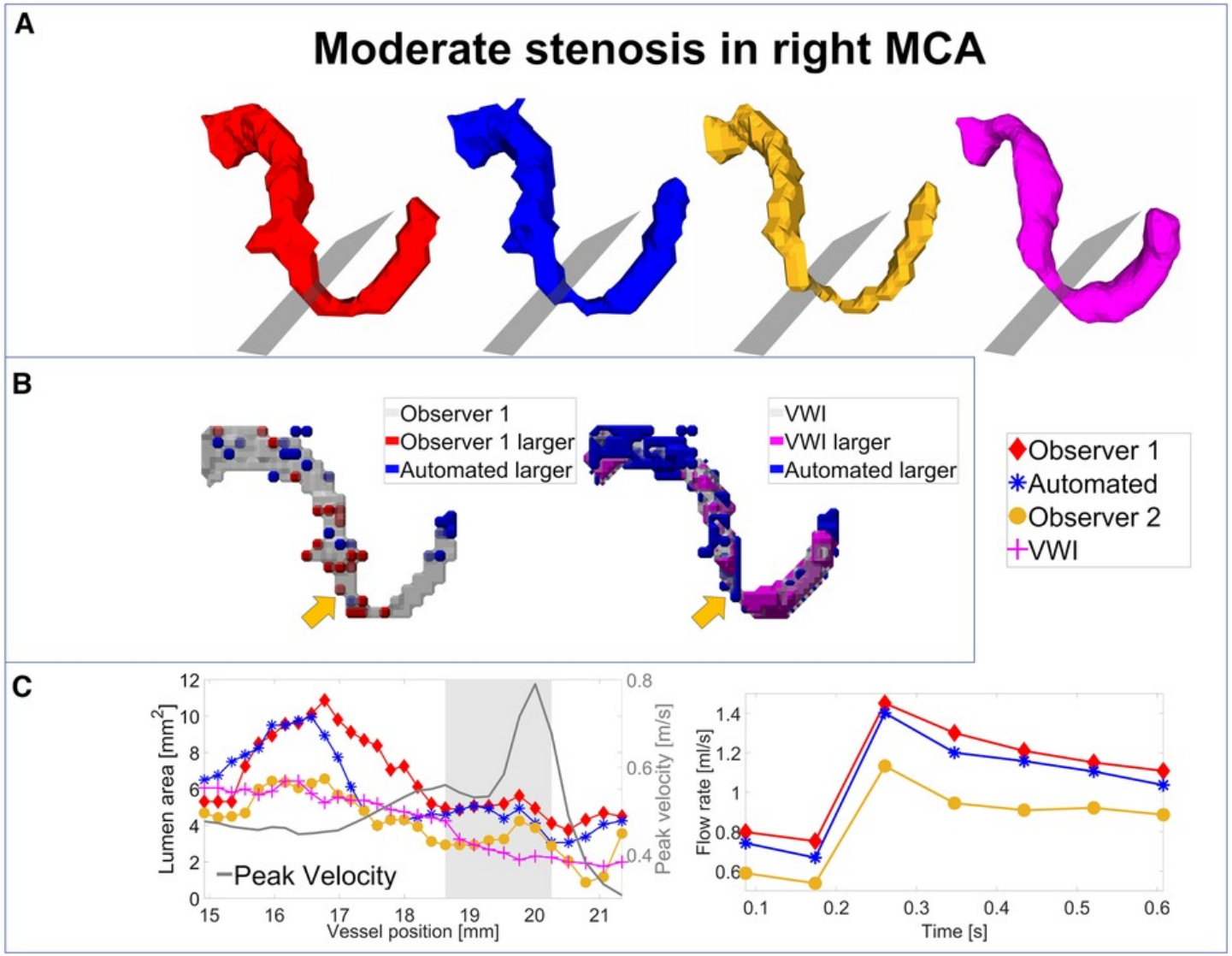
Segmented intracranial 4D Flow MRI datatasets
(86 healthy controls, 68 ICAD patients)

