APPLIED SIGNAL AND IMAGE PROCESSING RESEARCH FOR HEALTHCARE: THE INOVA+ EXPERIENCE

Válter Rocha

inova

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COMPANY PROFILE

INOVA+

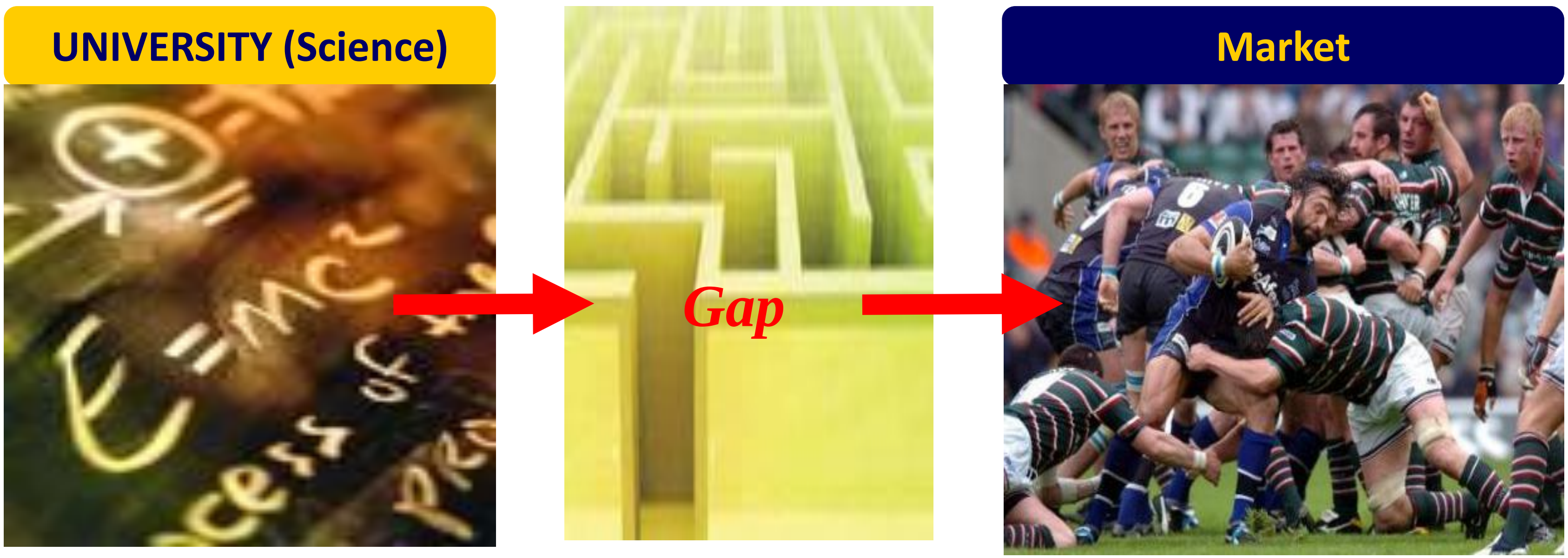
INOVA+ is a Portuguese consultancy firm founded in 1997 with headquarters in Oporto and offices in Lisbon specialized in **innovation management.**

As the Portuguese leader in the **promotion and management of European funded projects, INOVA+** has a vast experience in the field both as partner and as co-ordinator.

It is connected to the **INNOVA Group** the **largest private network for innovation services in Europe** with offices in Portugal, Italy, Belgium, Luxembourg, France, Poland, Czech Republic and USA.

INOVA+

Promoting **entrepreneurship** and **technology transfer** by matching research results with the market demand.



INOVA+

To be the innovation partner of a larger number of companies

coreworks FirstSolutions CNLL CONTACTUS

EMÍLIO DE AZEVEDO CAMPOS, S.A. Microfil devscope

Microsoft Development Center Polisport

To be the Technology Transfer partner of a bigger number of Universities and S&T centres

Universidade do Porto FEUP Faculdade de Engenharia ipt.pt Instituto Politécnico do Porto

UBI Universidade da Beira Interior

INOVA

INOVA+ | INOVAMAIS, S.A.

To be recognised in Portugal and in Europe as a reference in innovation

GPPQ Anetie Associação Nacional das Empresas das Tecnologias de Informação e Electrónica

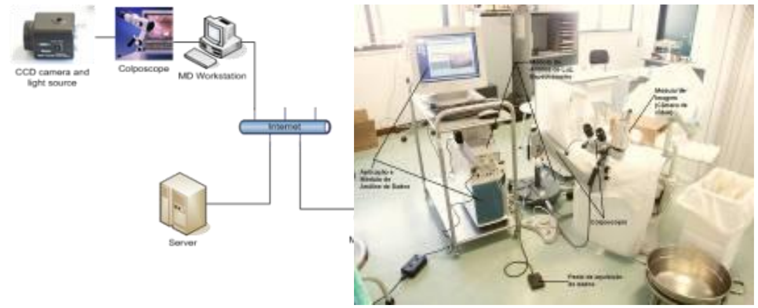
To be a prefered link to other european organizations

Enterprise Policy Group esa

PROJECTS

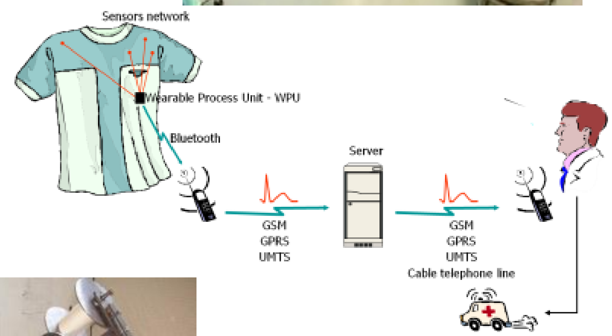
PROJECTS

Lifelinger & Cervicare– A new ICT-Based Diagnosis Procedure and Tool set for Early Detection of Cervix Cancer – image processing, spectrometry, neural networks, data-mining, Electronic record.



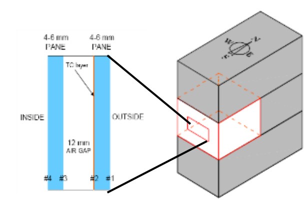
ADAPT - Automatic Data Transfer (paper, EDI, Fax…to ERP) – XML, OCR, BD

Heartronic – Prevention and early warning of cardiovascular anomalies – telemetry, embedded systems, neural networks



Multiweave – Weaving Machine for Producing Multiaxial Fabric – engineering, HW/SW control

Termoglaze – Production of thermochromic glazing for energy saving applications – simulation using mathematic models to optimize the glazing layers



PROJECTS

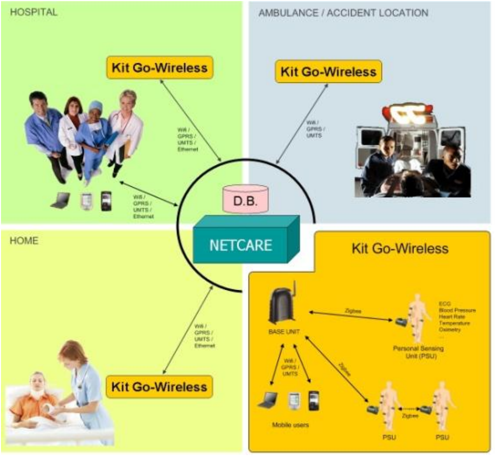
NETCARE – Wireless telemetry for continuous health care – telemetry, embedded systems, bio-sensors, zigbee, universal gateway, Zephir integration, Hospital Information System, automatic alarms

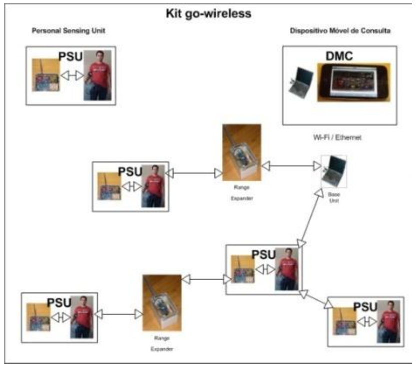
Healthreats – Integrated Decision Support System for HEALTH THREATS and crises management (Sep/2010) – DSS, workflow

