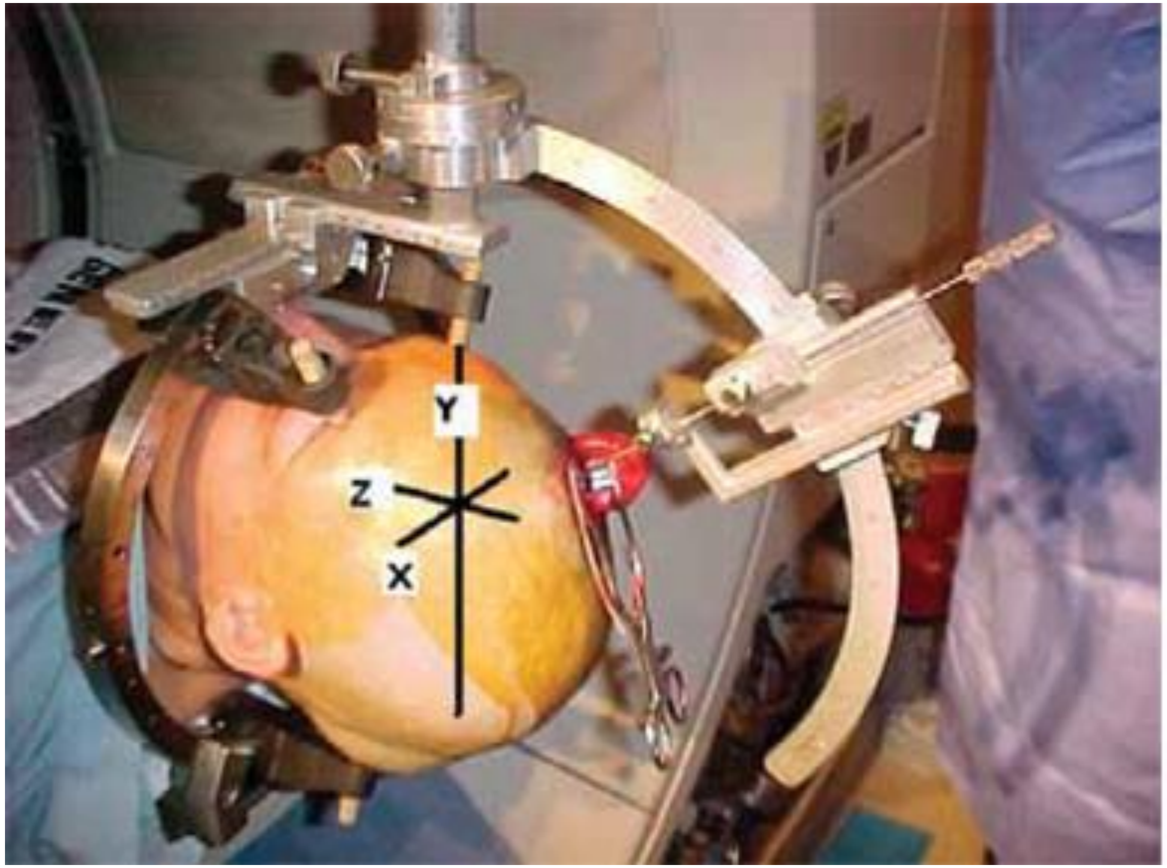
Surgery Navigation: System Overview

Miguel Ángel Padilla Castañeda (PhD, Eng)
miguel.padilla@icat.unam.mx

Bioinstrumentation Group
&
Research & Development Unit at General Hospital of México
Dr. Eduardo Liceaga
Instituto de Ciencias Aplicadas y Tecnología ICAT
Universidad Nacional Autónoma de México UNAM

