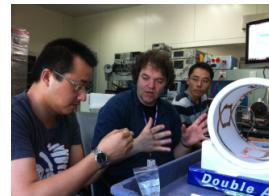


Navigation for *AR & Surgical Robotics*

Calibration & Computer Vision & Sensor Fusion



Wenyi Zhao
2020



What is Navigation and How?

navigation noun

2. the science of getting ships, aircraft, or spacecraft from place to place

especially : the method of determining **position**, **course**, and **distance traveled**

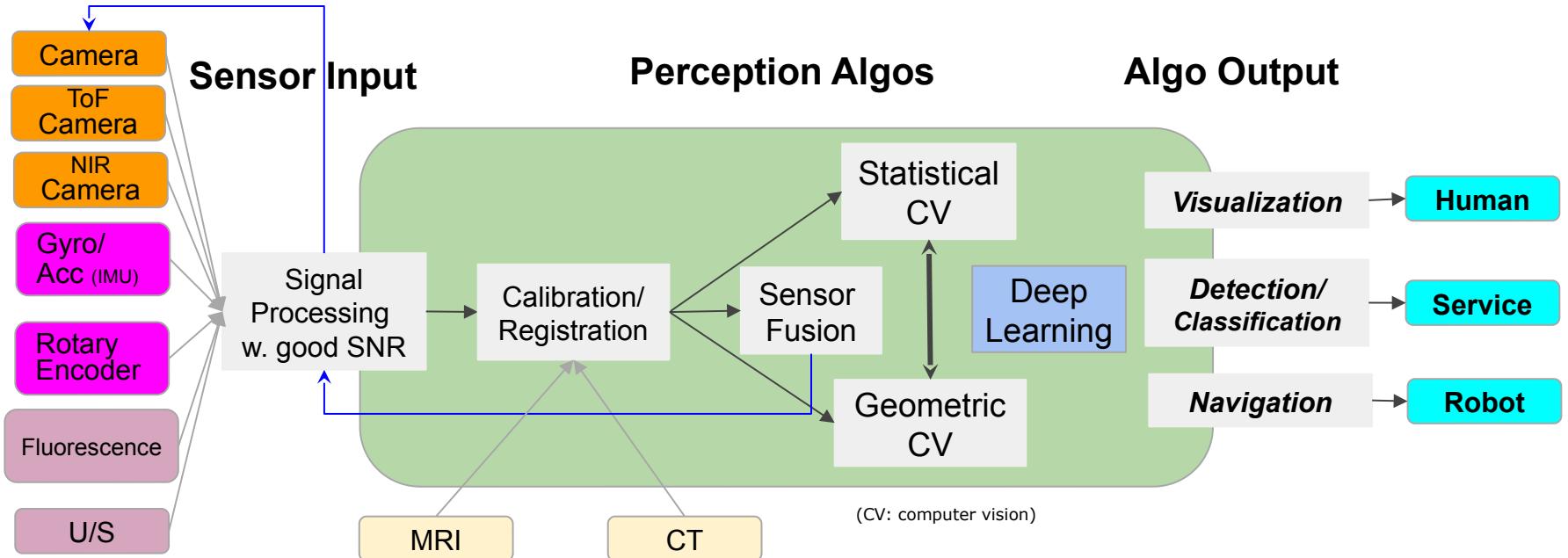


The [compass](#) was invented more than 2000 years ago. The first compasses were made of lodestone, a naturally magnetized stone of iron, in [Han dynasty](#) China (20 BC – 20 AD). The compass was later used for navigation during the Chinese [Song Dynasty](#) (960–1279 AD), as described by [Shen Kuo](#). Later compasses were made of iron needles, magnetized by striking them with a lodestone. Magnetized needles and compasses were first described in medieval Europe by the English theologian [Alexander Neckam](#) (1157–1217 AD).



Vikings navigated using [sundials](#) calibrated to show the direction of the North Pole. While there is no physical evidence for the navigational techniques adopted on cloudy days, there are references in the Viking sagas to “[sunstones](#)” being used.

Machine Perception (AI): Wenyi's Systems Perspective



Product Development Cycle (**Systems Perspective**)