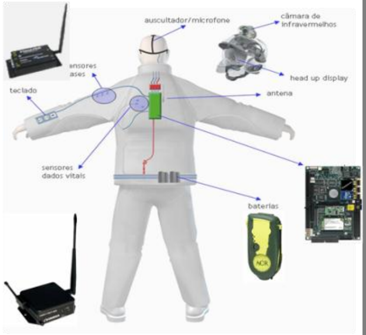
MAP – Microchip Analyzer of Proteins (Feb/2011) – data acquisition, analysis software

PHN - Personal Healthcare Networks (Aug/2011) - telemetry, embedded systems, bio-sensors, zigbee, universal gateway, automatic alarms, GIS

FIERCE - Future technologies for first responders in critical infrastructures (Aug/2011) - embedded systems, wireless sensors, zigbee, universal gateway, automatic alarms, GIS

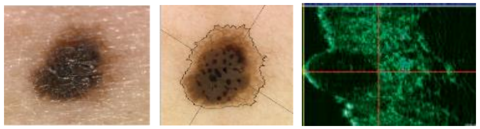






PROJECTS

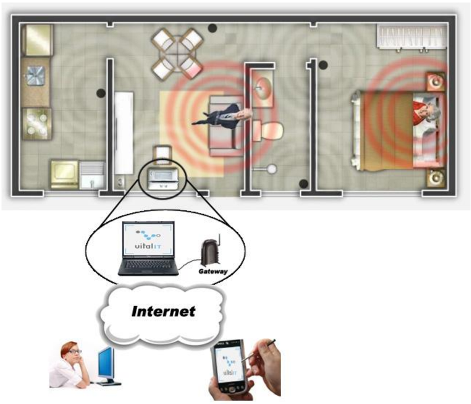
SkinMonitor – Diagnosis of skin cancer based on ICT tools –digital imaging, narrow band imaging, ultrasounds



NFCE – New functionalities for the endoscopic capsule – Automatic Diagnosis, spectrometry, Capsule movement control

PRK_TREATMENT - Exercise System for Parkinson continuous treatment and rehabilitation

AAL4ALL - Standard of Primary Care for AAL services



TICE.Healthy – Health and Life Quality Systems

troy

Endoscope Capsule Using Ultrasound Technology

TROY PROJECT

inova

Concept

Please Check the Video at:

http://www.inovacao.net/troy/VideoTroy.swf

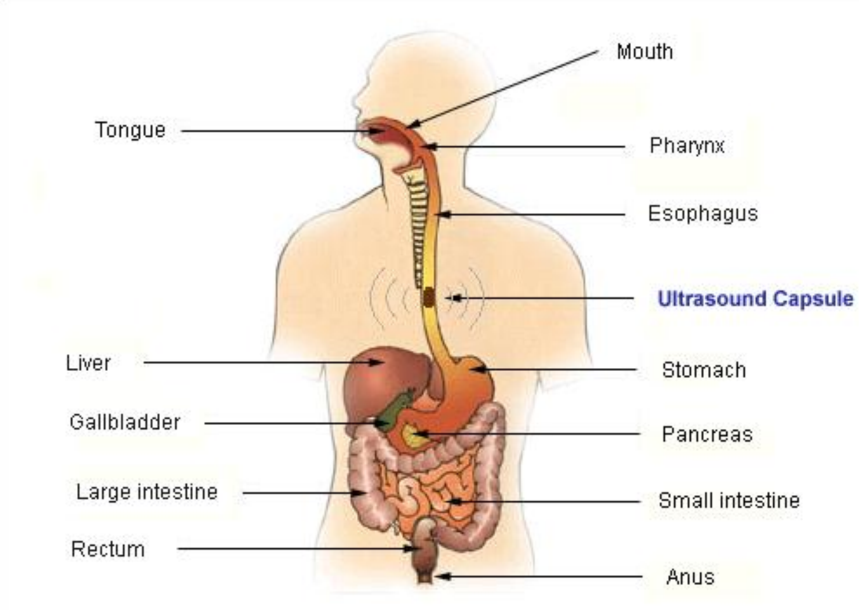
Concept

Drink it with a glass of water

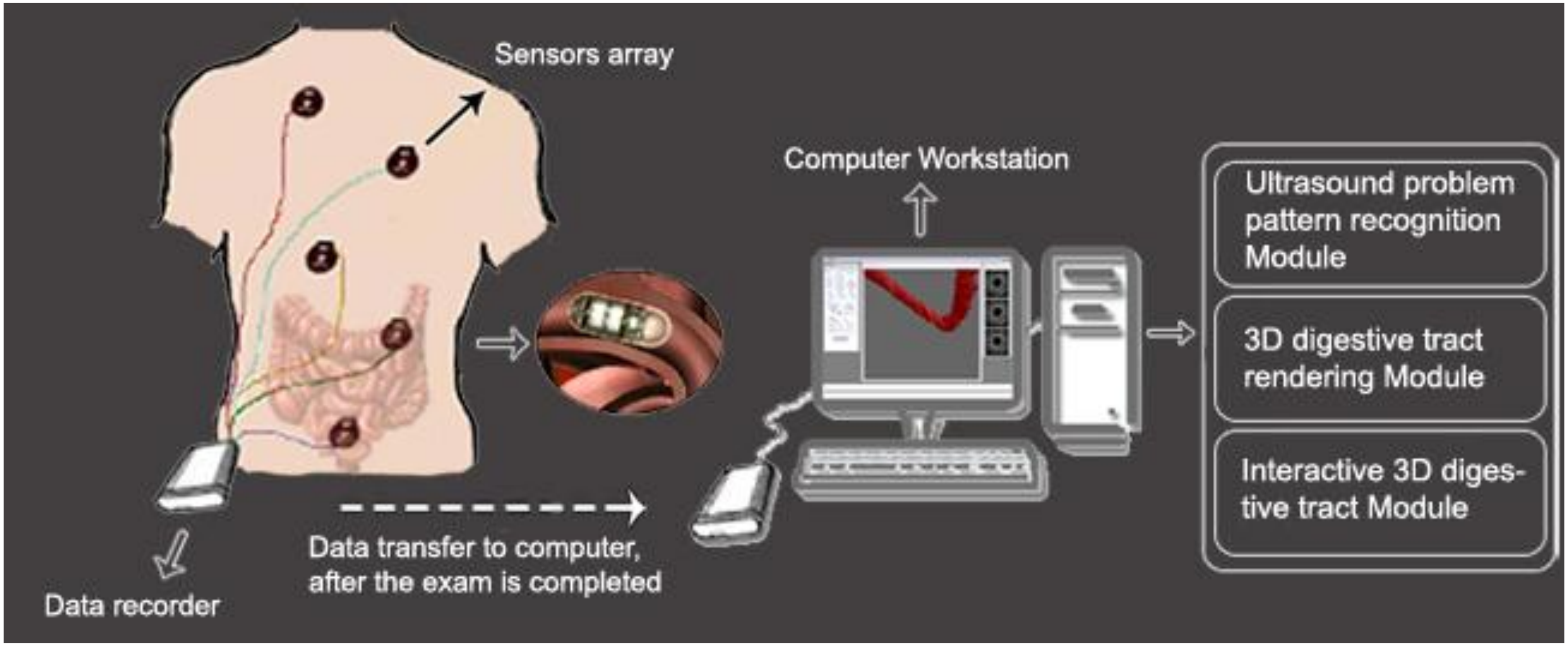
Do your normal life

Return the data logger

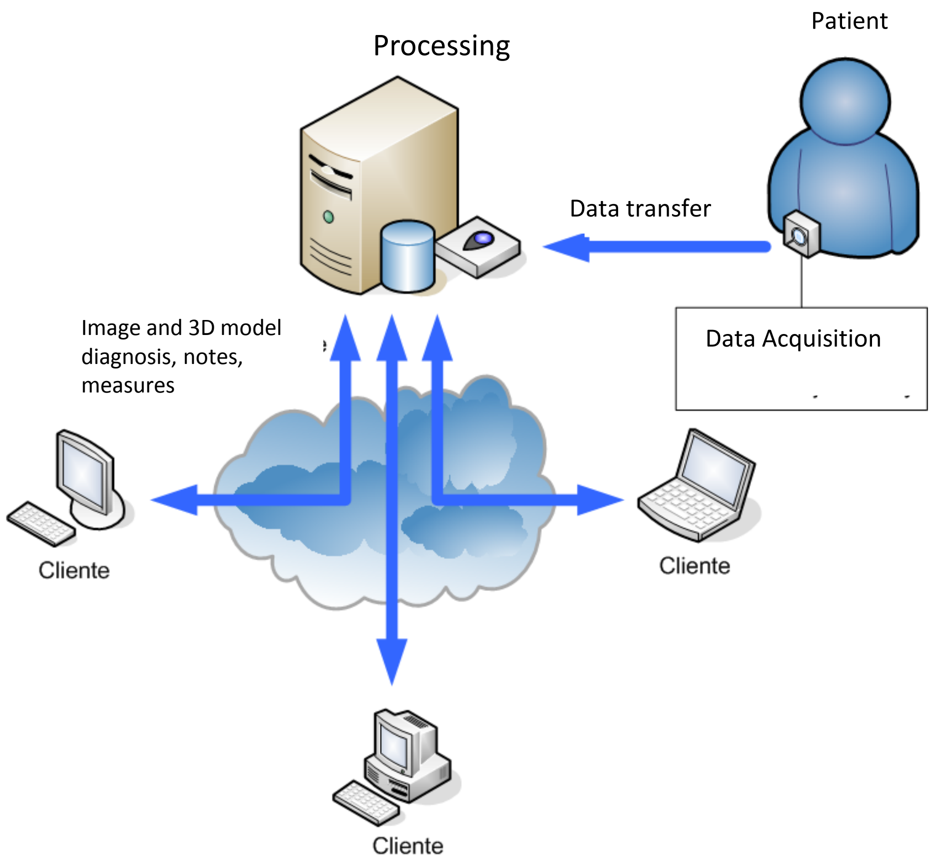
Get the results



Overview


Sensors array
Computer Workstation
Ultrasound problem pattern recognition Module
3D digestive tract rendering Module
Interactive 3D diges-tive tract Module
Data transfer to computer, after the exam is completed
Data recorder

Architecture

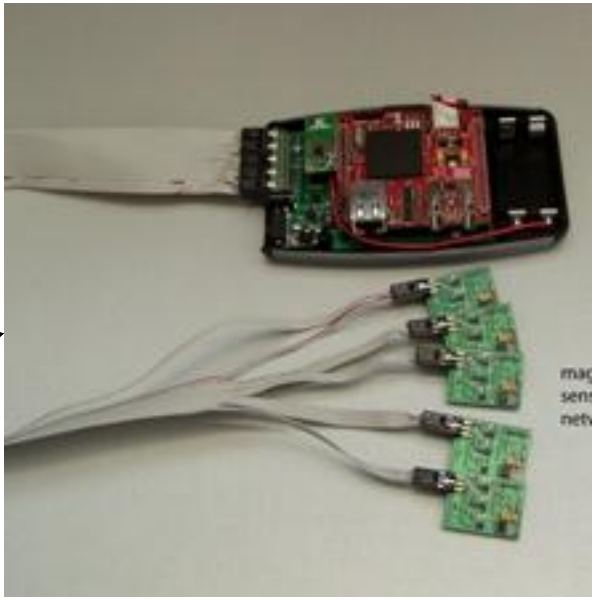


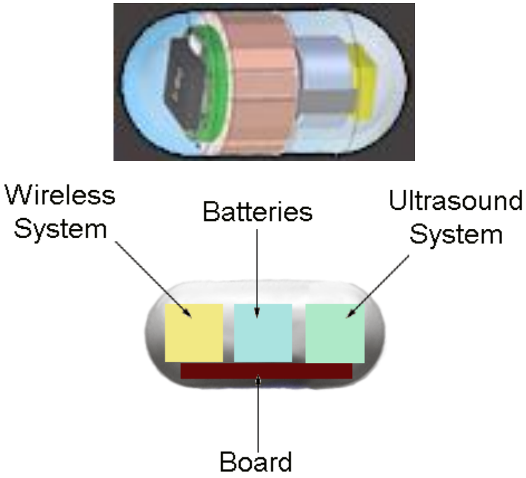
- Processing Server
  - Process
  - Storage
  - Simple Interface
- Clients
  - Data Access
  - Complex Interface 3D Model

System Architecture

Capsule Architecture

Capsule localization system based in Magnets

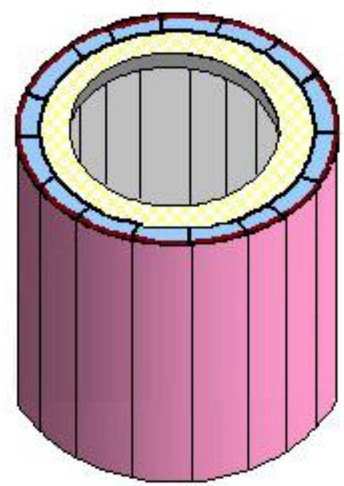


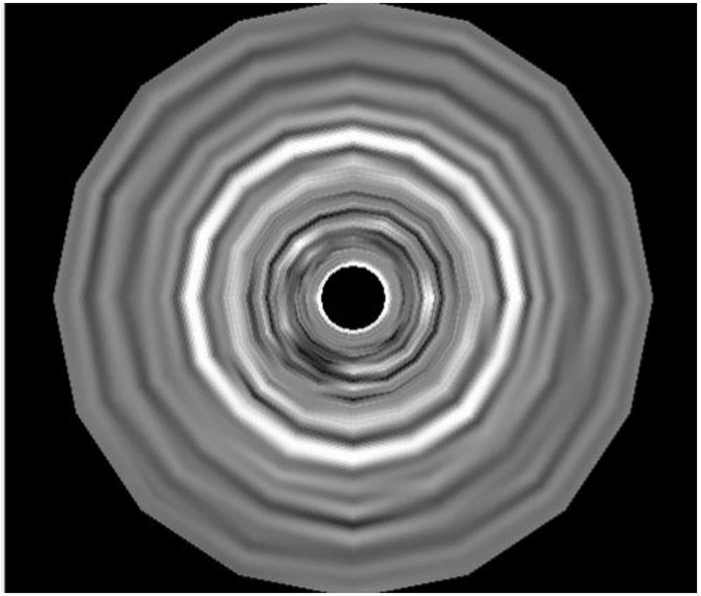


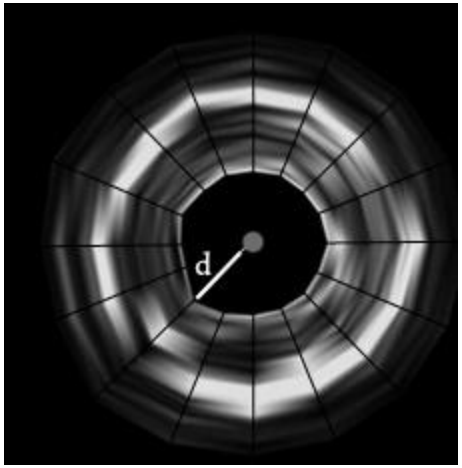
Pre-Processing (2D images)

2D image from ultrasound raw data

- The objective is to transform the
- 2D ultrasound data in 2D images.
- The capsule is composed of 16 / 32 sensors.
- Each sensor sends an ultrasound signal.