Stereotactic neurosurgery



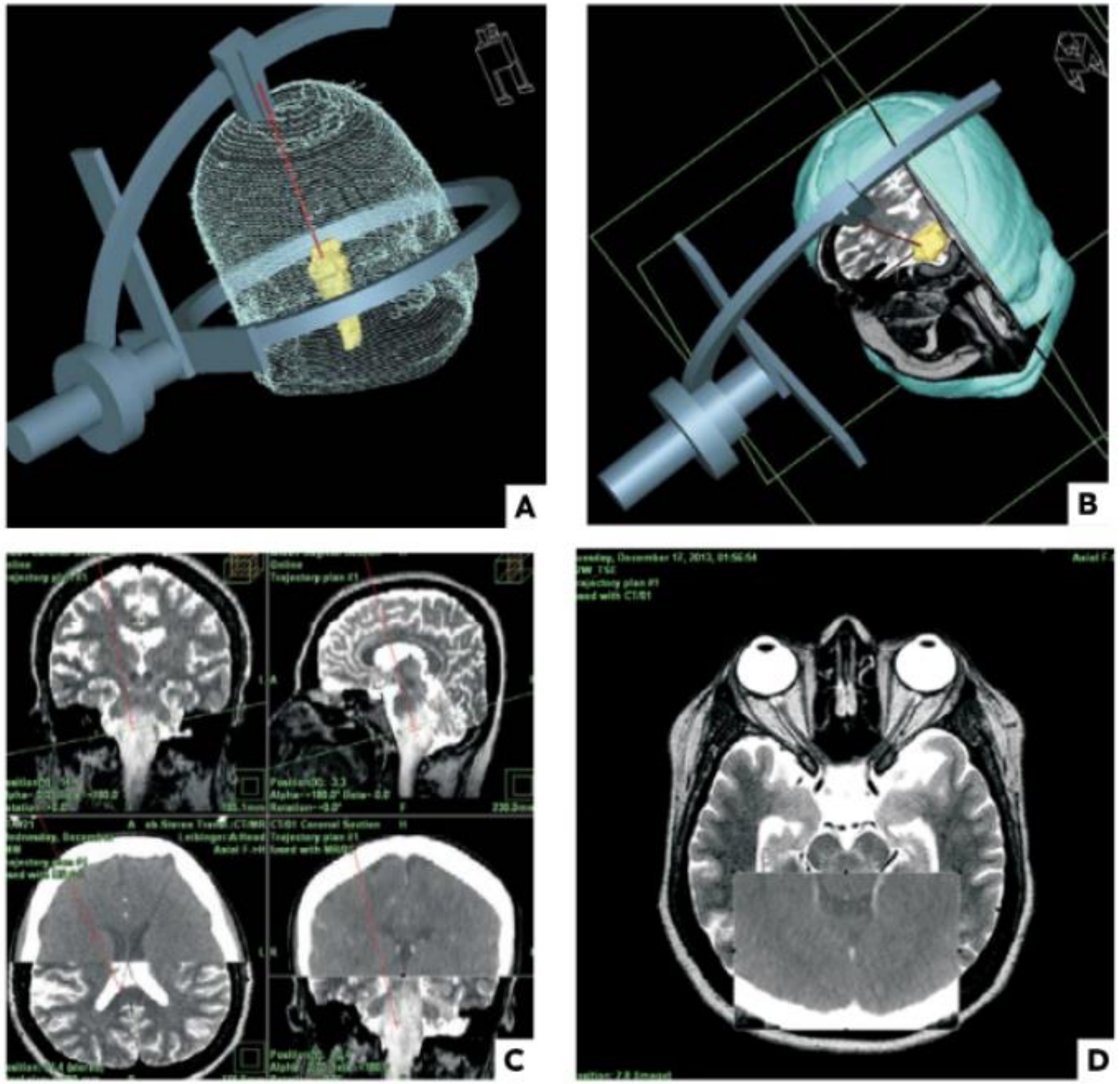
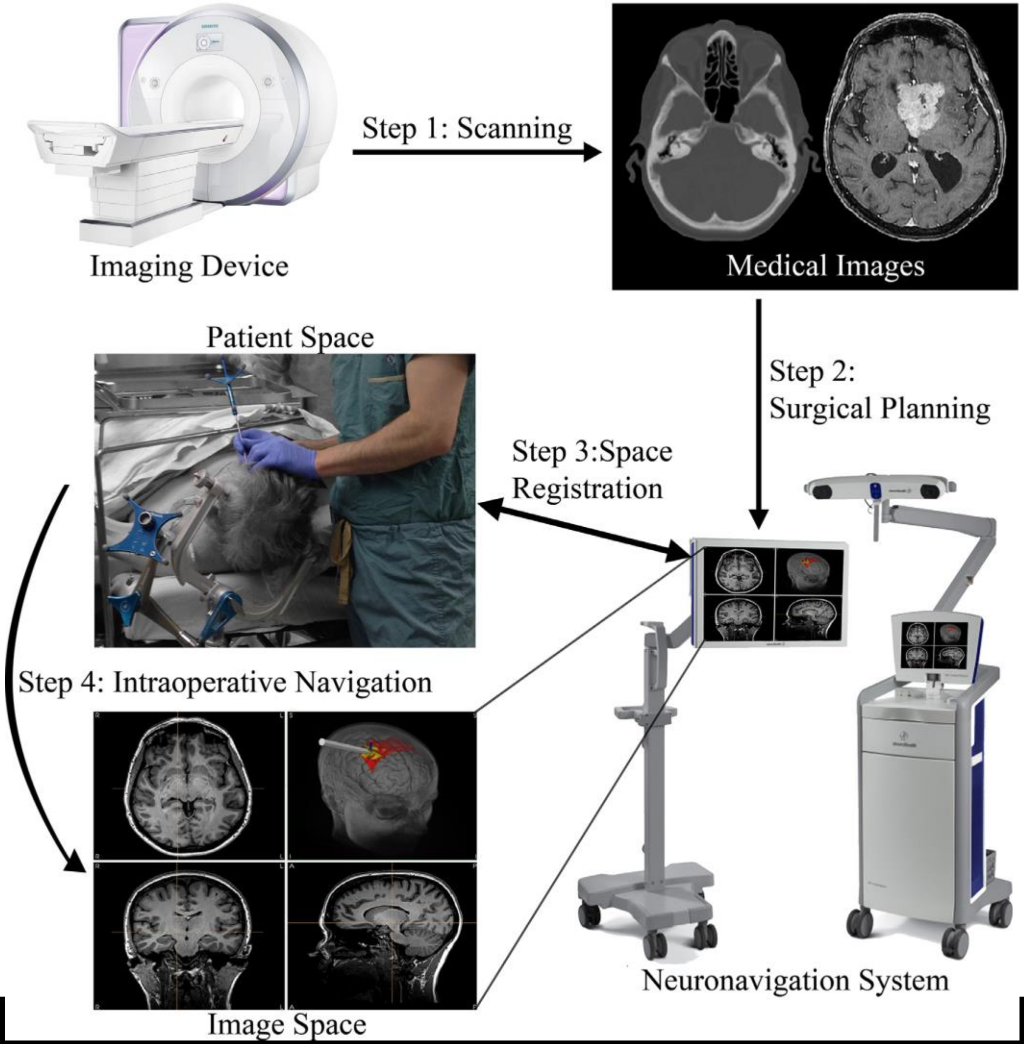


Figura 2.4: Realización de biopsia de lesiones en el tallo cerebral con posicionamiento de marco de estereotaxia de alta precisión (A, B) y utilización de software de alta precisión para planeación de trayectorias estereotácticas con fusión de imágenes (C, D) [33](Imagen: Revista Gastrohnup Año 2015 Volumen 17 Número 3; 144-153 [33]).

