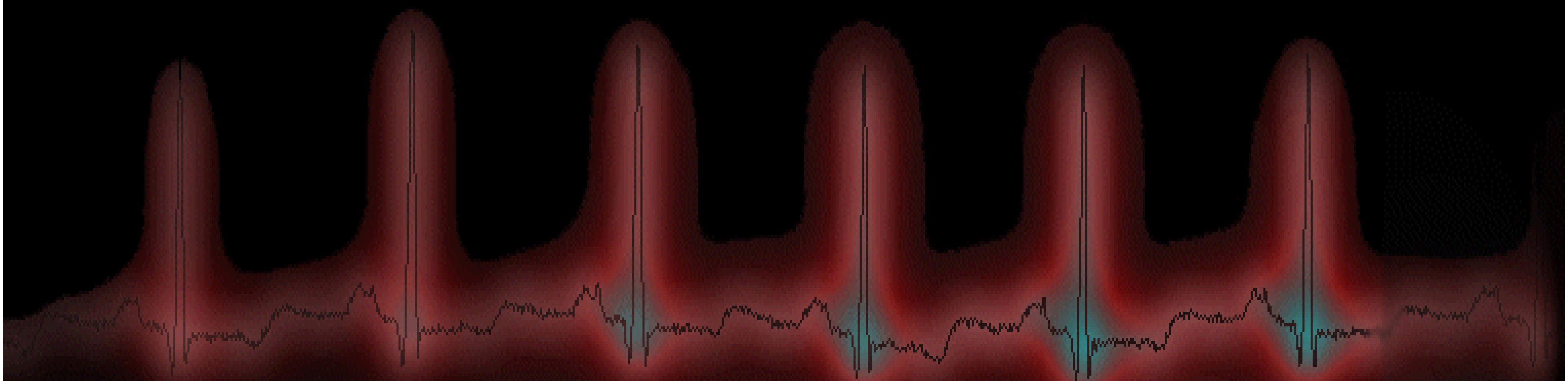
Fluoroscopic Navigation to Guide Catheter Ablation of Cardiac Arrhythmias