Pre-Processing (2D Images)

Metadata on images

Image, position, orientation, rotation and time

```
# filename pos_x pos_y pos_z orient_x orient_y orient_z rotation time

.\Screen0000.bmp -10,000 -50,000 50,000 0,000 1,000 0,000 0,000 0
.\Screen0001.bmp -9,963 -47,713 49,917 0,016 1,000 -0,018 0,000 1
.\Screen0002.bmp -9,855 -45,356 49,674 0,032 0,999 -0,036 0,000 2
.\Screen0003.bmp -9,679 -42,934 49,279 0,047 0,997 -0,053 0,000 3
…
```

Test data was created based on ultra-sound images collected

Pre-Processing (ultrasound)

Troy capsule data

Position, orientation, rotation, time, Raw data 16 sensors

Position,pos_x,pos_y,pos_z,Acceleration,orient_x,orient_y,orient_z, rotation,time, Sensor 0 , 3000 values, Sensor 1,…, Sensor 15, 3000 values

Position,0,0,0,Acceleration,16567,64954,64314,Sensor n. 0,0,0,2075,2076,2074,2072,2074,2071,2072,2062,3842,4054,…
Position,0,0,0,Acceleration,16547,64973,64372,Sensor n. 0,0,0,2072,2072,2070,2070,2069,2066,2064,2061,2141,3820,…
Position,0,0,0,Acceleration,16564,64808,64424,Sensor n. 0,0,0,2060,2058,2060,2062,2062,2063,2065,2066,3825,3810,…
Position,0,0,0,Acceleration,16570,64912,64352,Sensor n. 0,0,0,2043,2044,2046,2047,2046,2046,2048,2051,3836,3798,…

…

Test data collected at Roma

Pre-processing (2D images)

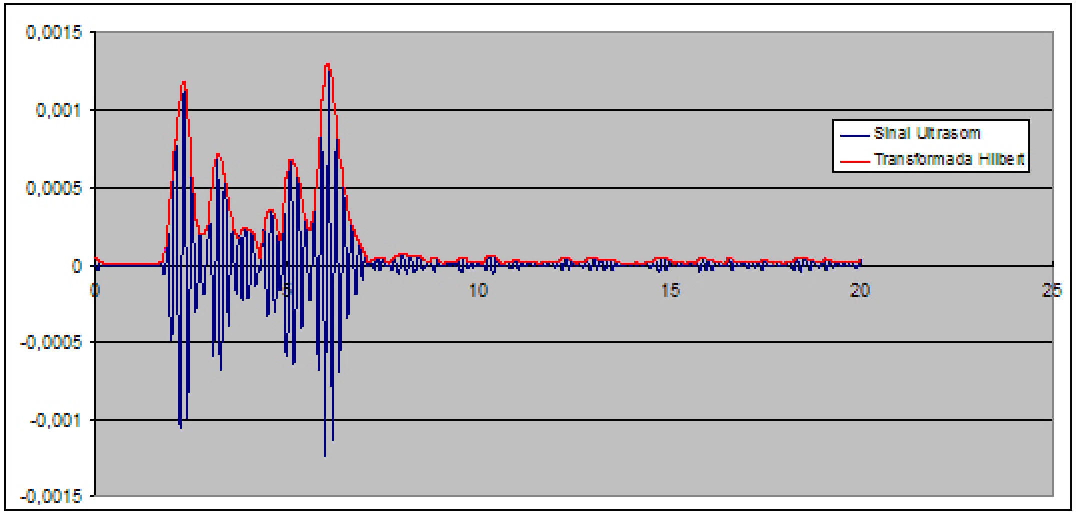
2D image from ultrasound raw data based on several consecutive slices

1. Hilbert transform applied to the calibrated signals;
2. Calculate maximums choosing them accordingly with MODA of X signals; MODA of the number of local "maximums" (contours)
3. Make mean and standard deviation of time and amplitude and exclude signals outside standard deviation; this is for signals not excluded in step before.
4. Calculate mean of valid maximums obtaining the contours.
5. Use the values of the fragment closer to the mean to apply the color.

Hilbert Transform Step

Signal is processed into the Hilbert transform.

This transform creates an envelope around the signal which facilitates identification and analysis of the peaks of the oscillations.



Signal analysis Step 1/3

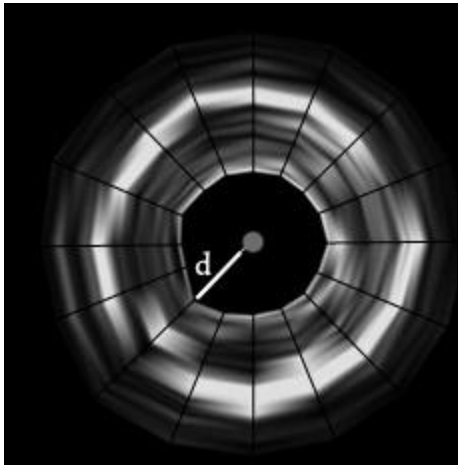
Calculating the distance to the center of the dish:

The contour is calculated using the formula:

$$d = t * 0.75$$

t is the instant of maximum time in millisecond

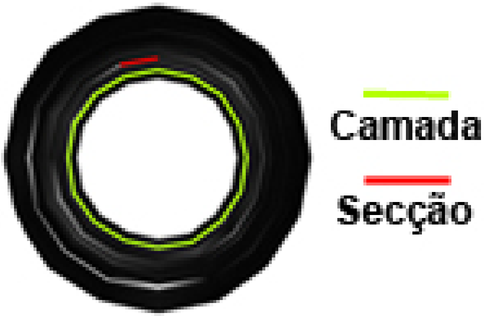
following pre-defined threshold.



Signal analysis Step 2/3

Calculation of the values that define the different sections of the various layers:

The average amplitude at intervals of 0.25 ms multiplied by 200 indicates the color intensity scale Gray.



TROY

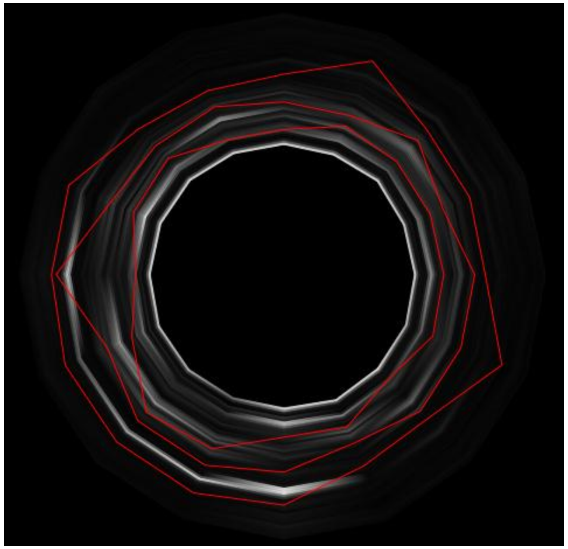
Signal analysis Step 3/3

Calculation of the different layers of the intestine:

Using the same formula

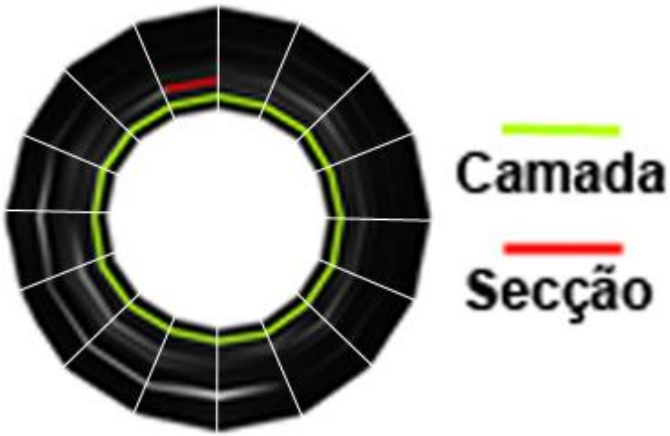
$$d = t * 0.75$$

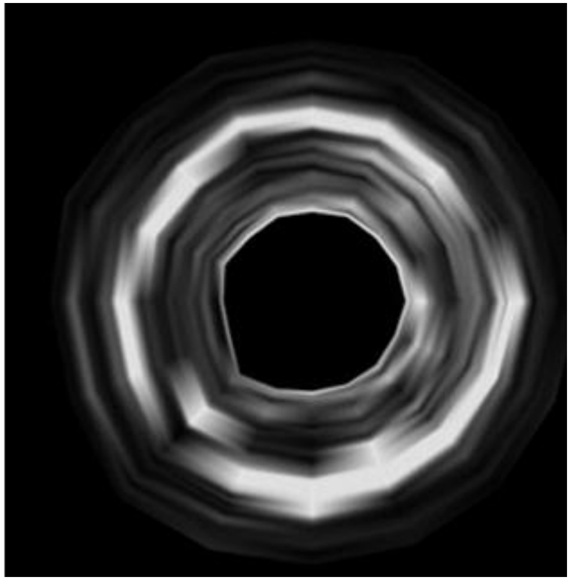
where t is the value of three peaks following the initial contour.



Final 2D reconstruction

The visual reconstruction of the 2D image is done after the analysis of all fragments. The reconstruction is done within a framework OpenGL.