Navigation systems in surgery



Workflow of traditional navigation:

- Step 1: The patient is scanned to acquire medical images.
- Step 2: These images are imported into a navigation system for surgical planning.
- Step 3: The patient-to-image mapping is determined allowing for Step 4, intraoperative navigation
- Step 4: Intraoperative navigation

Traditional Neuronavigation System

Navigation Systems Workflow

1. Image scanning –The patient is scanned to acquire necessary images for navigation.
2. Surgical planning –The preoperative images are imported into the neuronavigation system, co-registered together and then used for planning.
3. Patient-to-Image registration –The mapping between the physical space of the patient and the virtual space of the images is determined by either homologous landmark (or fiducial) matching or surface matching.
4. Intraoperative navigation –Using the transformation determined in the previous step, a tracked tool can be placed in the physical space of the patient and the corresponding anatomical location can be shown in the virtual space, *i.e.* on the images.

Navigation Systems Accuracy

A major limitation of traditional navigation systems based on preoperative imaging is the loss of accuracy in the mapping determined at patient-to-image step that leads to a physical location on the patient being incorrectly reported in relation to the images used for guidance.

Navigation Systems Accuracy

Spatial errors arise from the violation of two basic assumptions:

- That the equipment, registration and images are perfectly accurate. This assumes that the tracking device and associated hardware are free of positioning error, the registration between the patient and image spaces is free of errors and all preoperative images are free from any geometrical distortions.

- That the equipment and volume of interest form a rigid system. In neurosurgery, this assumes that structures of interest within the brain remain in the same position as when they were imaged, with respect to both the external features used to determine the patient-to-image mapping as well as the tracking device throughout the procedure.

Navigation Systems Accuracy

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Sources of error contributing to assumption accuracy:

Comes from determining the transformation between the physical and virtual image spaces.

Strategies for determining patient-to-image mapping:

- Surface-based registration
- Homologous paired point matching of landmarks, fiducials, and/or screws
- Transoperative initial patient-to-image registration using laser range scanners and vessel registration techniques

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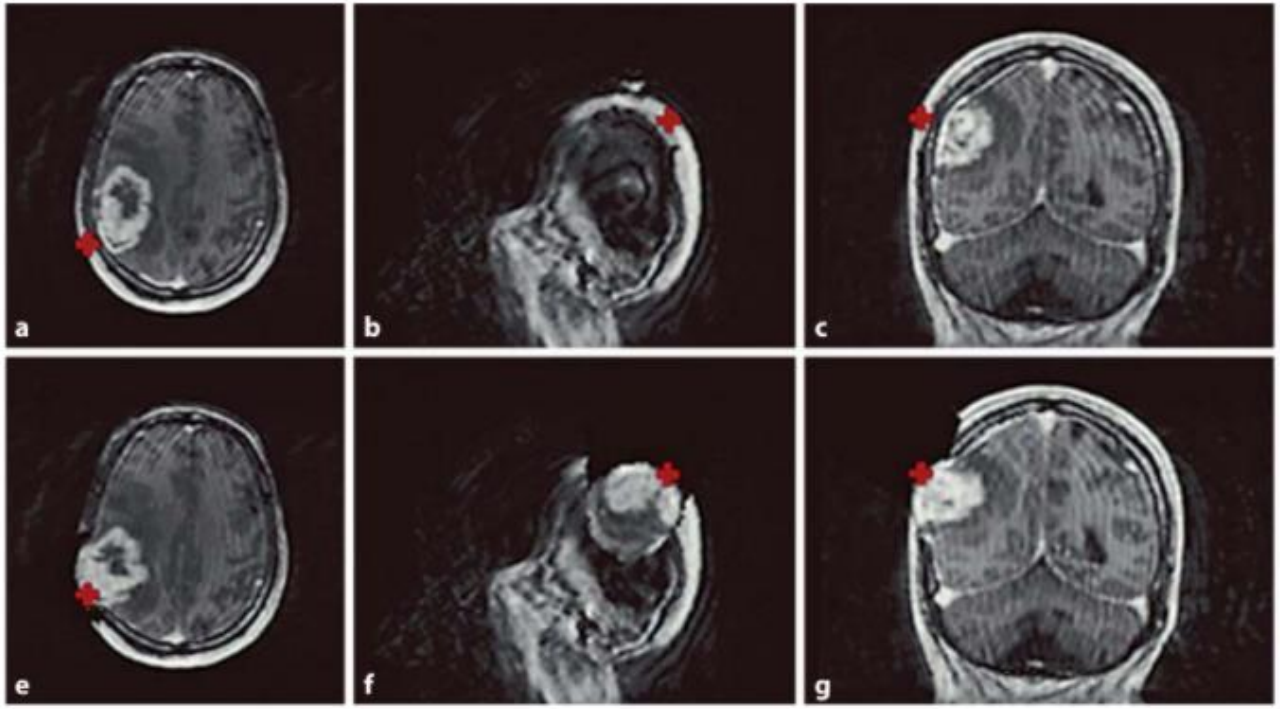
Brain-Shift Compensation: Estimación de la deformación del tejido para mejorar la ubicación del tumor