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Queens University

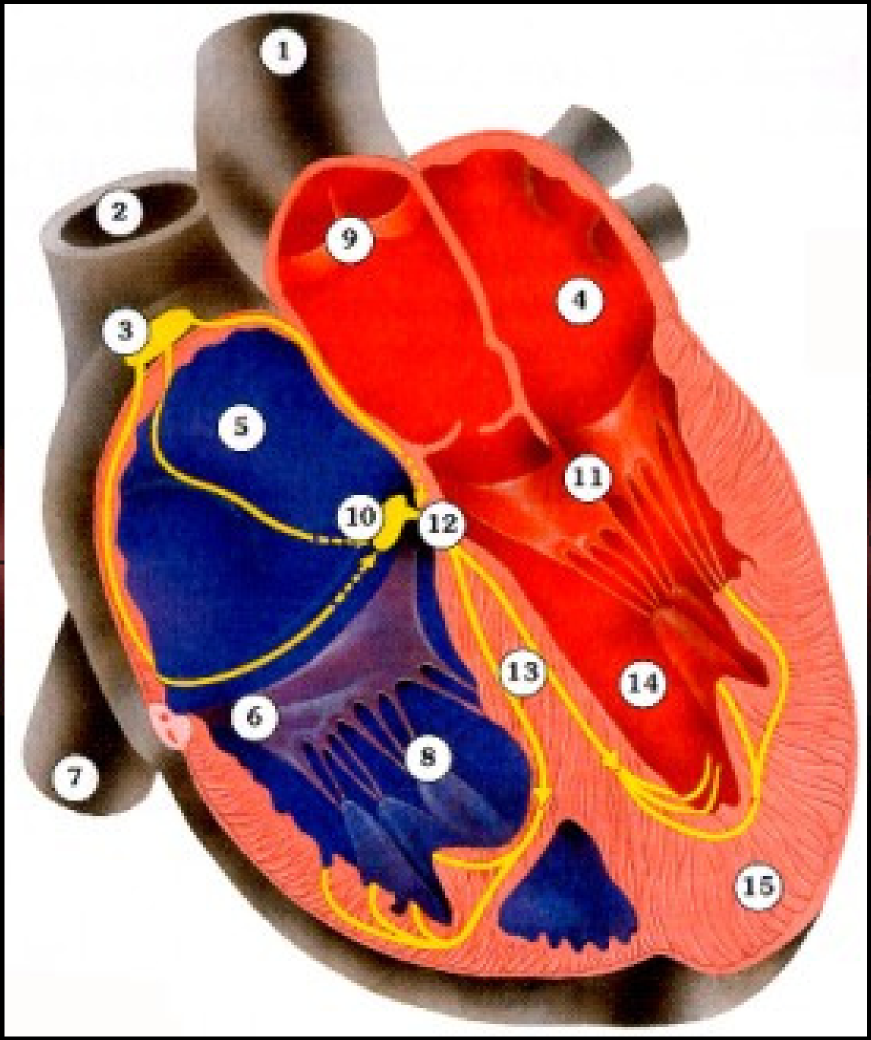
School of Computing

Anatomy

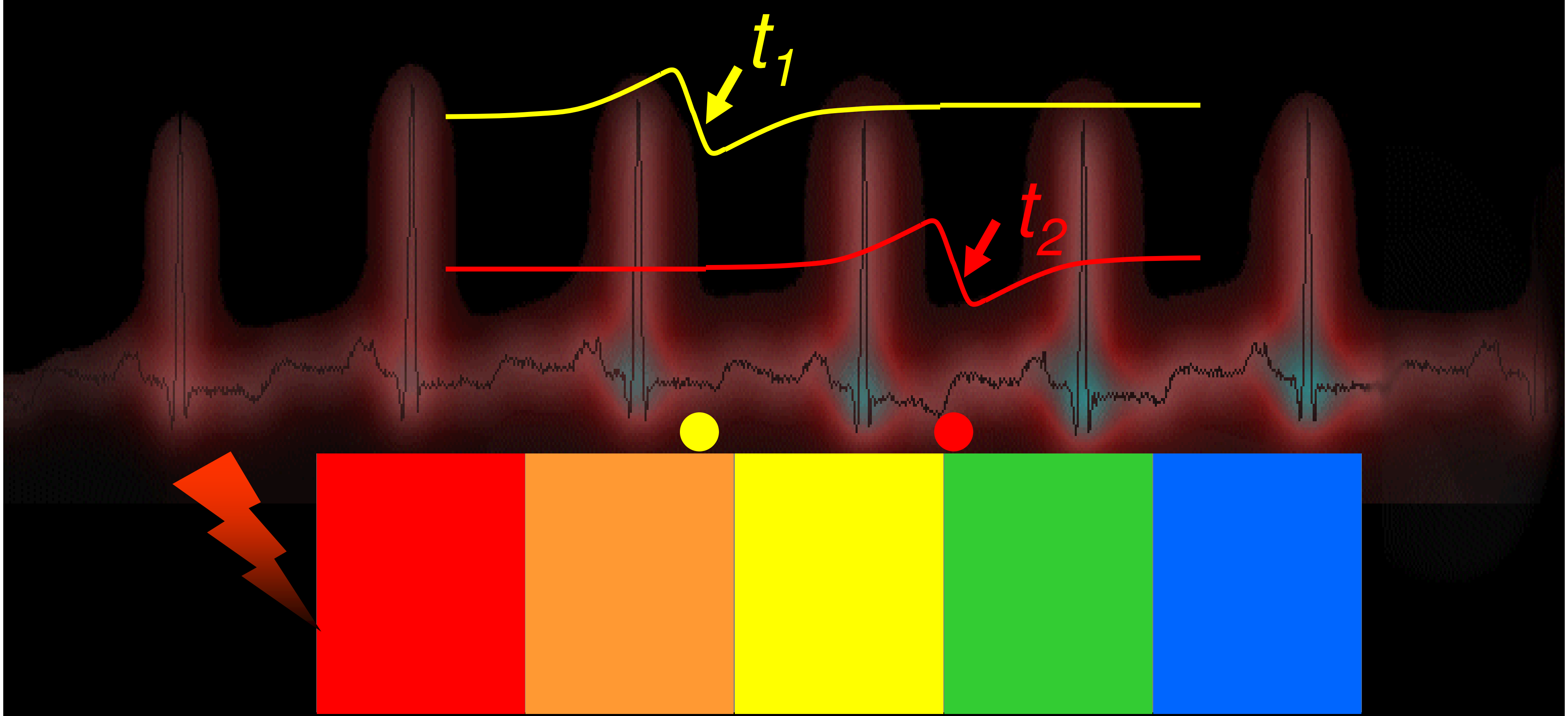
4. Left Atrium
5. Right Atrium

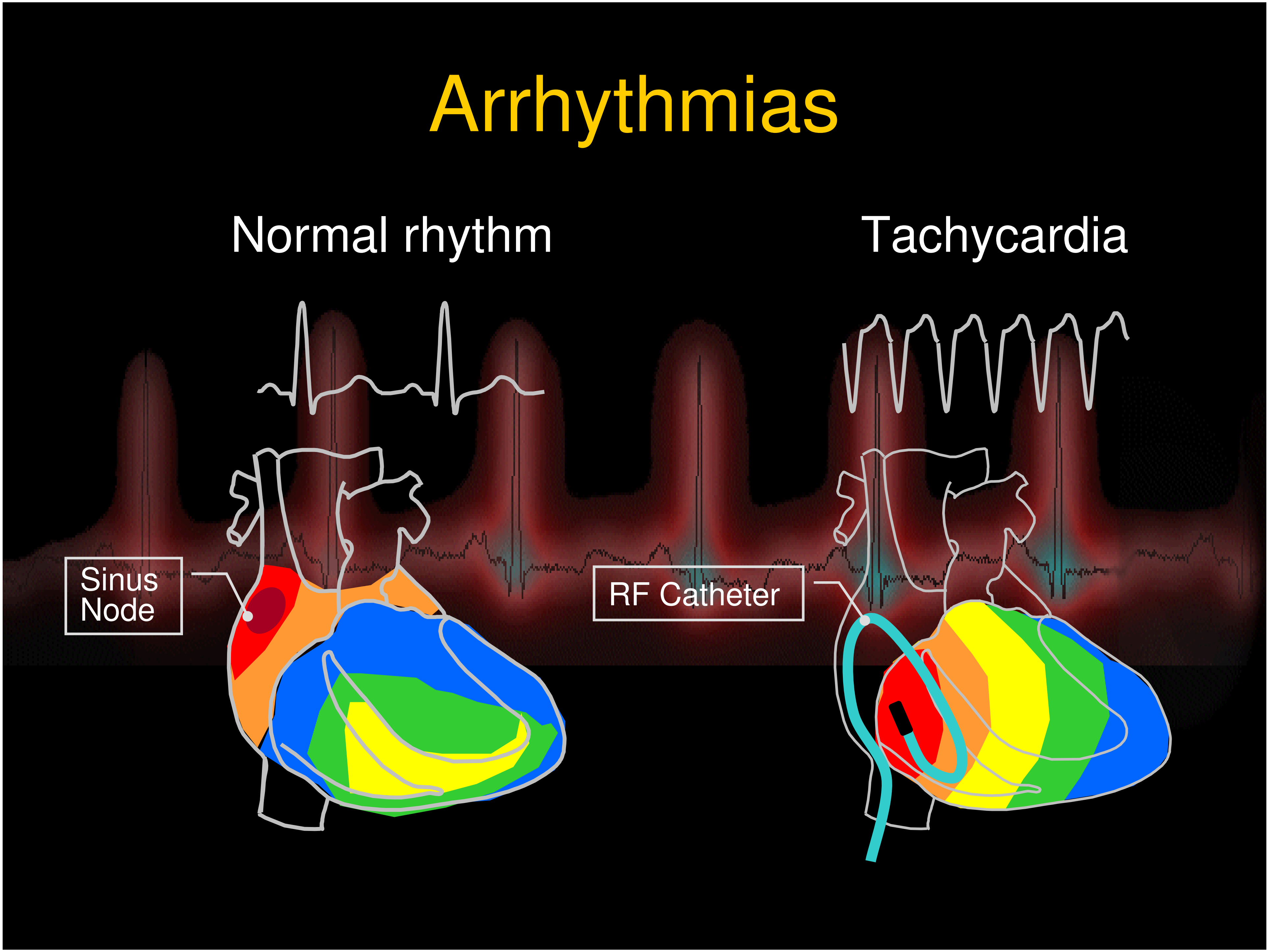
8. Right Ventricle
14. Left Ventricle

13. Septum (wall)



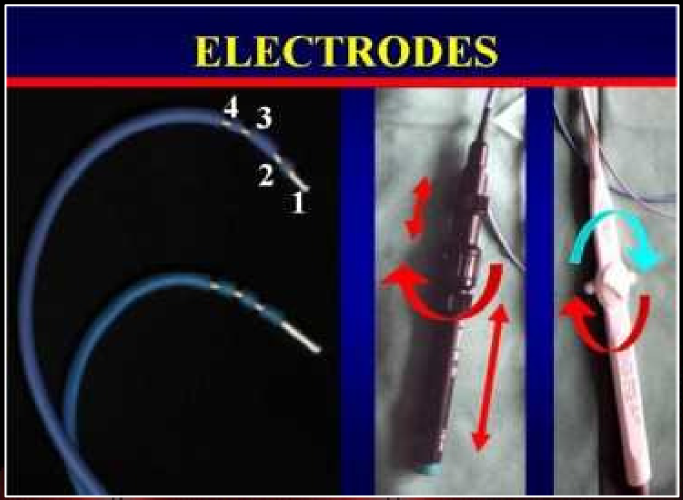
Cardiac Electrical Activation



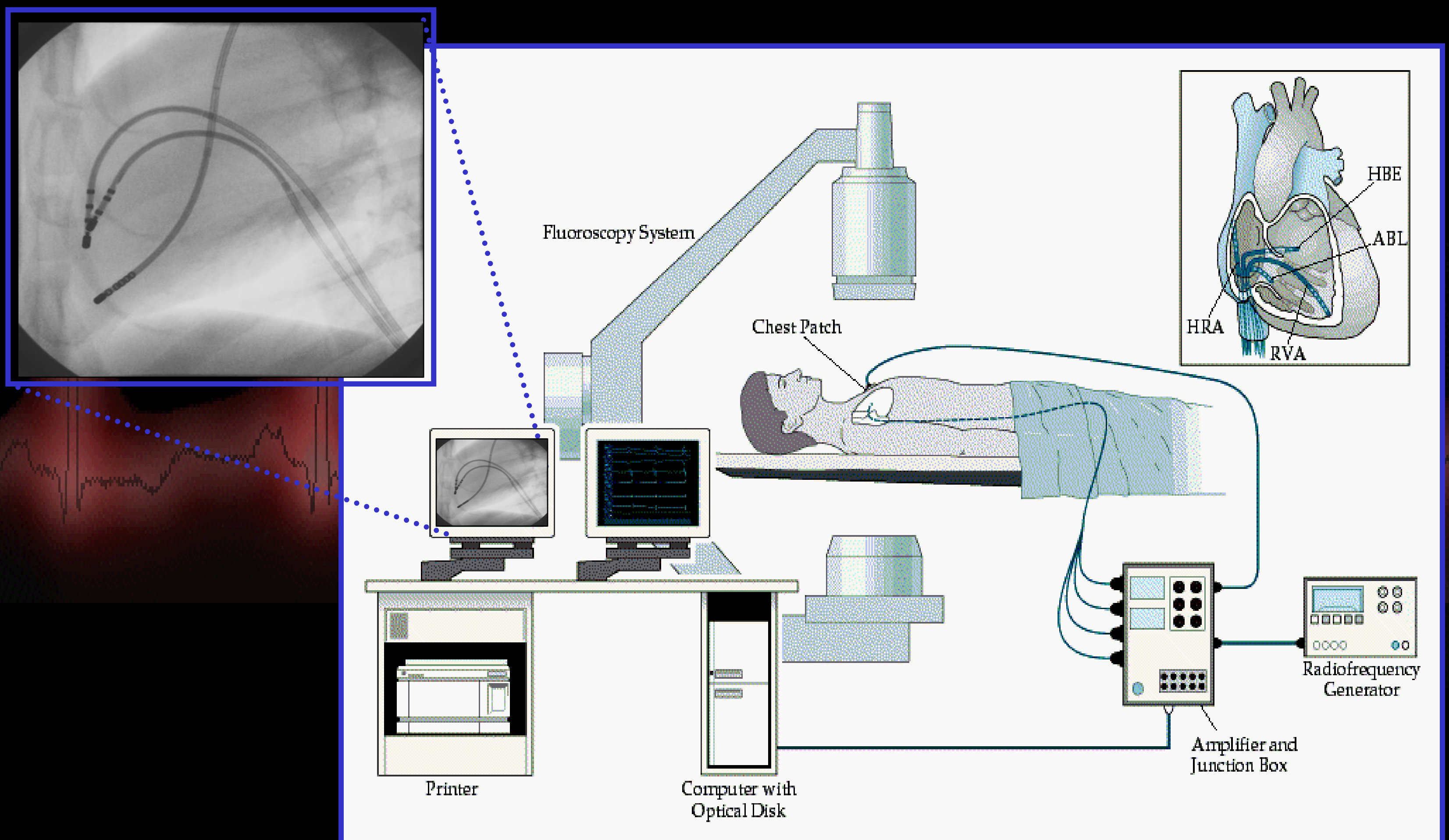

Arrhythmias
Normal rhythm
Tachycardia
Sinus Node
RF Catheter

Radiofrequency (RF) Ablation

- Goal: ablate arrhythmogenic sites
- RF Generator:
  - frequency: about 500 kHz
  - power: 10-30 W
  - energy transmitted to electrodes
- Efficiency: high
- Duration: several hours