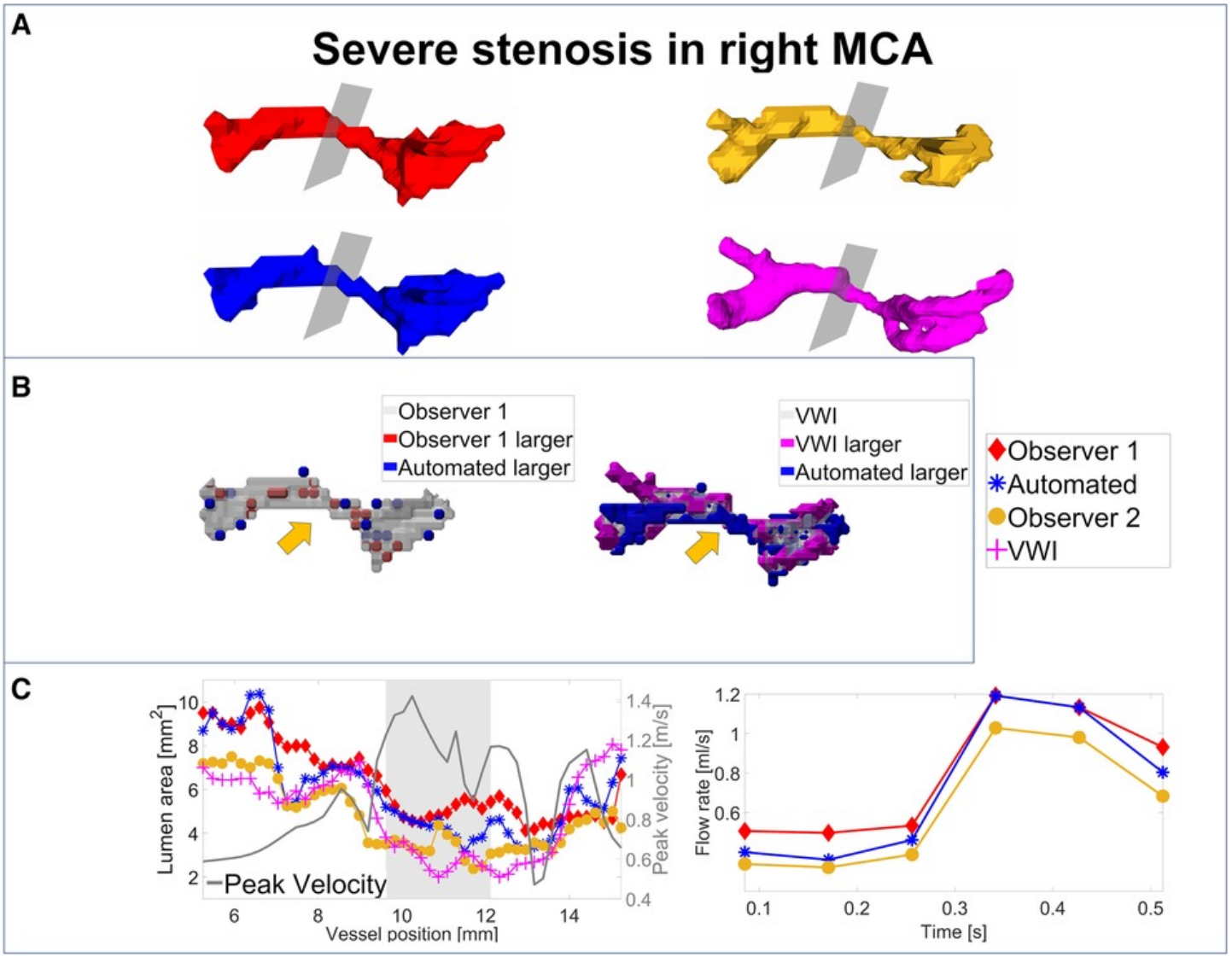
Training dataset
(76 healthy controls, 58 ICAD patients)