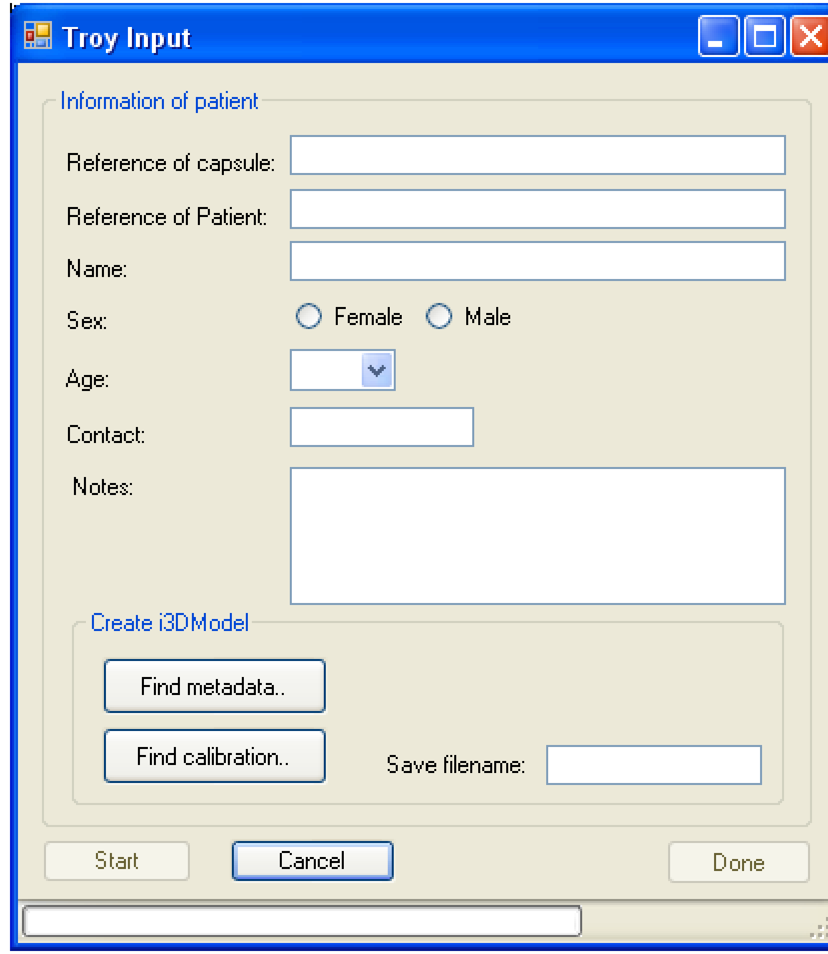
3D Reconstruction

Contour detection based on 2D images based on simulated annealing algorithm

Contour detection based on US raw data using information from several consecutive slices

3D rendering based on triangulation of obtained points

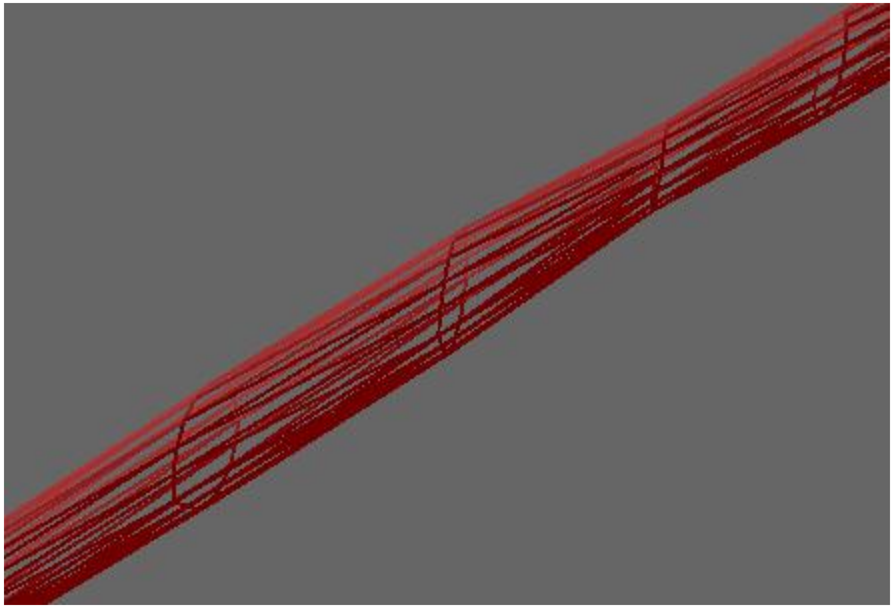
XML writer/parser for writing and reading 3D models



3D Reconstruction

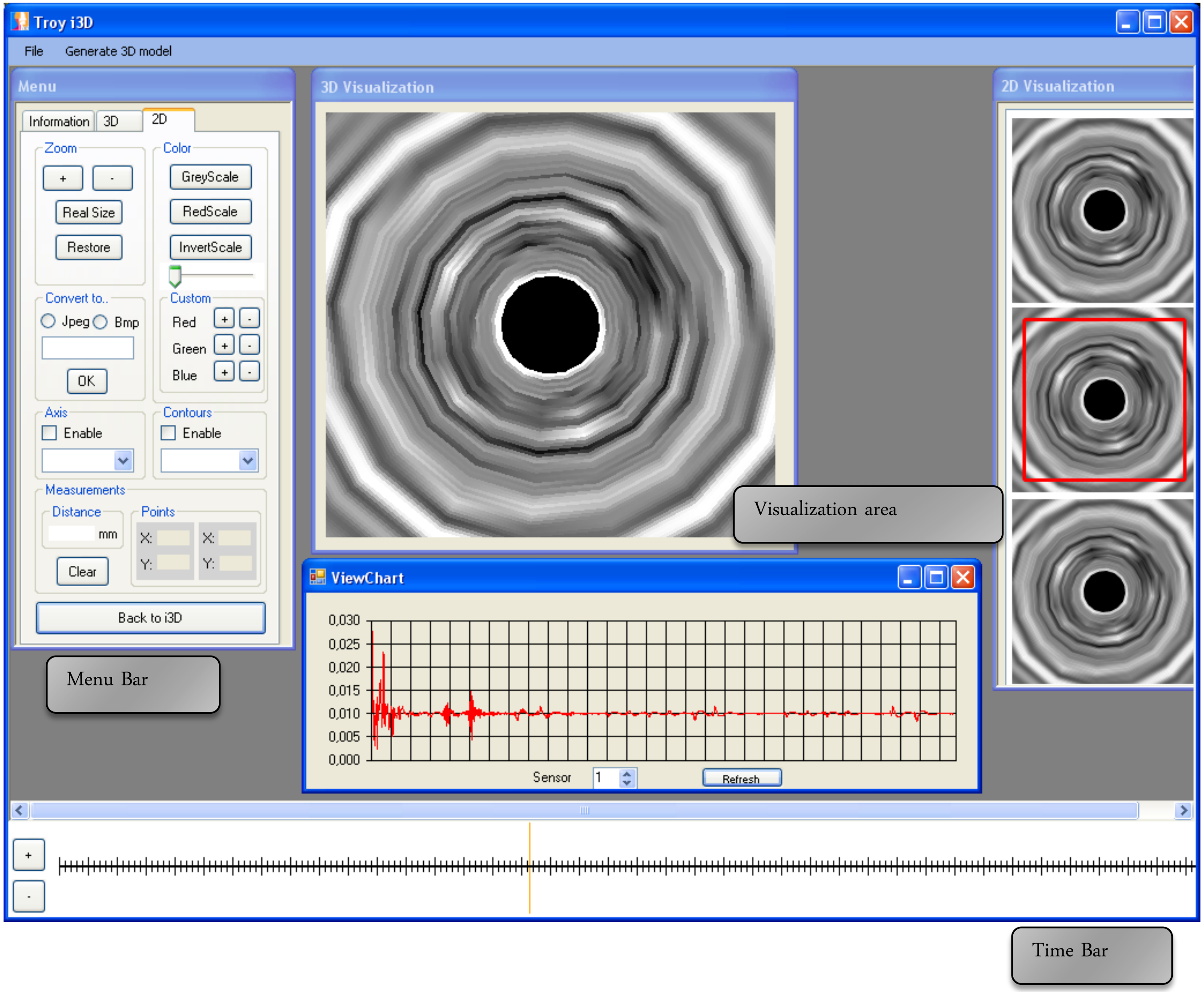
3D reconstruction is based on the triangulation of the contour points positioned in sequential images in accordance with the sensors placed on the abdomen.