Simulation & Analysis

Systems Architecture

Compute Architecture

Hardware Development

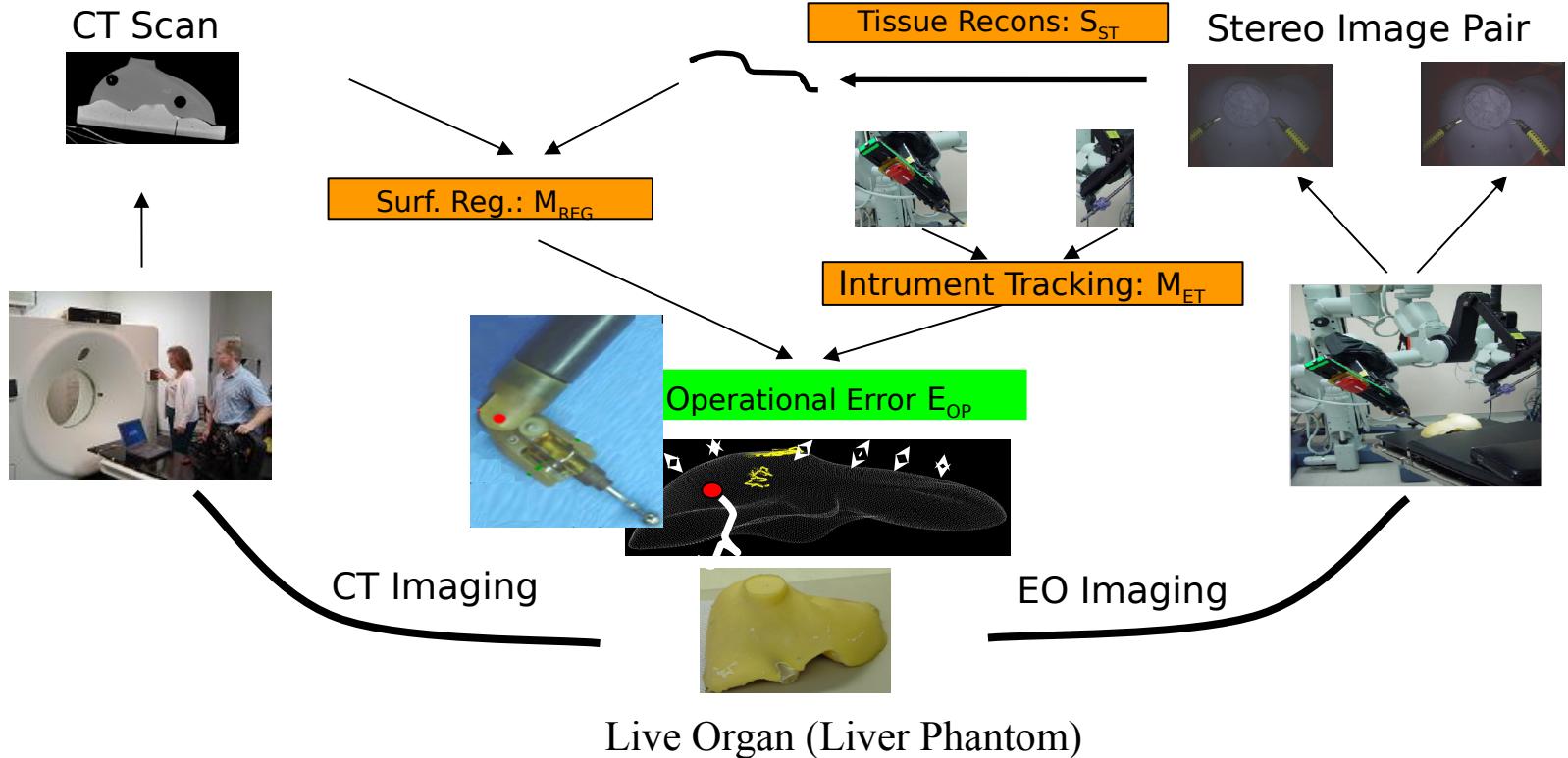
Software Development

Manufacture/Calibration

AR Application: Real-time Overlay

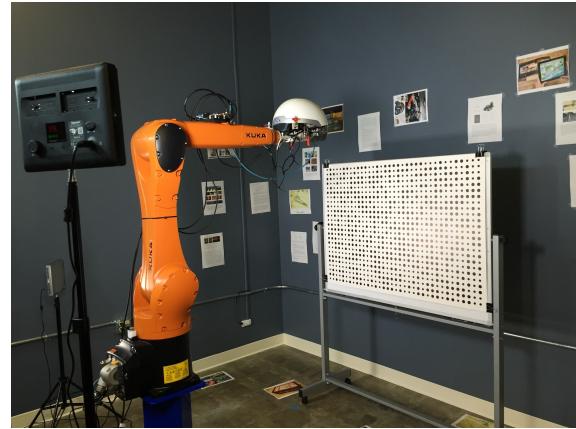
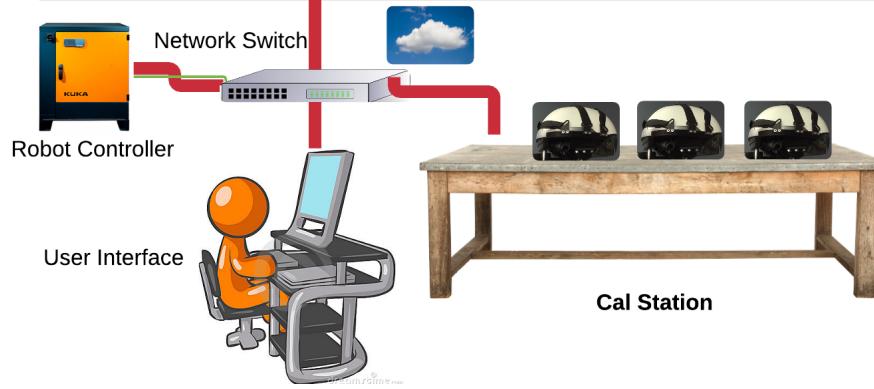
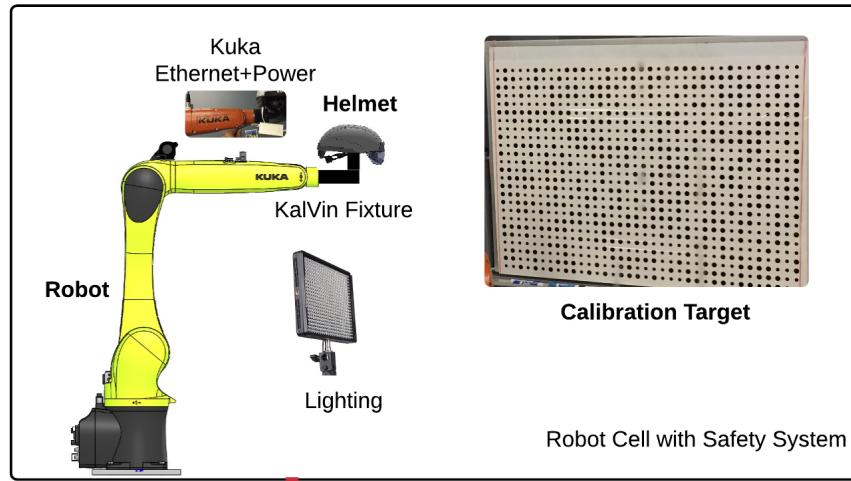


Surgical Robotics Application: Image Guided Surgery

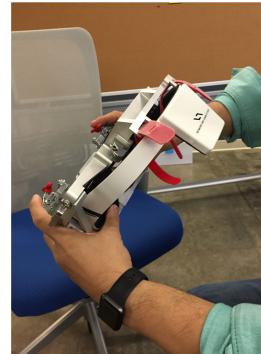


1. Calibration

Factory Calibration Automation/DAQRI: Key Enabler



Smart Helmet



Smart Glasses 6

Navigation for AR: Visual Innertial Navigation/DAQRI

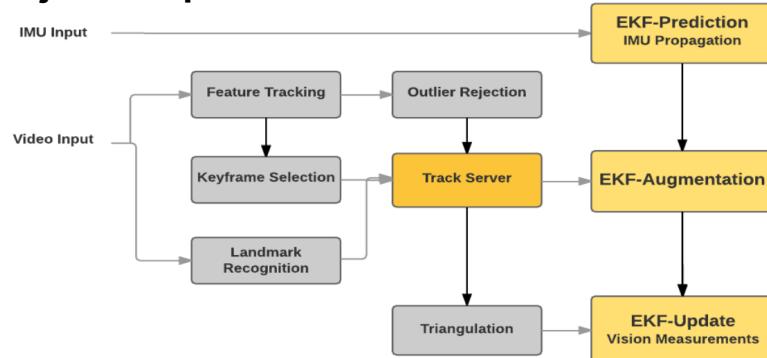