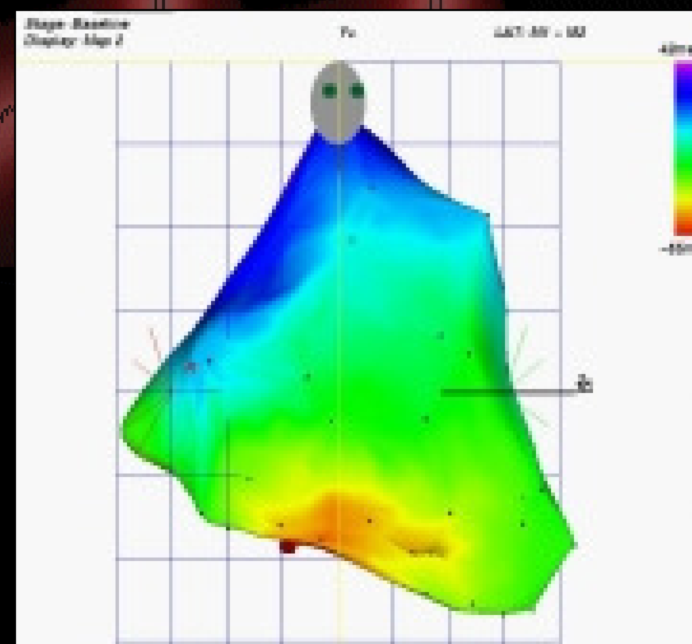


RF Ablation Laboratory



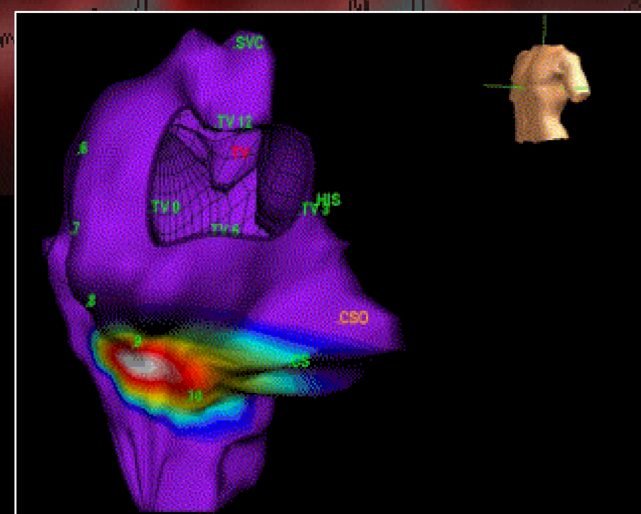
CARTO^{TM} System

- 3D magnetic sensor
- Real time positioning
- Point- by - Point system
- Price: ~360 000$ CDN



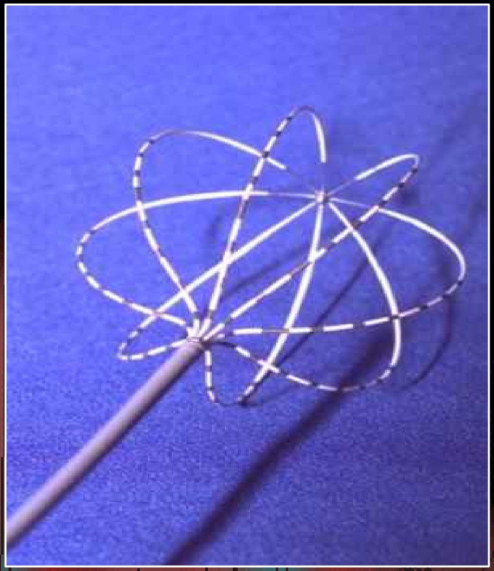
ENSITE 3000 System

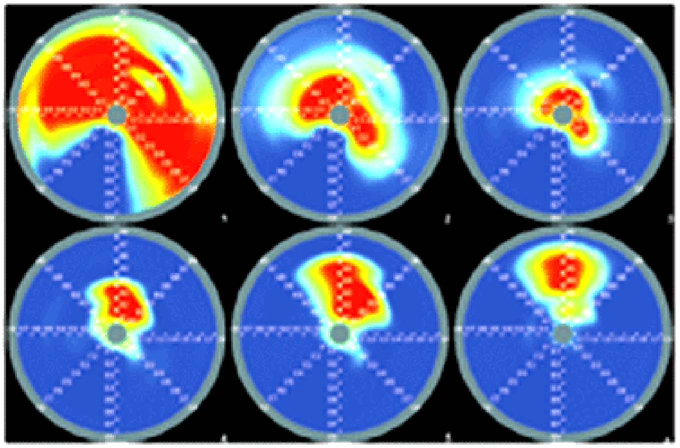
- Catheter balloon with 64 electrodes
- Catheter receives signals from surrounding cardiac walls
- Electrical signals treated by computer to produce 3D
- Price: ~390 000$ CDN



Constellation Basket

- 64 electrodes on basket shaped catheters
- Expand basket so that it touches cardiac walls
- Price: ~100 000$ CDN





General Objective

1. Reduce the duration of catheter ablation procedure.

2. Improve its efficiency by providing visual guidance to the cardiologist about the position of the catheter with respect to the origin of activation.