The position, orientation and rotation information of each fragment are essential for this reconstruction.

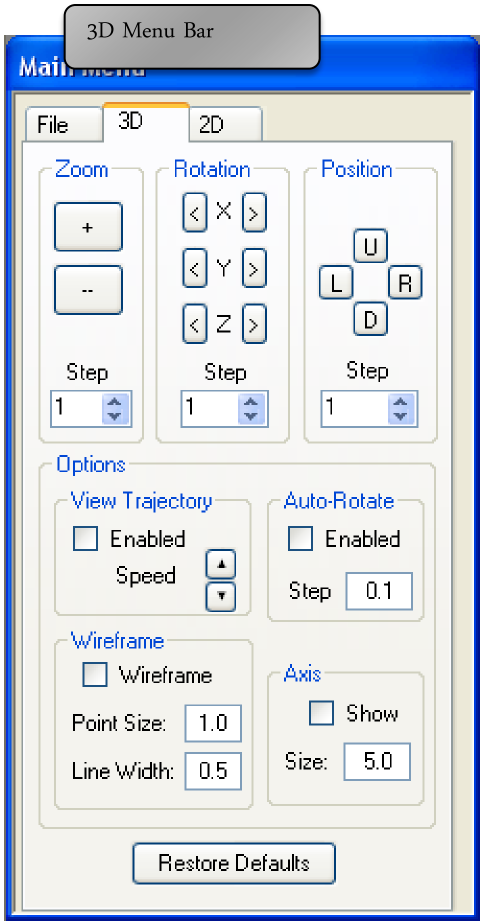


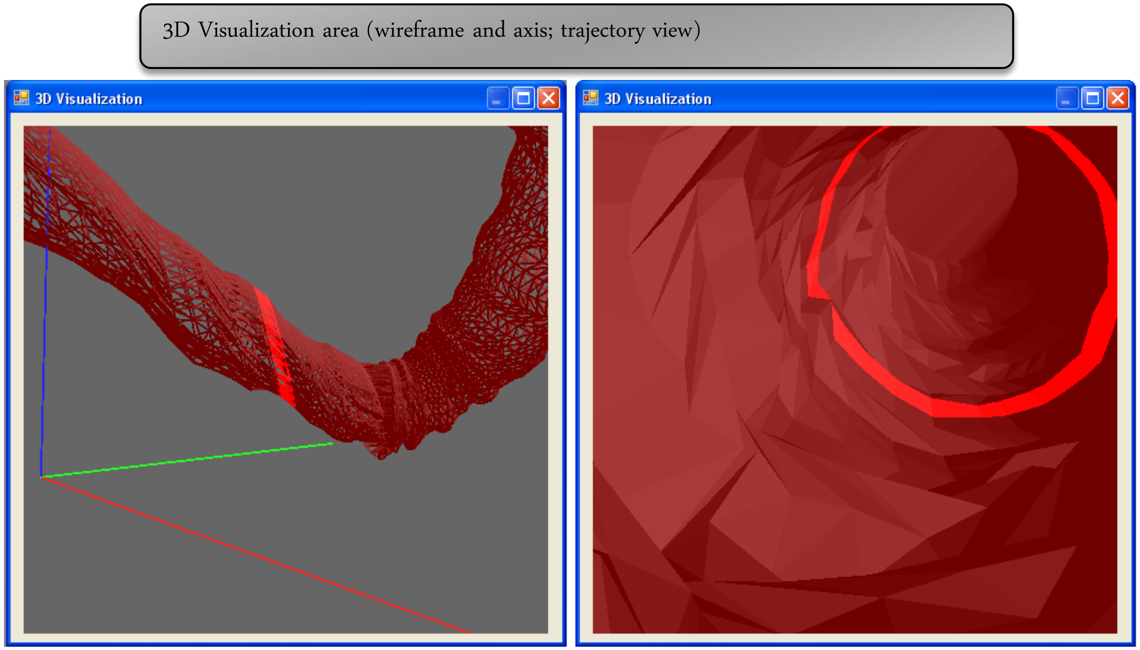
Presentation layer

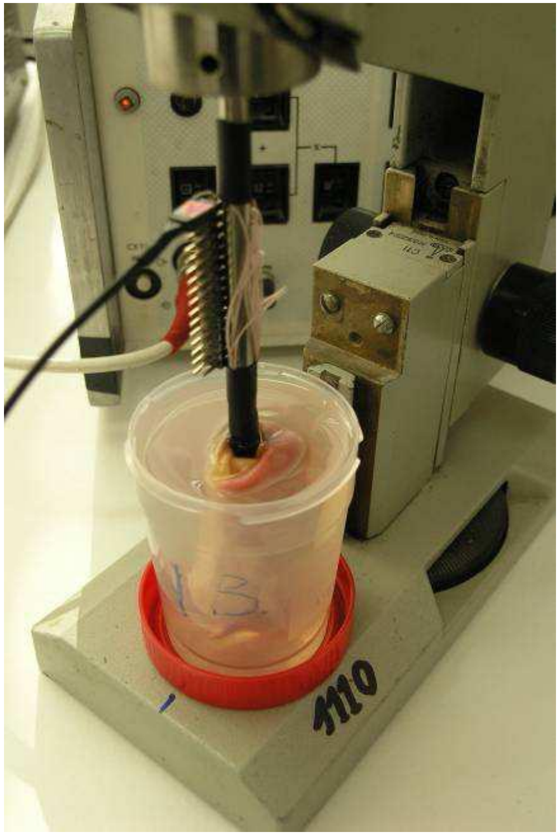
- 2D /3D Manipulation;
- Inside view Animation;
- Measures;
- Color scale;
- Visualization Filters;
- Contours;
- Notes;
- Time bar.
- US chart data



Presentation layer





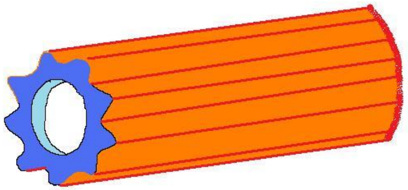


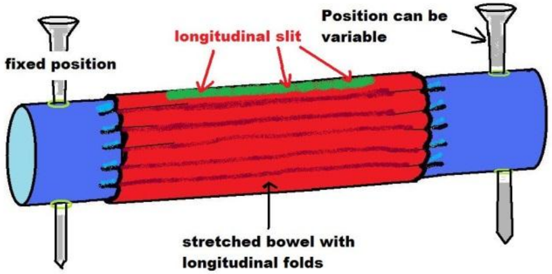
TESTS

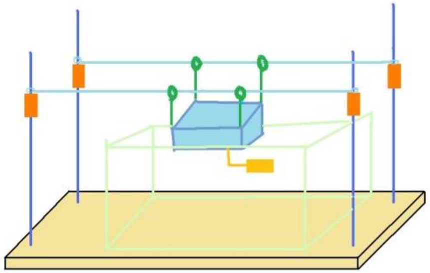
Planned Tests

Planned phantom preparation

- 16 Longitudinal zones needed for correlation between circumferential sectors of bowel to corresponding crystals/channels.
- Several (>5) transversal zones corresponding to several positions of capsule during linear manual movement. Their role is to ensure approximate positioning of capsule and to make possible a correlation between position of normal or abnormal segments of bowel to corresponding signals, without seeing the probe.
- Longitudinal folds to reshape the bowel.