Sensor Fusion for Real-time VIN

- IMU & Camera Sensor Fusion for 1kHz 6DOF pose
- IMU@1kz for low-latency pose with little jitter
- Vision@30hz with accurate calibration for absolute pose accuracy
- Extendable to include auxiliary sensors - GPS, WiFi

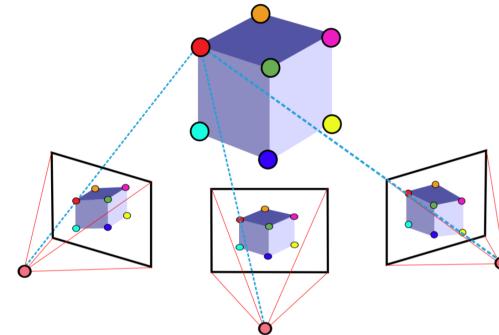
IMU (inertial measurement unit) 15-dim State

$$X_I = \begin{pmatrix} {}^W\mathbf{p}_I \\ {}^W\mathbf{v}_I \\ {}^W\mathbf{q}_I \\ \mathbf{b}_g \\ \mathbf{b}_a \end{pmatrix} \begin{array}{l} \text{Position x3} \\ \text{Velocity x3} \\ \text{Unit Quaternion x3} \\ \text{Gyro bias x3} \\ \text{Acc bias x3} \end{array}$$