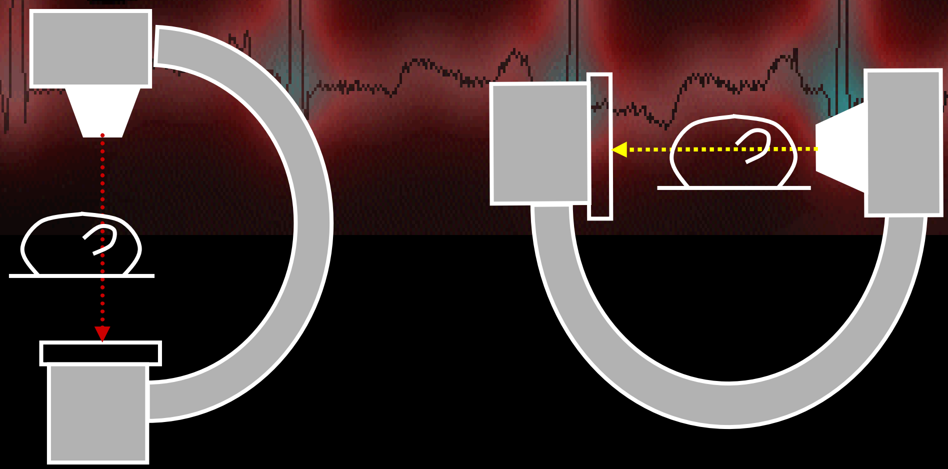
Specific Objectives

1. To perform a 3D analysis on geometric and electrical data obtained from two perpendicular fluoroscopic images.

2. Fusion of this information together.

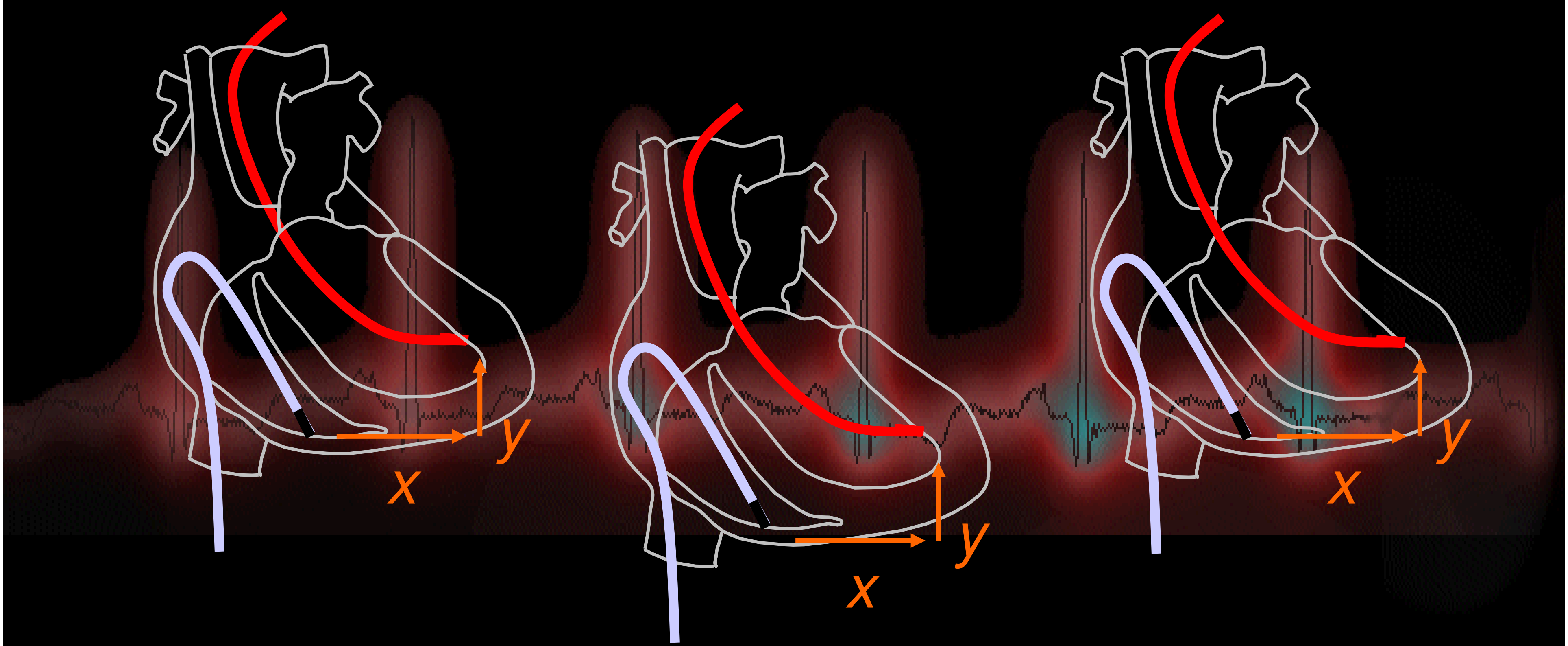
Experimental Protocol

- Animal: 1 mongrel dog
- Catheters:
  - Mapping: 20 sites visited in left ventricle
  - Reference: right ventricle
  - Stimulation: right ventricle
- Fluoroscope: *Philips* Monoplane Fluoroscope



- Image acquisition: end of expiration, in diastole

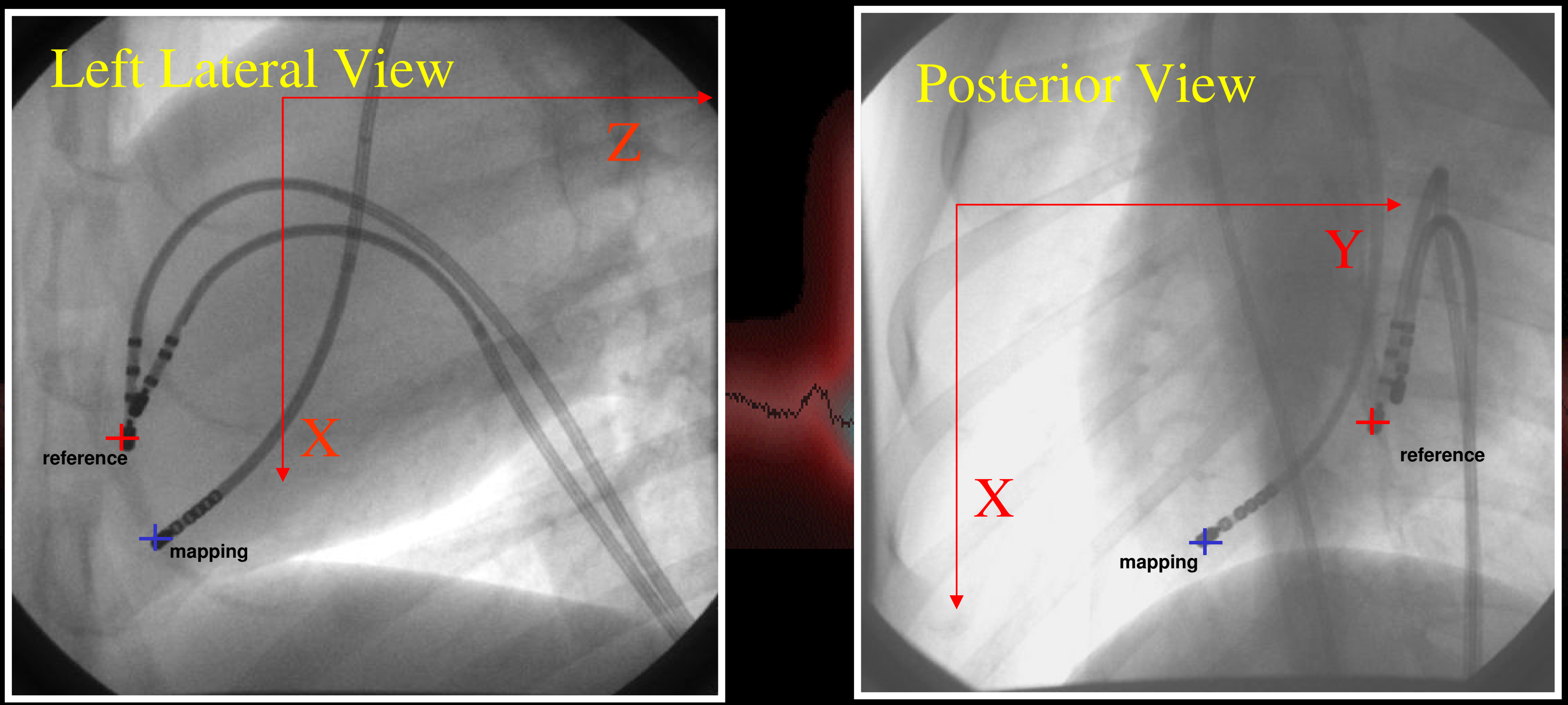
Catheters



Reference catheter

Mapping catheter

Electrode Measurement



Two-View reconstruction and extraction of 2D pixel coordinates from mapping and reference catheters throughout the 20 biplane datasets