Planned Tests

Tests were made to 4 smaller phantoms

Annular Polyp

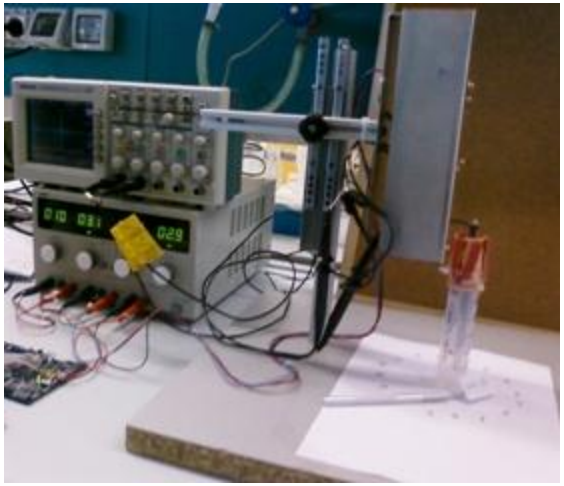
1 Polyp inside

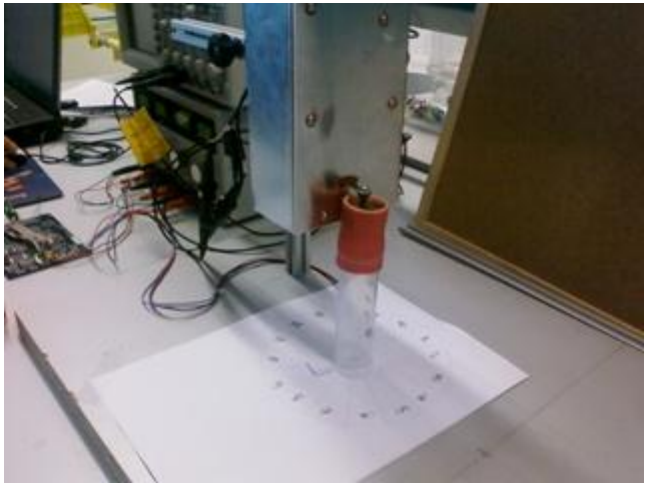
Strips outside / inside

No pathology

Actual Tests

Setup of the testbed:





Actual Tests

Data acquisition

- 11 samples collected from each 5 phantoms
  - With polyp in different positions
  - With strips inside
  - With strips outside
  - With tumour / inflammation (annular polyp)
  - Clean bowel (no pathology)

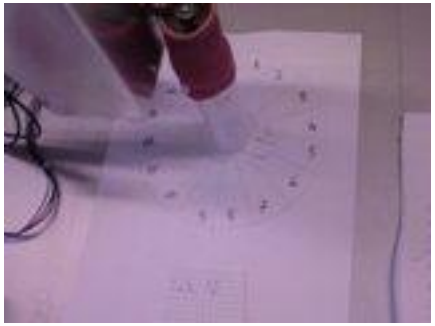
- Each data file contains several captures from the same view (1/second)

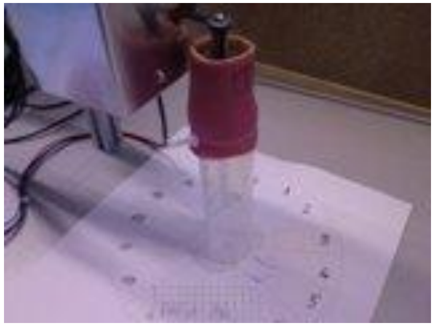
- 1 calibration set

Actual Tests

Data acquisition - Polyp

Data file name	Timing	Description	Other Remarks
Data 28	11:29	no polyp	Polyp in pos 9
Data 29	11:30	no polyp	Polyp in pos 5
Data 30	11:32	no polyp	Polyp in pos 5
Data 31	11:34	no polyp	Polyp in pos 5
Data 32	11:39	no polyp	Polyp in pos 5
Data 33	11:40	no polyp	Polyp in pos 5
Data 34	11:42	no polyp	Polyp in pos 5
Data 35	11:43	no polyp	Polyp in pos 5
Data 36	11:46	with polyp	Polyp in pos 5-6
Data 37	11:48	with polyp	Polyp in pos 5-6
Data 38	11:50	with polyp	Polyp in pos 5-6





Actual Tests

Data acquisition – Strips inside

Data 39	11:59	with "strips" inside
Data 40	12:00	with "strips" inside
Data 41	12:04	with "strips" inside
Data 42	12:06	with "strips" inside
Data 43	12:09	with "strips" inside
Data 44	12:12	with "strips" inside
Data 45	12:14	with "strips" inside
Data 46	12:16	with "strips" inside
Data 47	12:18	with "strips" inside
Data 48	12:20	with "strips" inside
Data 49	12:22	with "strips" inside

Actual Tests

TROY

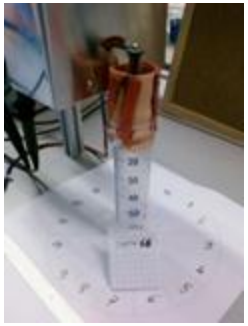
Data acquisition – Annular Polyp

Data 50	12:28	with tumor/inflammation
Data 51	12:29	with tumor/inflammation
Data 52	12:31	with tumor/inflammation
Data 53	12:32	with tumor/inflammation
Data 54	12:34	with tumor/inflammation
Data 55	12:35	with tumor/inflammation
Data 56	12:36	with tumor/inflammation
Data 57	12:38	with tumor/inflammation
Data 58	12:39	with tumor/inflammation
Data 59	12:41	with tumor/inflammation
Data 60	13:42	with tumor/inflammation

Actual Tests

Data acquisition – Strips outside

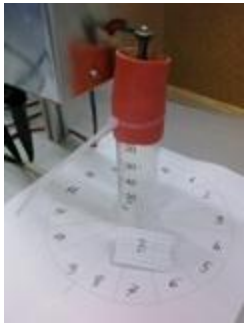
Data 61	13:45	with "strips" outside
Data 62	13:46	with "strips" outside
Data 63	13:50	with "strips" outside
Data 64	13:52	with "strips" outside
Data 65	13:57	with "strips" outside
Data 66	13:58	with "strips" outside
Data 67	14:00	with "strips" outside
Data 68	14:07	with "strips" outside
Data 69	14:09	with "strips" outside
Data 70	14:10	with "strips" outside
Data 71	14:12	with "strips" outside
Data 72	14:16	with "strips" outside



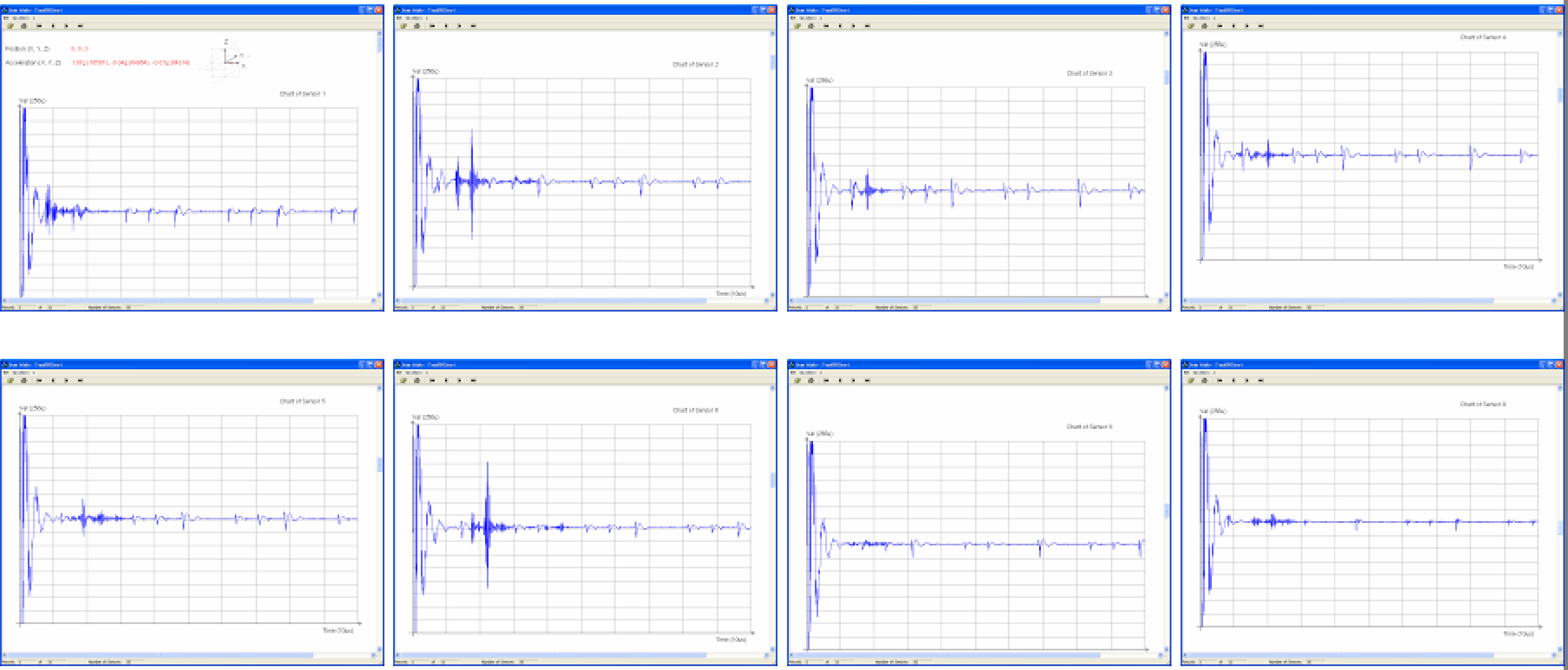
Actual Tests

Data acquisition – No Polyps

A	14:23	Clean bowel
B	14:25	Clean bowel
C	14:26	Clean bowel
D	14:30	Clean bowel
E	14:32	Clean bowel
F	14:33	Clean bowel
G	14:34	Clean bowel
H	14:36	Clean bowel
I	14:37	Clean bowel
J	14:39	Clean bowel
K	14:41	Clean bowel