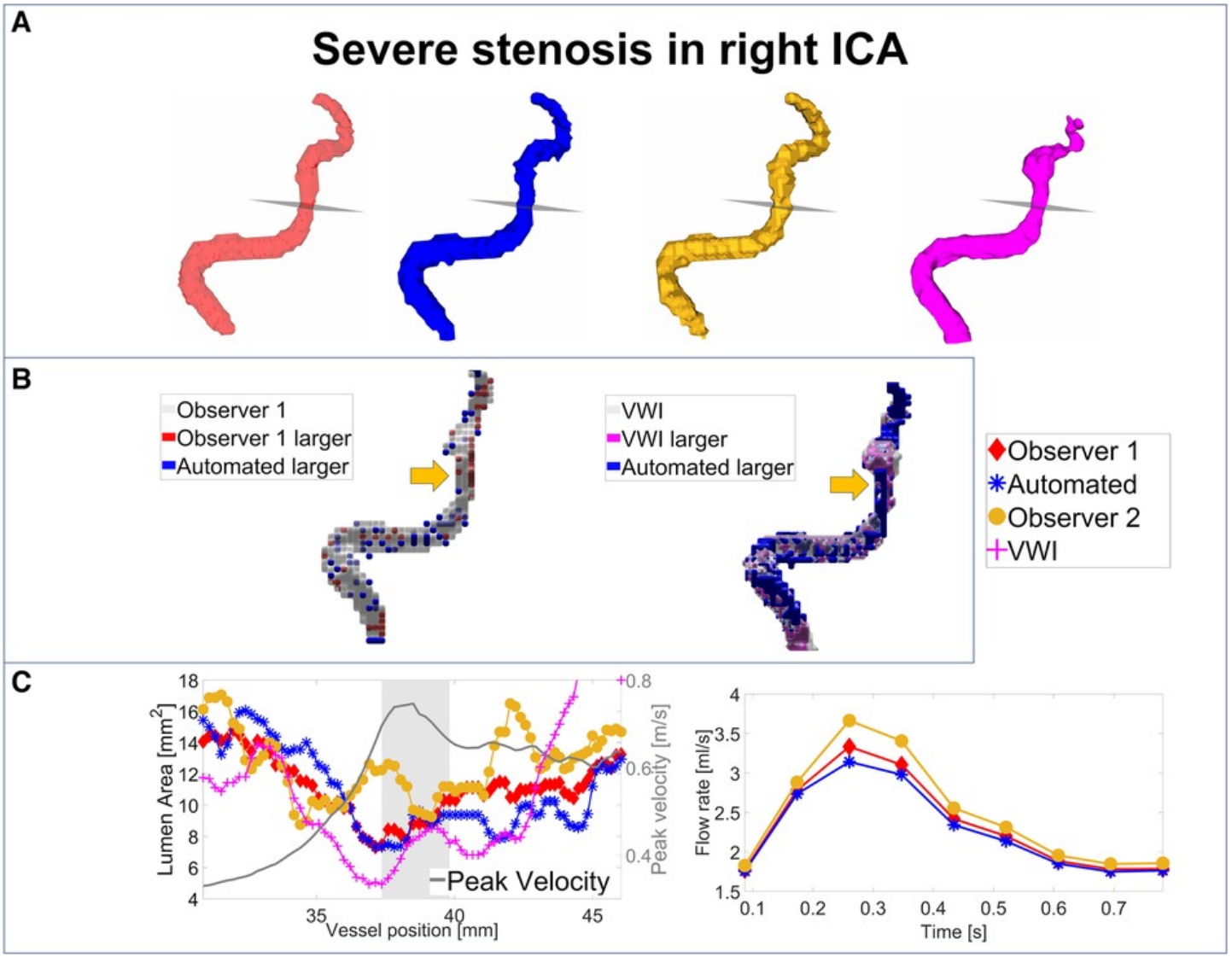
Validation dataset
(10 healthy controls, 10 ICAD patients)

CPU: i9-137000K / GPU: RTX 4070 Ti
~10 hours


A
B
Manual
Automated
Difference
Manual
Manual Larger
Automated Larger


A
Moderate stenosis in right MCA
B
Observer 1
Observer 1 larger
Automated larger
VWI
VWI larger
Automated larger
Observer 1
Automated
Observer 2
VWI
C
Lumen area [mm²]
Peak velocity [m/s]
Peak Velocity
Vessel position [mm]
Flow rate [ml/s]
Time [s]


A
Severe stenosis in right MCA
B
Observer 1
Observer 1 larger
Automated larger
VWI
VWI larger
Automated larger
Observer 1
Automated
Observer 2
VWI
C
Lumen area [mm²]
Peak velocity [m/s]
Peak Velocity
Vessel position [mm]
Flow rate [ml/s]
Time [s]


A
Severe stenosis in right ICA
B
Observer 1
Observer 1 larger
Automated larger
VWI
VWI larger
Automated larger
Observer 1
Automated
Observer 2
VWI
C
Lumen Area [mm2]
Peak velocity [m/s]
Vessel position [mm]
Peak Velocity
Flow rate [ml/s]
Time [s]

Conclusioni

- AI è sicura? **NO**

Med. Imaging
- Aspecifico
- Impreciso

Patologia
- Multiforme
- Multifocale

Paziente
- Speciale
- Dinamico

⇩

INCERTEZZA

- AI migliora la precisione e agevola personalizzazione[1]

[1] Placidi G., AI and Ethics (2022). 10.1007/s43681-022-00139-7

Ringraziamenti

Grazie

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