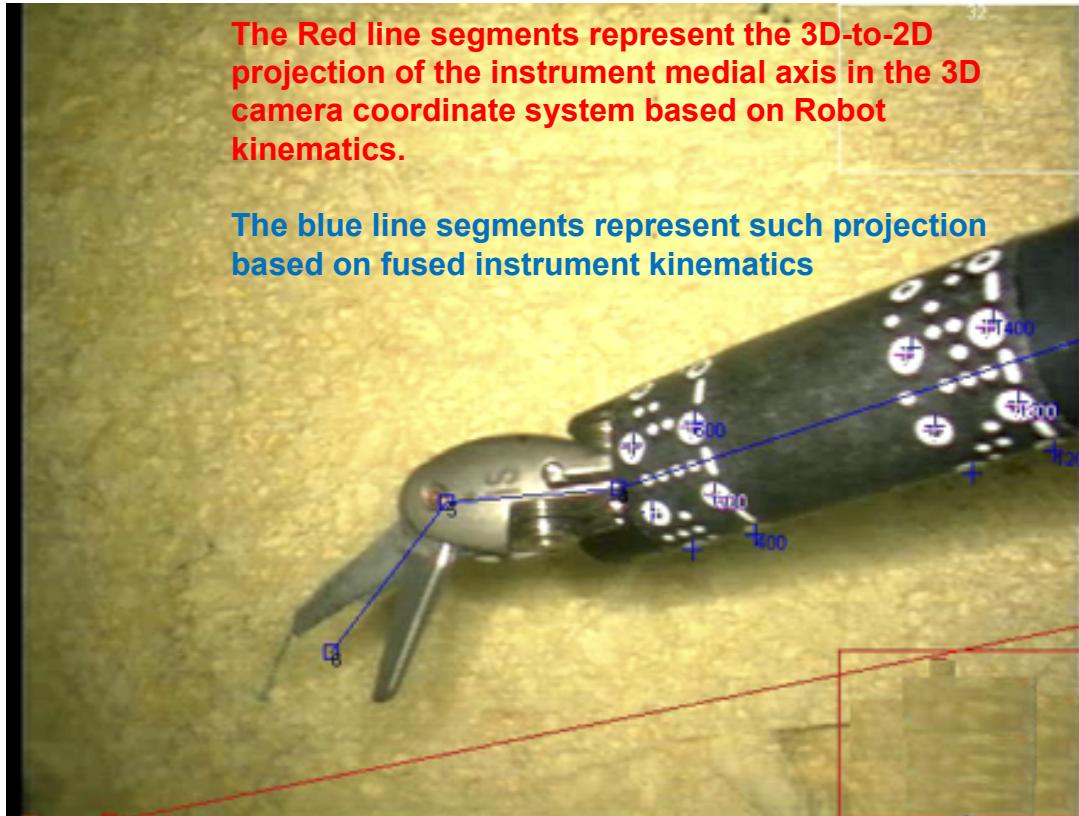
Major Components of VIN



CV: 2D rays ↗ Triangulation ↗ 3D points

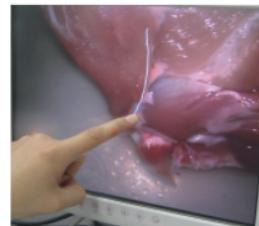


Navigation for Surgical Robotics: Instrument Tracking



daVinci Instrument Tracking

3D Telestration based on Sparse Tissue Tracking

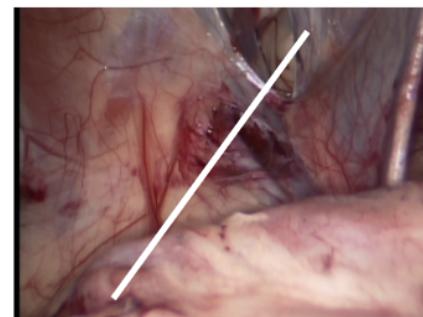
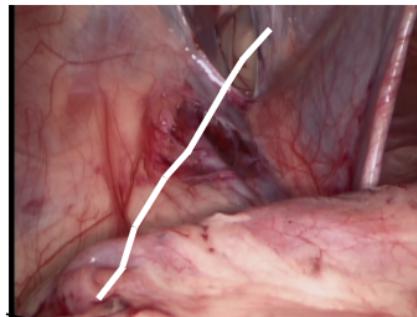


Mentor drawing on
2D Touch Screen
(local or remote)



Algorithm drawing

← Mentor drawing



Resident seeing where the
mentor draws in 3D