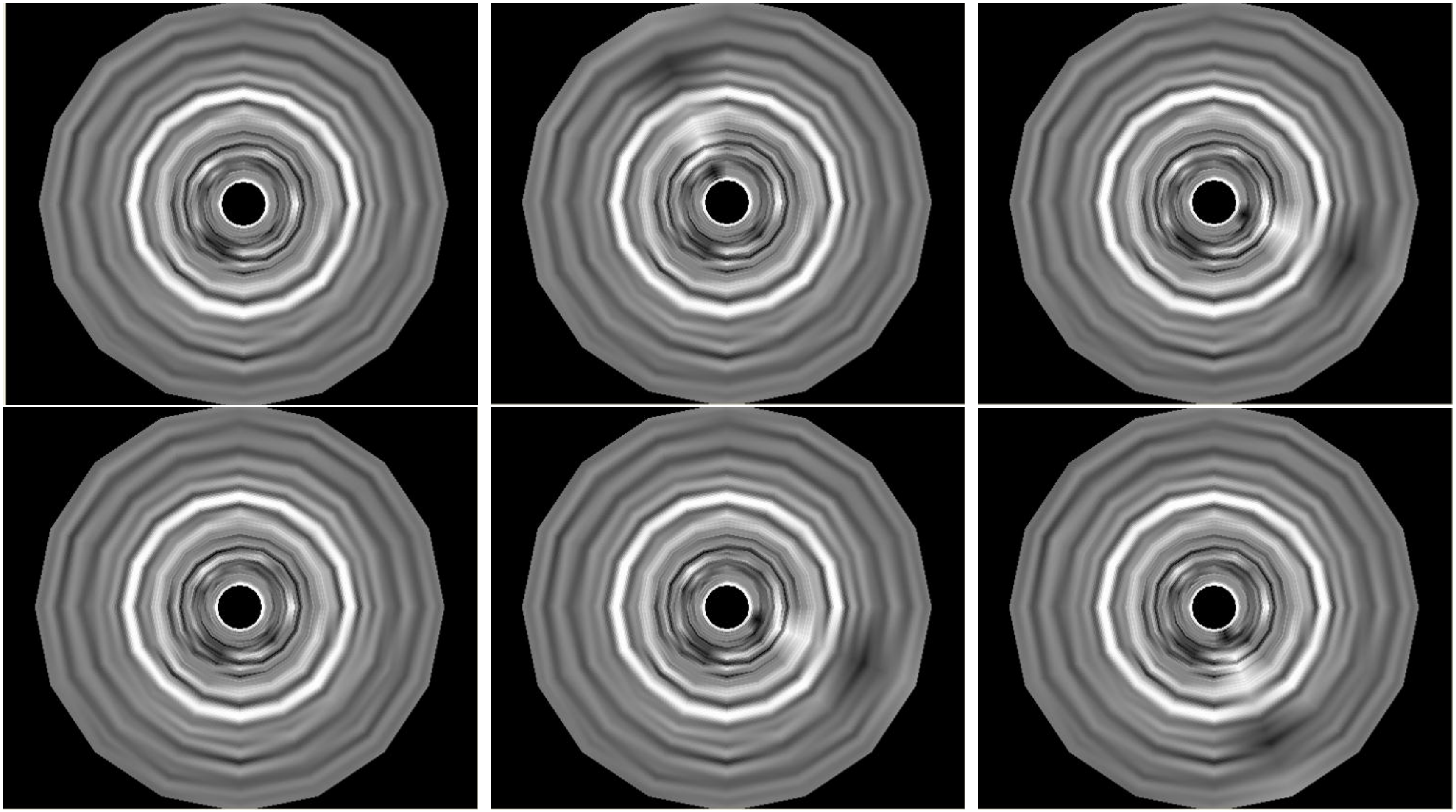


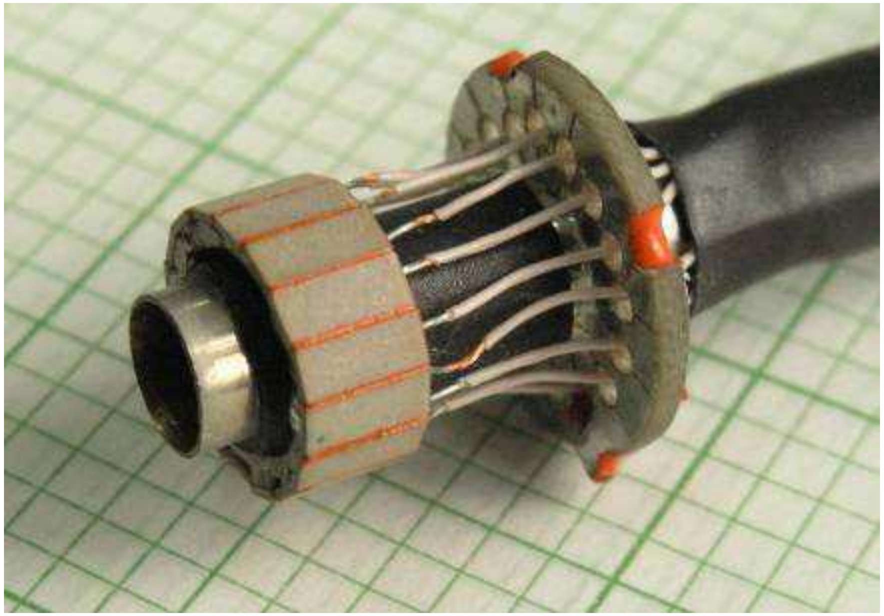
Tests Results



Actual Tests

Tests Results





RESULTS AND CONCLUSIONS

Results / Conclusions

Based on these results it is possible to determine a set of classifiers for the TROY concept and its characterization as a screening test. The most significant parameters, according to Wilson and Jungner, are the following:

· Specificity TN/(FP+TN).

· Sensitivity TP/(TP+FN).

· Prevalence (TP+FN)/(TP+FP+FN+TN).

· Likelihood ratio + sensitivity/(1-specificity).

· Likelihood ratio - (1-sensitivity)/specificity.

· Positive predictive value TP/(TP+FP).

· Negative predictive value TN/(FN+TN).

· Pretest odds prevalence/(1-prevalence).

· Post-test odds pretest odds x likelihood ratio.

· Post-test probability post-test odds/(post-test odds+1).

1 Wilson J. M. G., Jungner G., "Principles and practice of screening for disease", World Health Organization, Public Health Paper 34 (1968)
2 UCI College of Medicine, “Evidence-based Medicine Guidebook” (2004)

Results / Conclusions

These parameters were calculated and are presented in the Table:

- The two most important parameters for a screening diagnostic exam are: sensitivity and specificity
- They show that the exam is very accurate in classifying as positive the abnormal cases and as negative the normal cases.
- The other parameters are also very interesting and demonstrate that the TROY system can be a very useful tool for screening possible disorders in the gastrointestinal tract.

Parameter	Value
Specificity	97%
Sensitivity	88%
Prevalence	80%
Likelihood ratio+	31,34
Likelihood ratio -	0,13
Positive predictive value	0,99
Negative predictive value	0,67
Pretest odds	3,91
Post-test odds	122,5
Post-test probability	99%

SUMMARY

PORTO
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Fax: +351 214 211 383

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