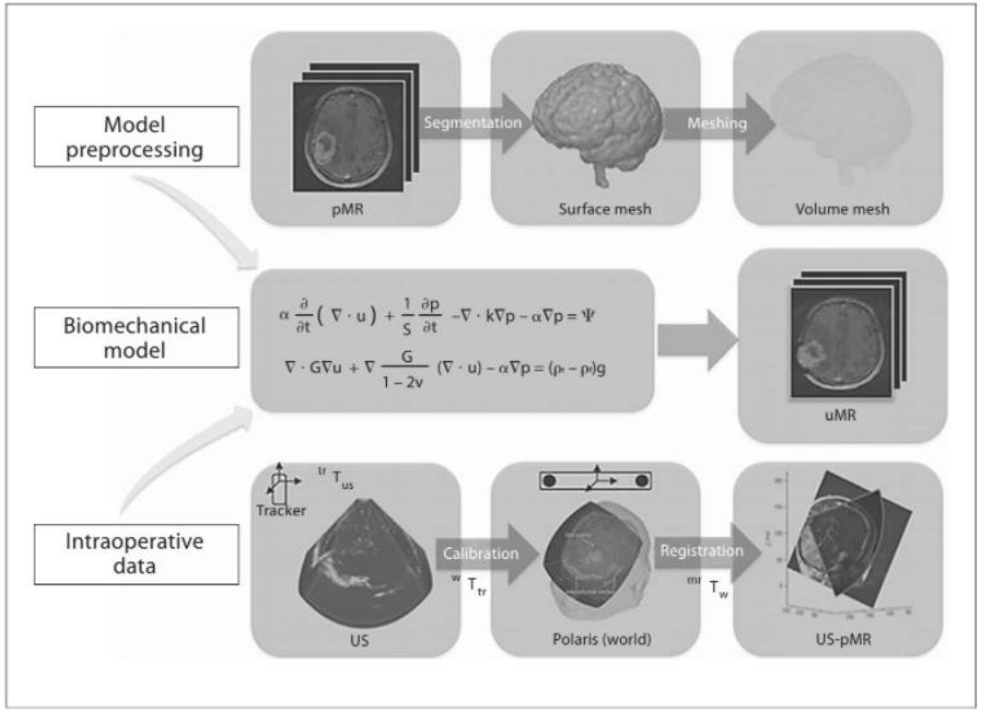
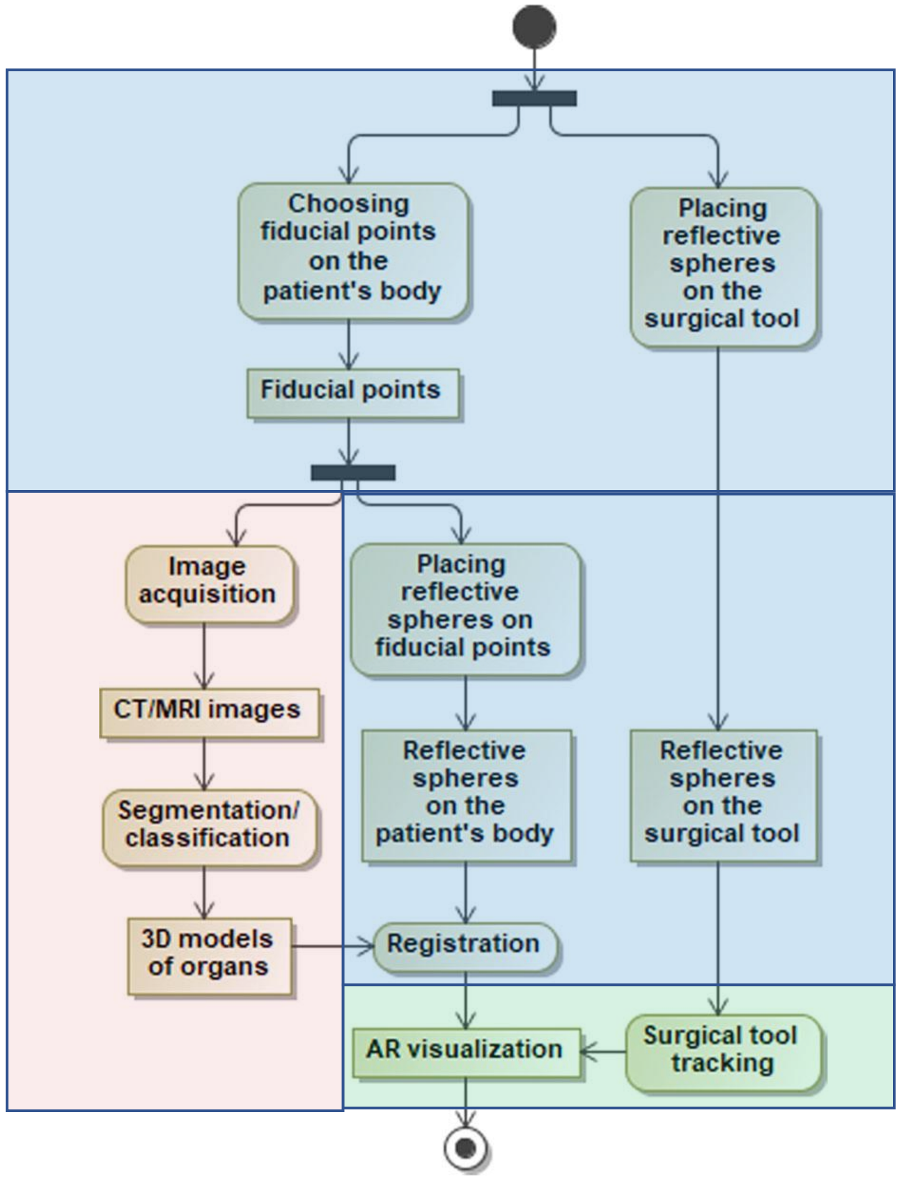


Fig. 1. Preoperative, updated, and intraoperative images of patient 1. The top row from left to right (**a–c**) shows preoperative T_1-weighted postdurotomy MR images without compensation for brain shift (pMR). The bottom row from left to right (**e–g**) shows the updated T_1-weighted MR images immediately after durotomy with compensation for brain shift (uMR). The surgical microscope was coregistered and tracked by the navigational system.