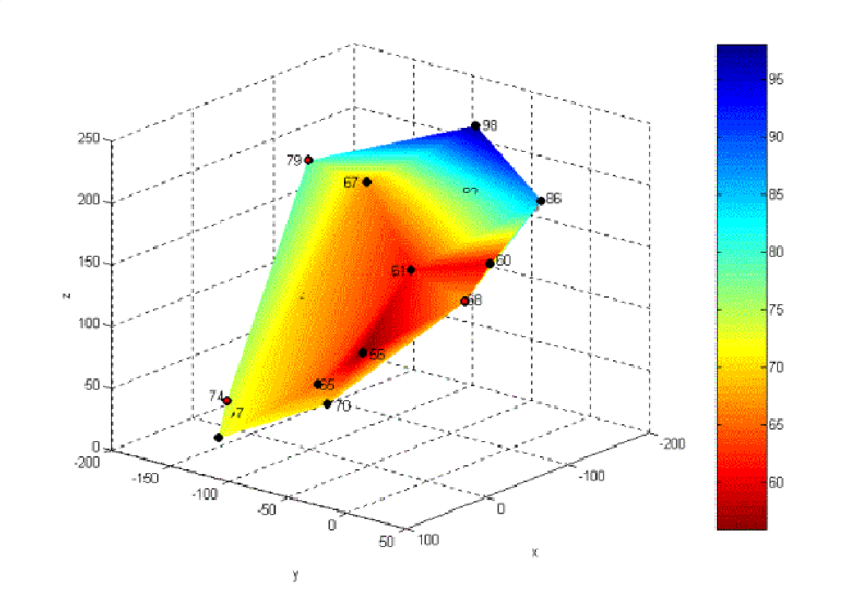
Convex hull 3D

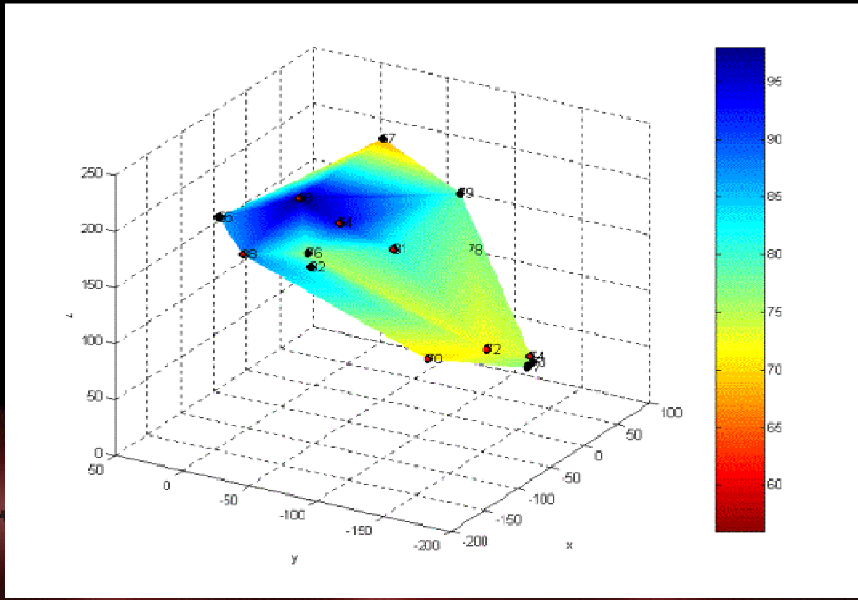
X	Y	Z	Temps (ms)
78	-124	24	73
19	-43	98	56
-35	-126	218	79
-126	9	196	86
-156	-72	197	76
6	-48	231	67
5	-82	43	70
-58	-157	96	72
-143	-68	178	82
50	-134	33	77
-54	-6	130	68
-3	-17	166	61
-149	-20	179	88
-142	-58	236	98
-129	-82	216	94
3	-113	150	78
38	-68	71	65
-72	3	158	60
-99	-108	188	81
51	-136	43	74

DATA

- 20 coordinates in XY
- 20 coordinates in XZ
- 20 activation times (ms)

Convex hull 3D





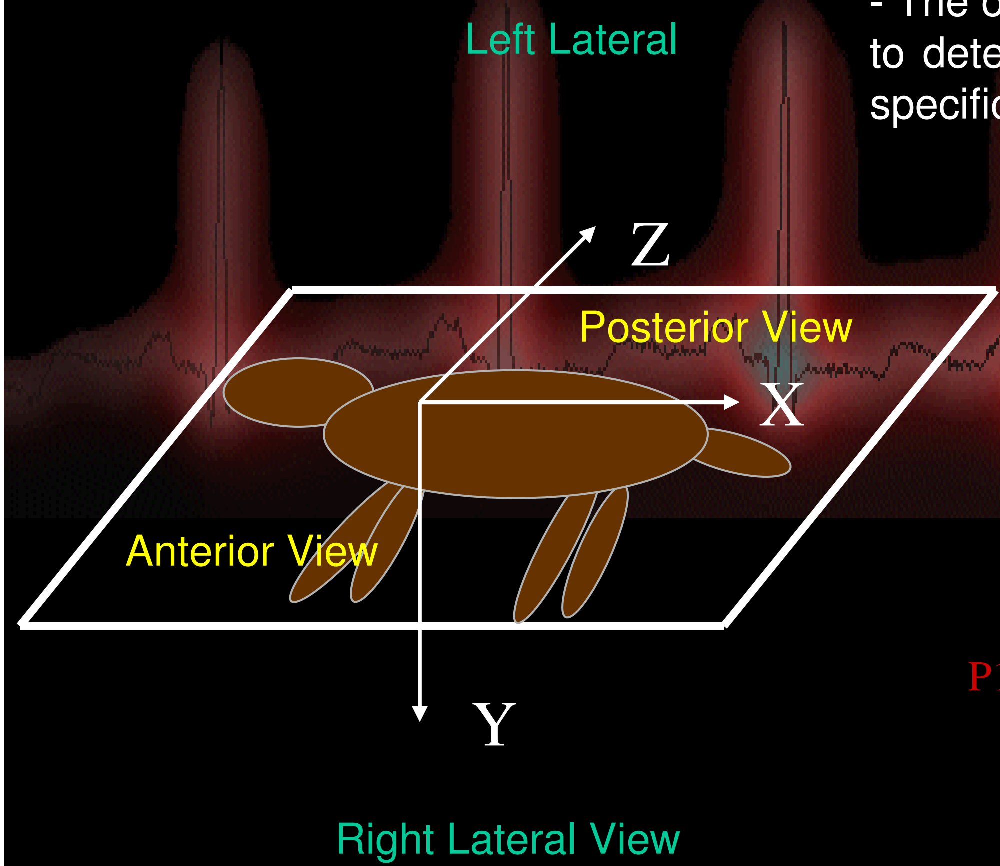
3D Reconstruction of ventricle using a convex hull fitting method through all 20 mapping sites.

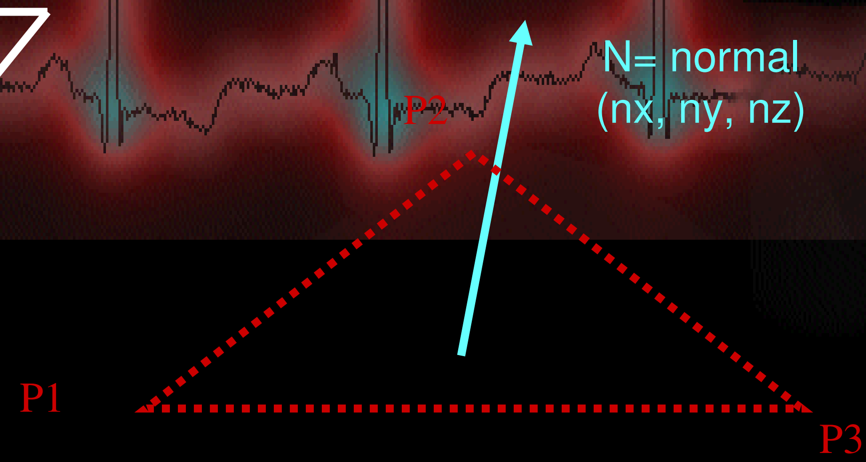
Electrophysiological data (in ms) is superimposed directly on volume using interpolation.

2D Fusion Mapping

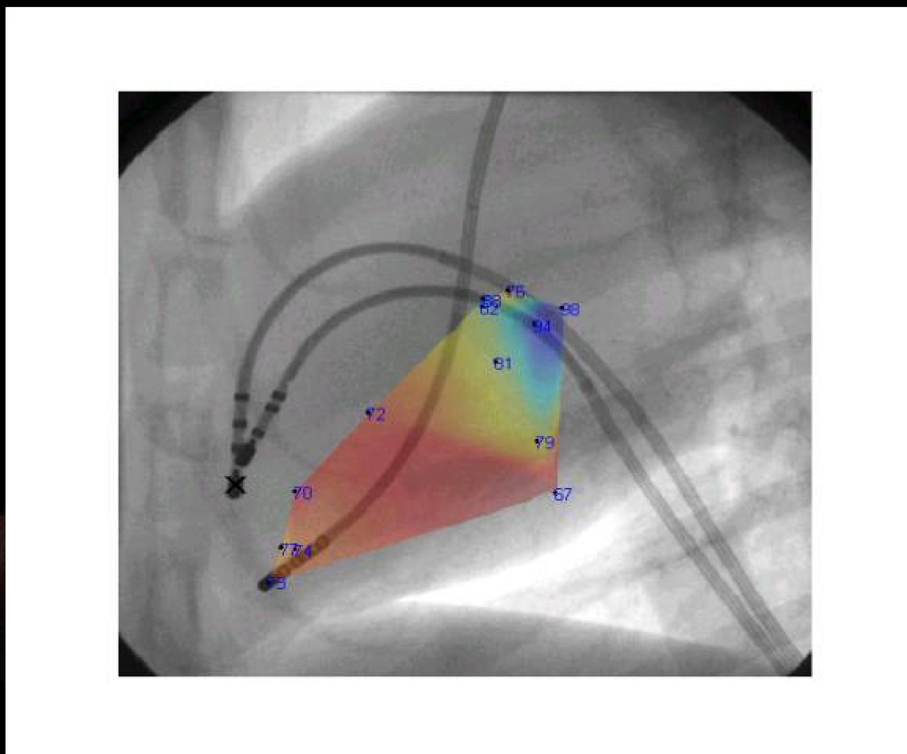
- 20 coordinates representing the C*onvex hull vertices. Each vertex is an association of triangles in space.*