Stereotact Funct Neurosurg 2010;88:1–10
DOI: 10.1159/000258143

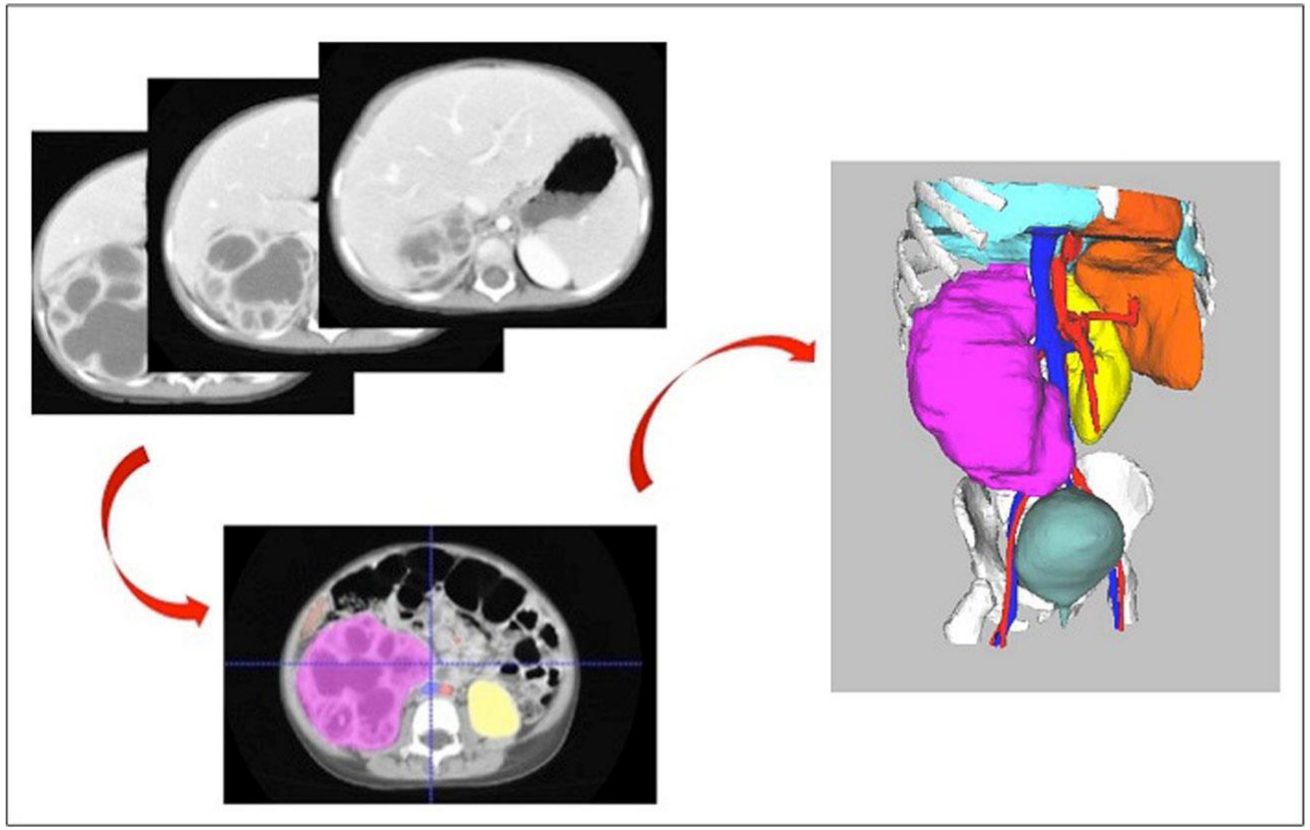
Navigation Systems Workflow



- Building of the 3D models of organs
- Image registration with respect to the patient's body
- Tracking of surgical tools

Paolis, L. T. D., & Luca, V. D. (2018). Augmented visualization with depth perception cues to improve the surgeon's performance in minimally invasive surgery. *Medical & Biological Engineering & Computing*, *57*, 995-1013.

3D models of the patient’s organs

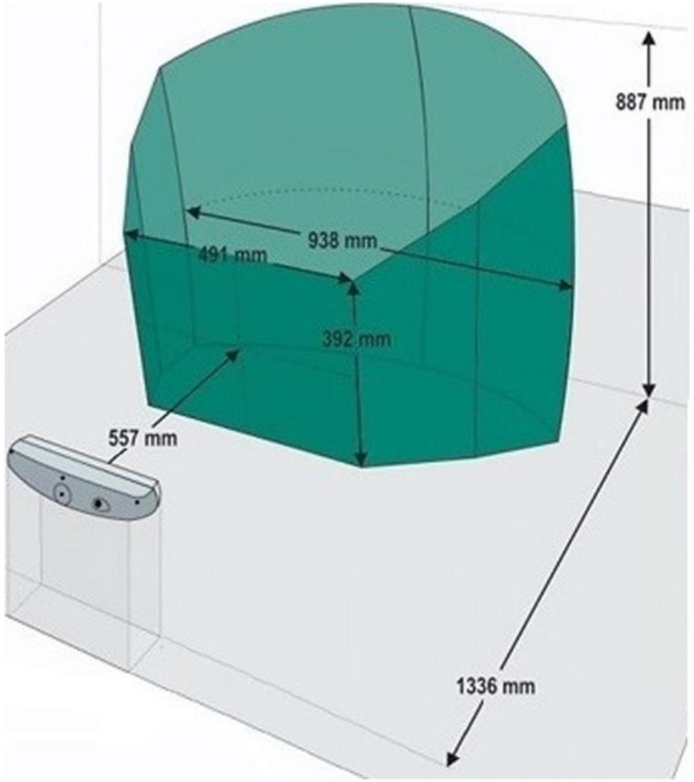


- Image segmentation
- 3D Mesh Reconstruction
- 3D Mesh Simplification

Paolis, L. T. D., & Luca, V. D. (2018). Augmented visualization with depth perception cues to improve the surgeon’s performance in minimally invasive surgery. *Medical & Biological Engineering & Computing*, *57*, 995-1013.

Image processing steps for a case study of a 2-year-old child with a benign tumor of the right kidney;
some organs (the liver and stomach) are completely hidden and the skin and the muscles of the abdominal region are displayed in total transparency; the tumor is shown in magenta

Tracking systems



- Detect without delay the position and the orientation of the surgical tool.
- Two infrared cameras and a position sensor to detect infrared-emitting or retroreflective markers affixed to a tool or object.
- Know the position and orientation of the tools within a specific measurement volume.
- Accuracy up to of 0.2 mm and 0.1º.

Some Commercial systems:

- Polaris Vicra optical tracker (NDI Inc.)
- OptiTrack VT120 Duo optical tracker (OptiTrack)

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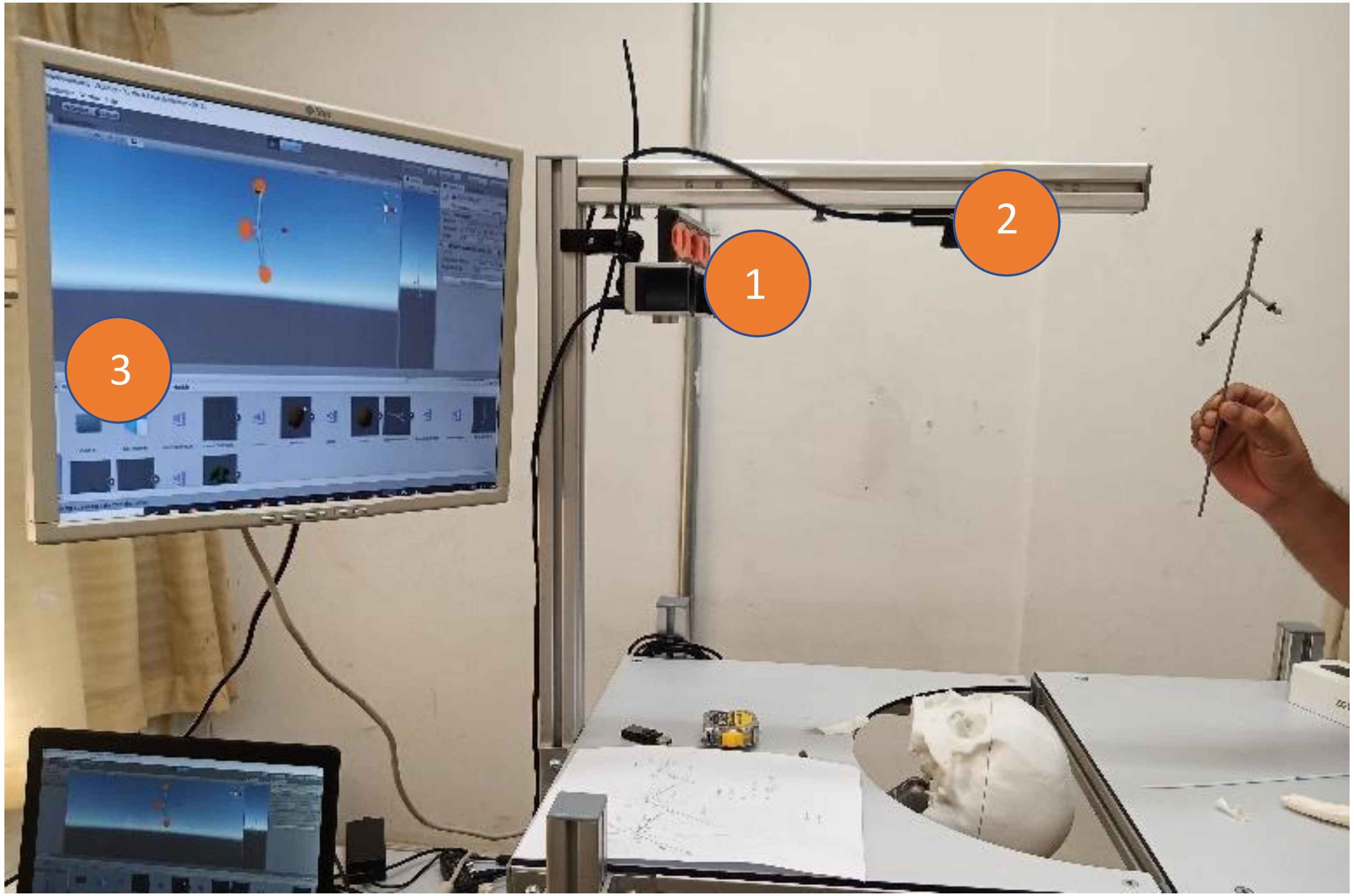