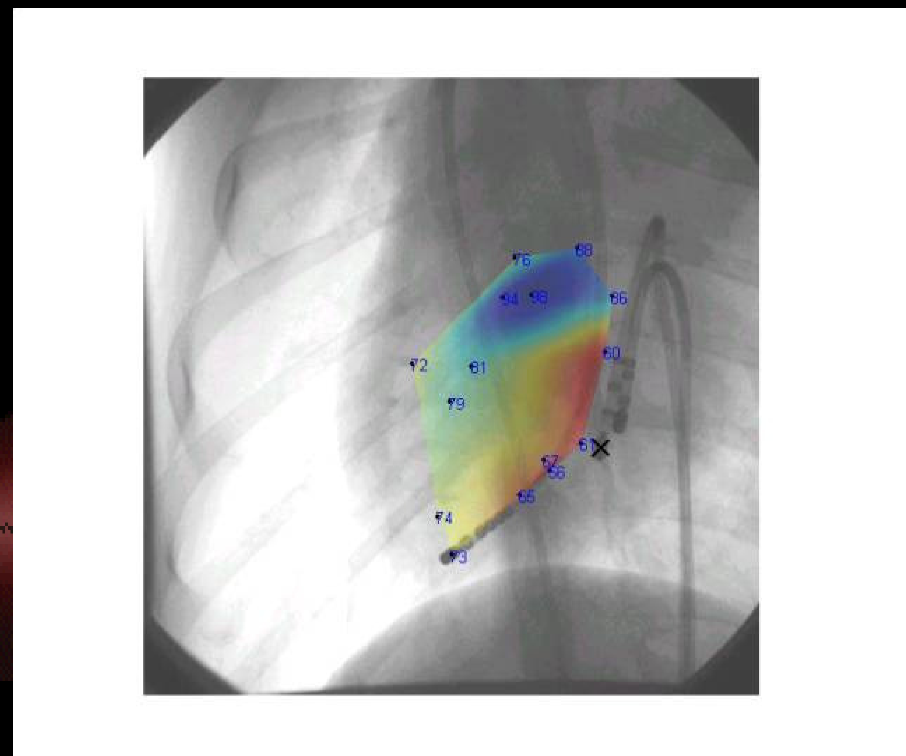
- The outward normal of each triangle are calculated to determine the 2D visible activation times from a specific point of view.





Fusion Mapping



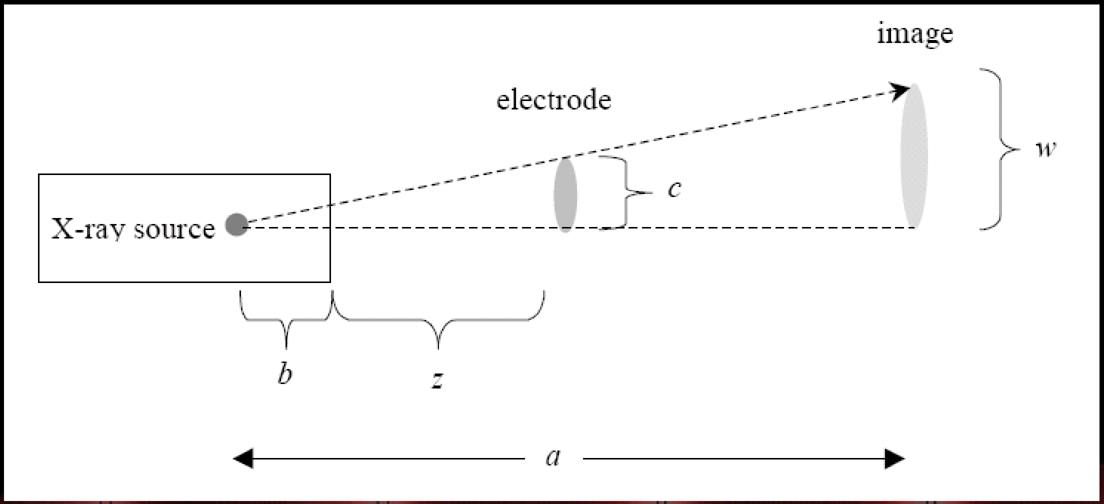


- 2D fusion mapping (or projection) of visible spatial and electrophysiological data.
- The stimulation or pacing catheter, located above the reference catheter, triggers the natural pacing of the heart cells.
- Color code proves that the quickest activations lie close to the pacing catheter.

SINGLE VIEW IMAGING

ELECTRODE DEPTH ESTIMATION

Electrode depth from one image

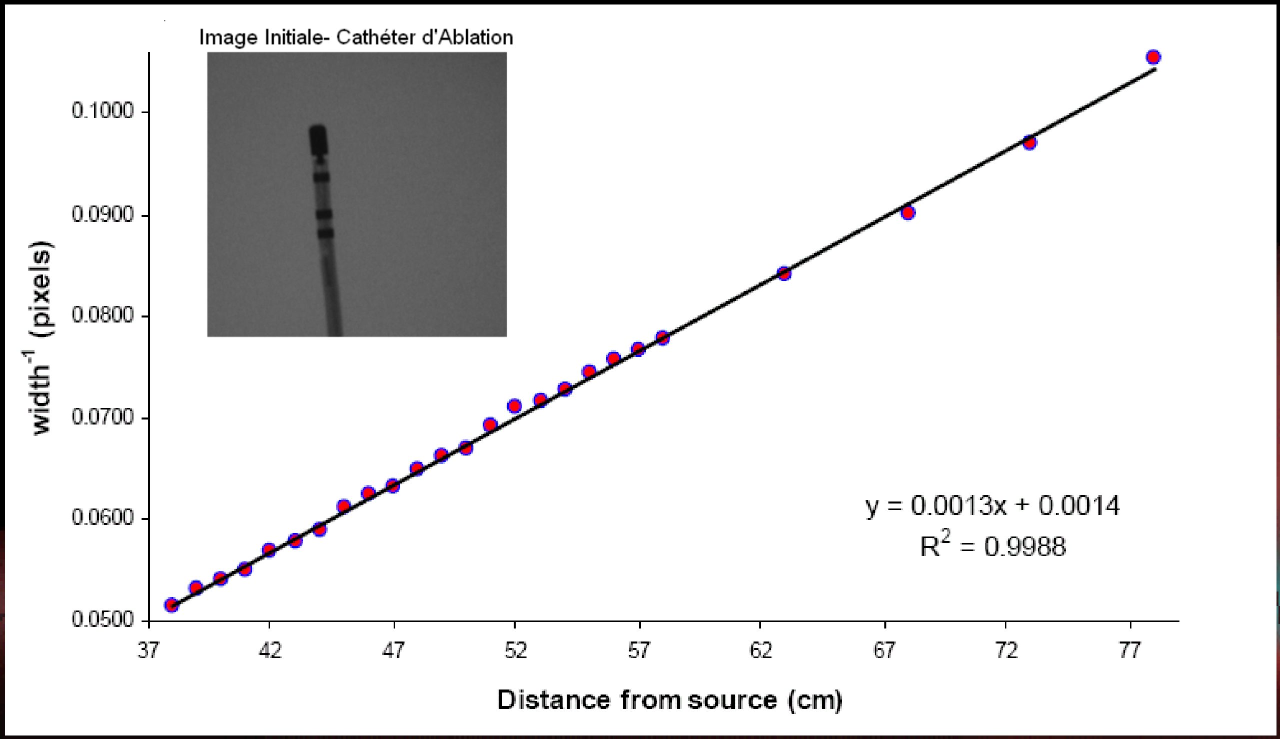


The depth of an electrode can be estimated from the width of its projection: *the projection becomes much larger as it approaches the X Ray source.*

$$\frac{1}{w} = \left(\frac{1}{ac}\right) z + \left(\frac{b}{ac}\right)$$

The inverse of the projected electrode width, *w*, is proportional to the depth, *z.*