Configuración del sistema, incluida la cámara de seguimiento de objetos reflectantes OptiTrack (1), cámara estéreo para visualización RA (2) e implementación en el mundo virtual (3)

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PHACON: Sinusoidal Training Sytem

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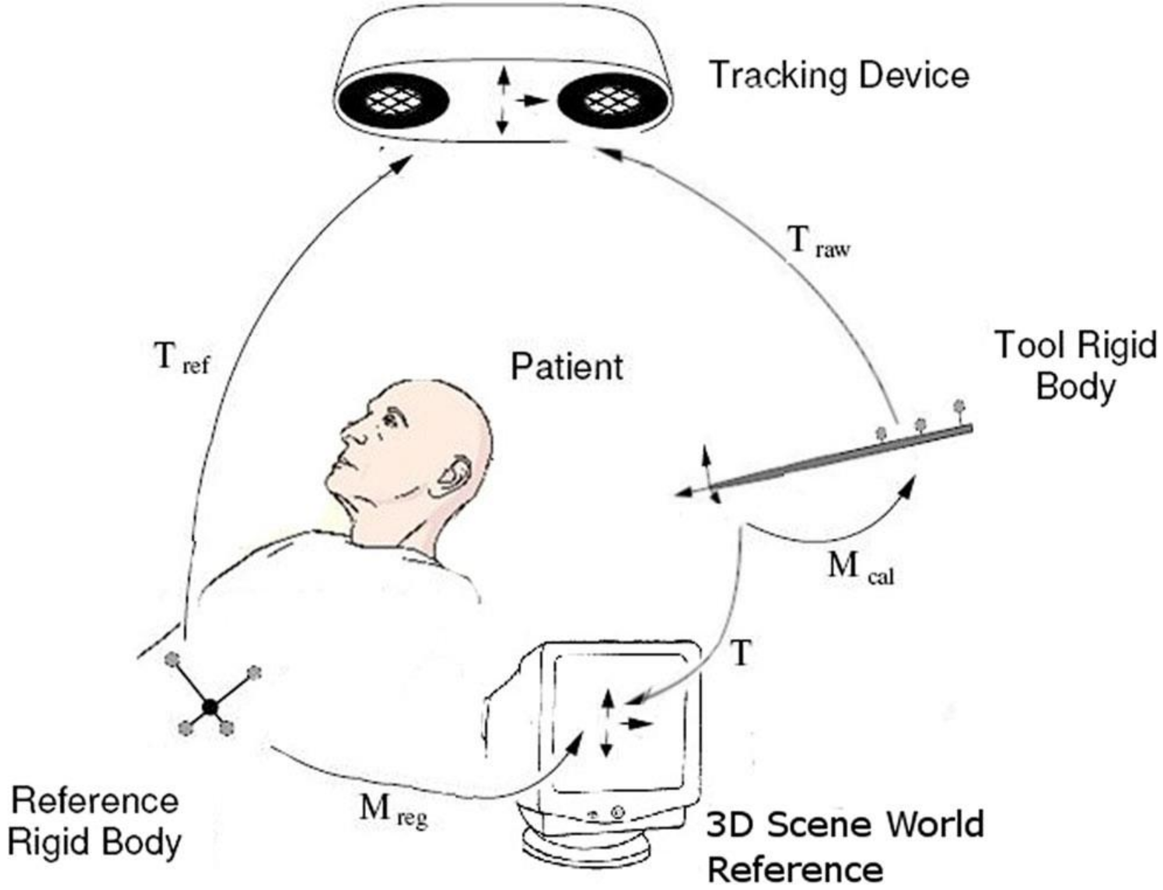
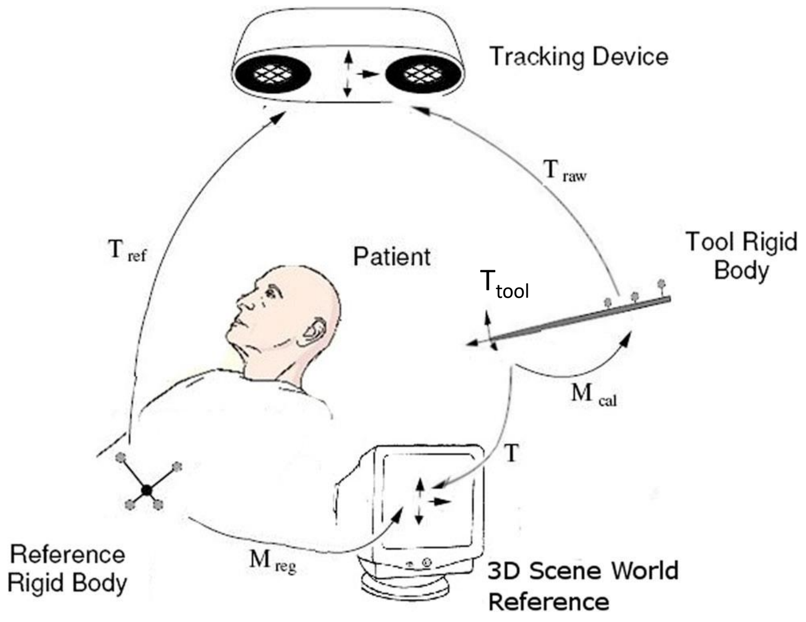
Surgical Navigation



The entire system consists of four different reference systems:

- The reference system of the optical tracker;
- The reference system of the camera;
- The reference system associated with the tool located on the camera;
- The global reference system that identifies the position of the virtual object in the real scene.