Experiment: catheter in the air



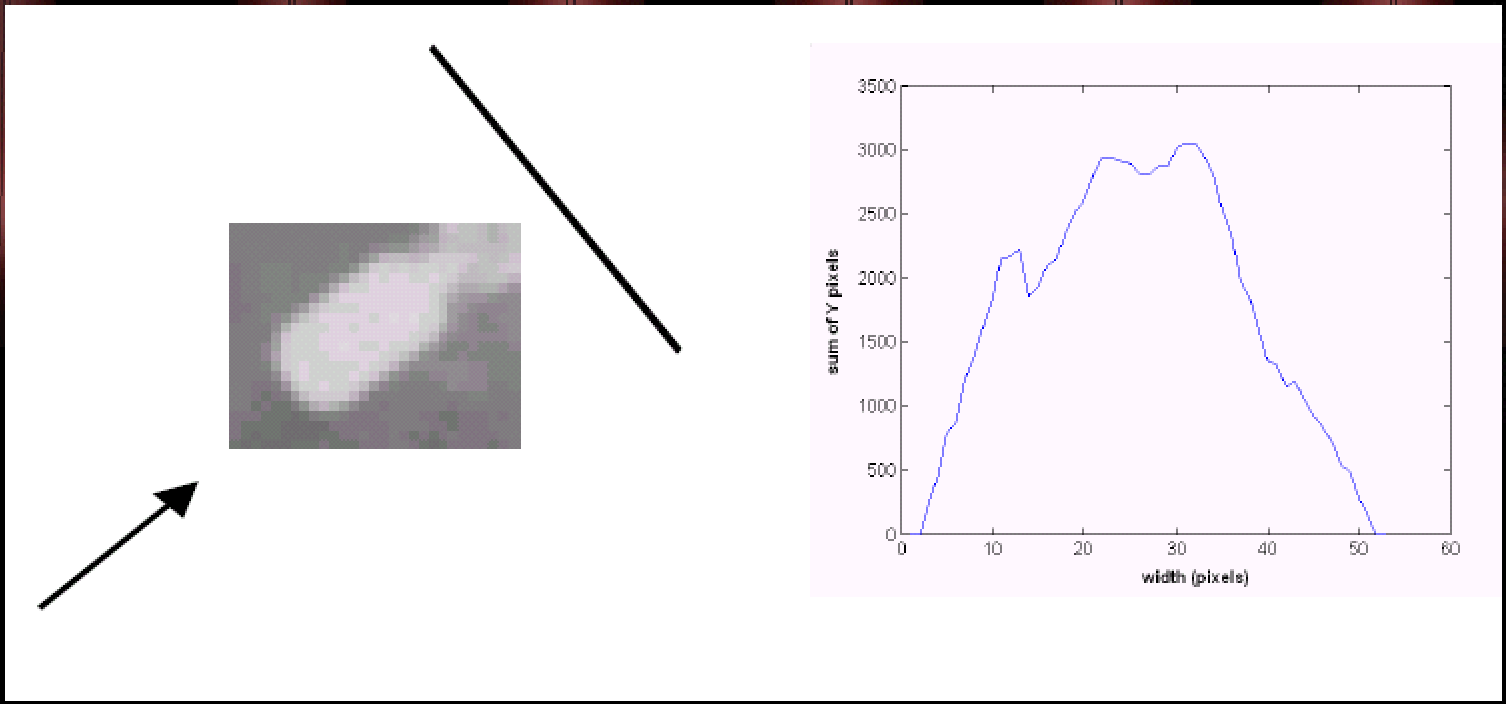
Width measurement

Correlation coefficient: r = 0.999

Standard Error of estimate: 3.6 mm

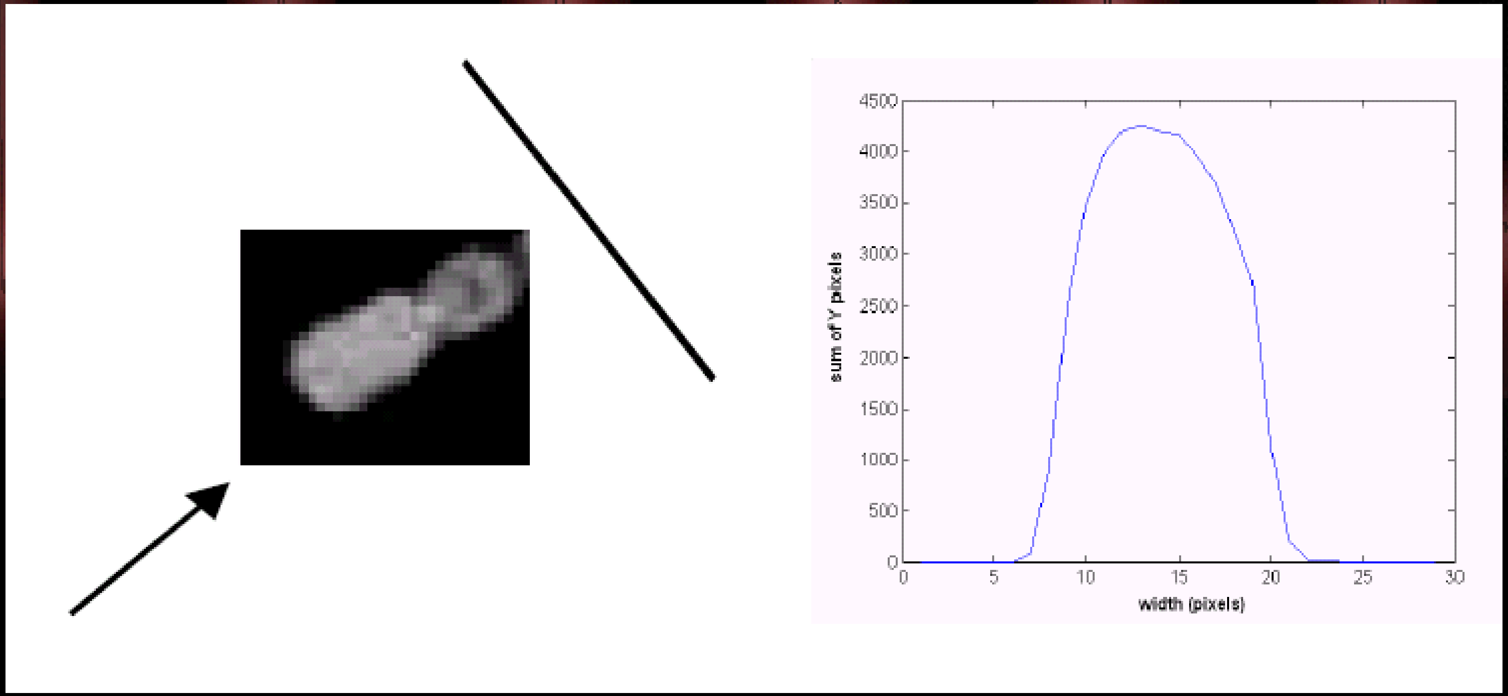
Projection Technique

Method based on the projection of a grayscale image along the perpendicular axis of the electrode.

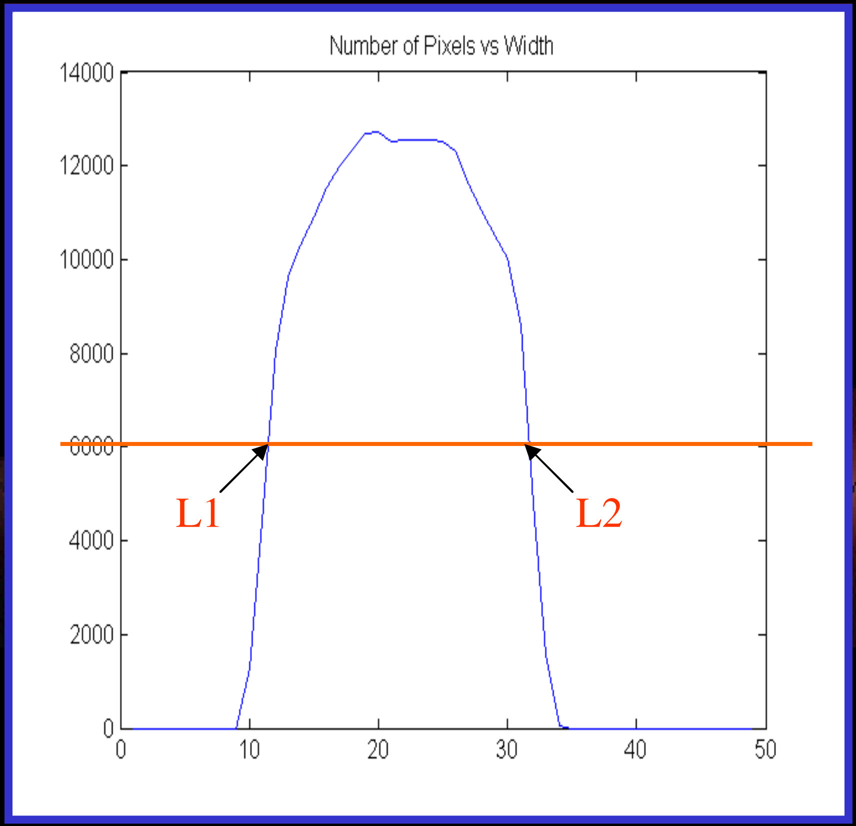


Morphological Filtering

Morphological Filtering was applied in order to eliminate the background and keep only the object of interest: the tip electrode.