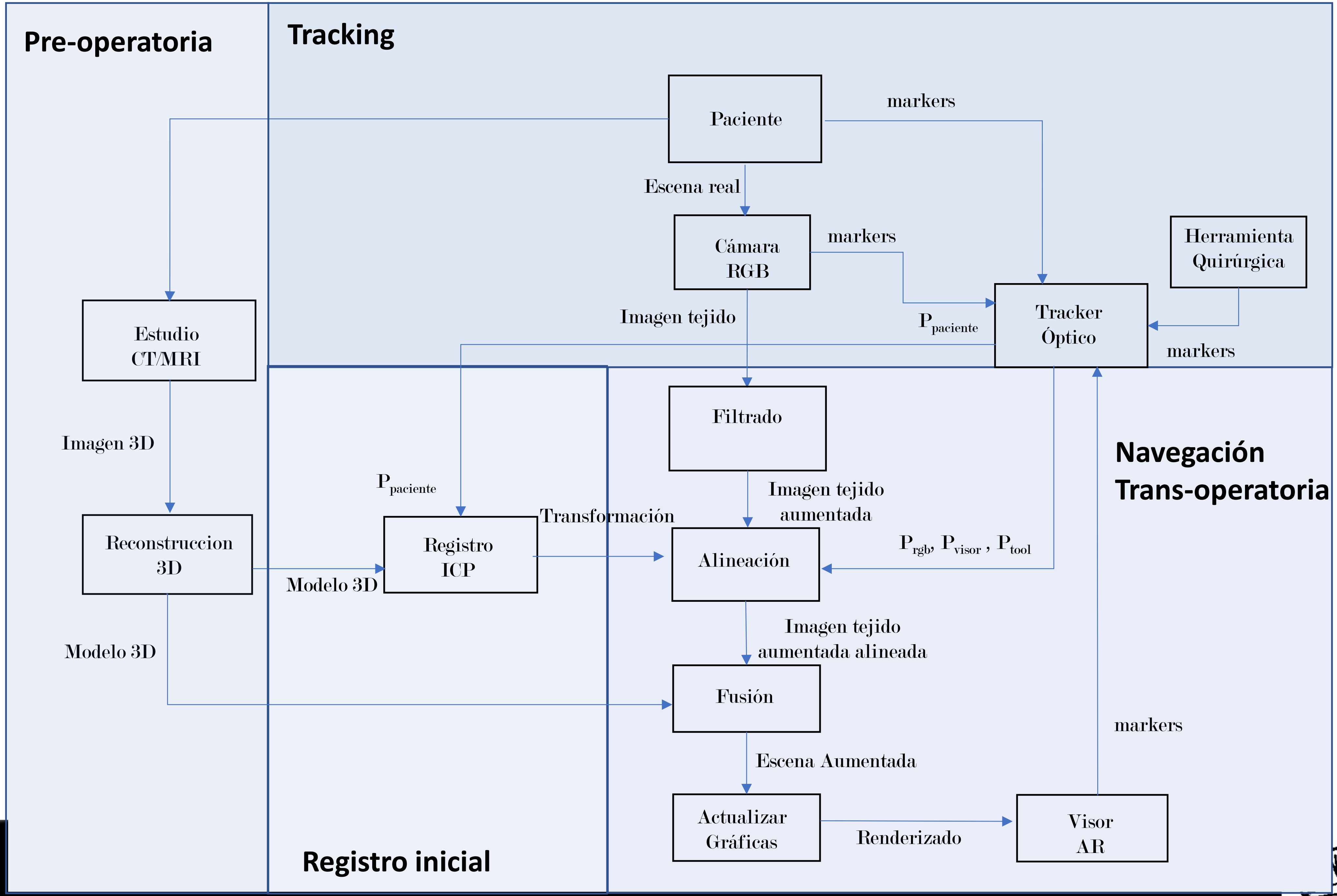
System transformations



$$T_{tool} = T_{ref}^{-1} T_{raw} M_{cal}$$

$$T = M_{reg} T_{ref}^{-1} T_{raw} M_{cal}$$

- T_{tool} is used to find the position of the surgical instruments compared to the reference rigid body.
- T_{raw} specifies the surgical tool pose with respect to the tracker coordinate system.
- T^{-1}_{ref} sets the relation between the reference rigid body coordinate system and the tracker coordinate system.
- M_{cal} the relation between the surgical tool pose and position of its tip.
- T describes the position of the probe tip inside the 3D virtual scene.
- M_{reg} is the transformation is the result of the **registration phase** and is used to define the reference rigid body position in the global 3D scene reference system.



Pre-operatoria
Tracking
Paciente
markers
Escena real
Cámara RGB
markers
Herramienta Quirúrgica
Imagen tejido
P paciente
Tracker Óptico
markers
Estudio CT/MRI
Filtrado
Imagen 3D
Navegación Trans-operatoria
P paciente
Imagen tejido aumentada
Transformación
Reconstruccion 3D
Registro ICP
Alineación
P rgb, P visor , P tool
Modelo 3D
Imagen tejido aumentada alineada
Modelo 3D
Fusión
markers
Escena Aumentada
Actualizar Gráficas
Renderizado
Visor AR
Registro inicial
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