Projection Algorithm



- Manual selection of tip electrode
- For each *column*, we add all the pixels (projection)
- Threshold= max-min/ 2 (robustness)
- Interpolation to calculate width:

(L2-L1)

Catheter Depth Estimation: dog experiment

Posterior/Anterior View

Domain of widths: *7.4 – 9.6 pixels* with average width of *8.5 pixels*

estimation of depth ~ *15mm*

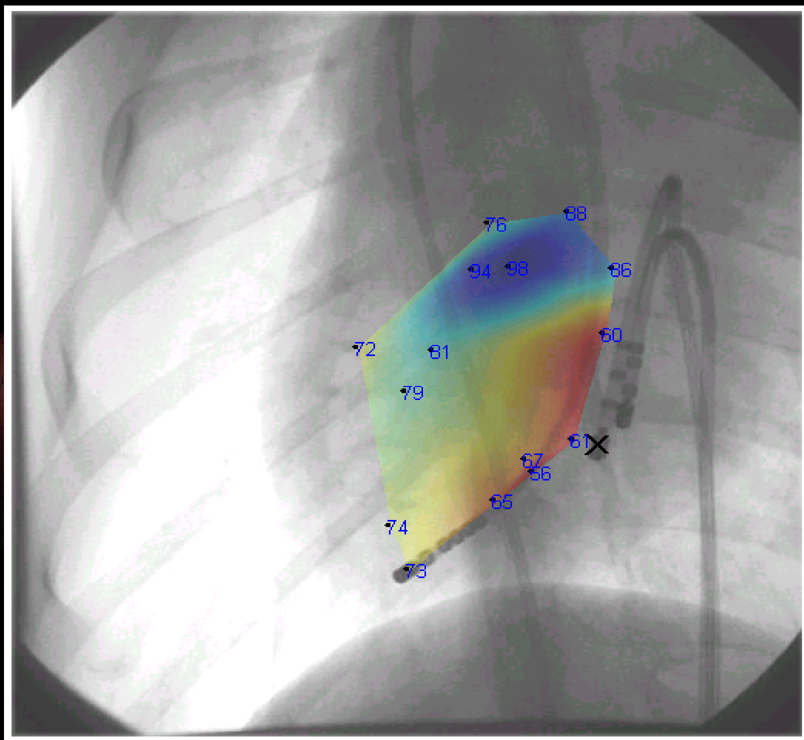
Left Lateral View

Domain of widths: *7.1 – 8.9 pixels* with average width of *8.0 pixels*

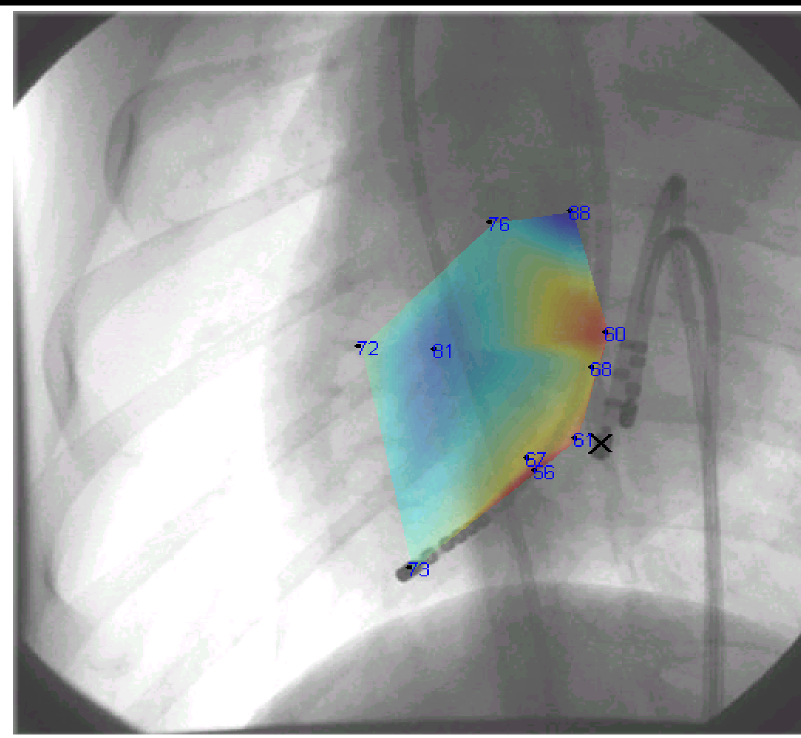
estimation of depth *~ 10mm*

Catheter Depth Estimation: visual error

Original



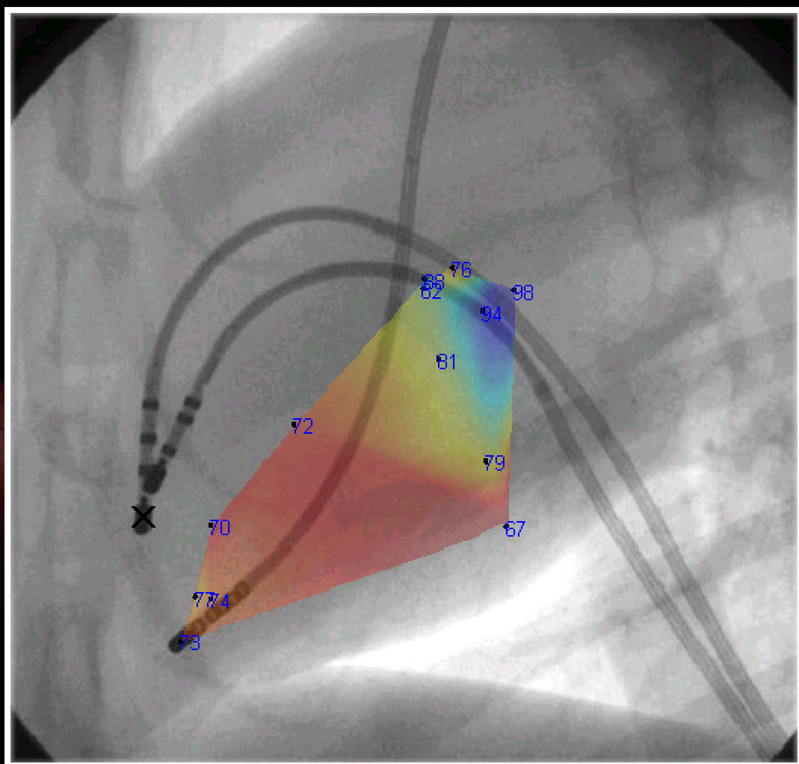
Depth Estimation



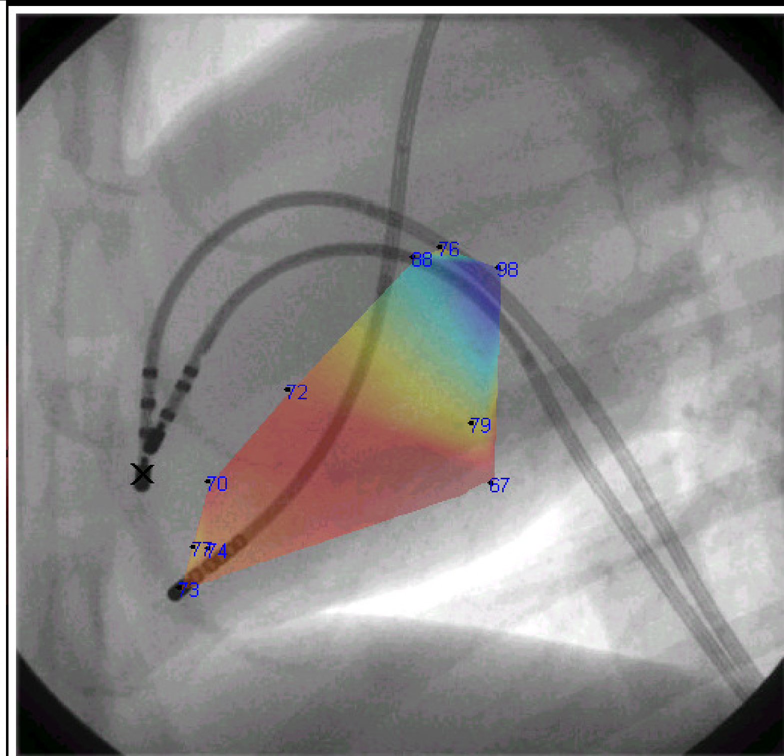
A 15 mm error when estimating the depth of the mapping catheter using the PA image datasets, yields false 2D fusion maps.

Catheter Depth Estimation: visual error

Original



Depth Estimation



…..similarly, a 10 mm error when estimating the depth of the mapping catheter using the left lateral image datasets, yields false 2D fusion maps.

Results are more precise than PA view as X-ray quality is better in this case, therefore less potential in errors subject to motion or structural artefacts.

Future Work

- Biplane Approach: X-ray Calibration methods need to be implemented in order to minimize error for the 3D surface reconstruction and fusion approach.

- Monoplane Approach: new algorithms need to be developed in order to extract 3D information from a single image….hint…..think registration methods using *a priori* information.

QUESTIONS