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Development of a Robotic Driven Handheld Laparoscopic Instrument for Non-Invasive Intraoperative Detection of Small Endoluminal Digestive Tumors

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Highlights

This paperwork introduces a

framework design methodology for guided decision-makers towards development of a laparoscopic instrument

which aims achieving:

a balance between quality, efficiency and surgical procedure

in the process of:

detection of small endoluminal digestive tumors

A prototype of the experimental developed instrument is shown within this presentation

Agenda

- Actual context
- Available surgical procedures & constraints
- Problem statement & proposed solution
- Framework methodology
- Developed instrument
- Conclusions

Context

Advancements in endoscopic techniques together with

better health care plans generated an **improvement**

in addressability to endoscopic evaluations

for identification of :

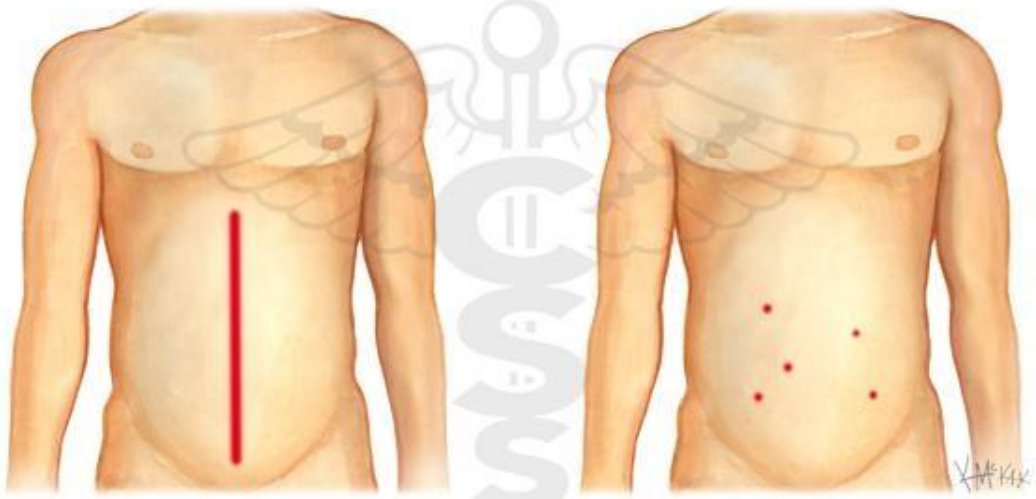
stomach, small intestine, colon and rectum tumors.

High number of evaluations resulted in an increased number of surgeries

Available procedures & limitations

Two medical procedures are often used for digestive tumor resection:

- **Traditional open surgery,**
- **Minimally Invasive Surgery (MIS) – Laparoscopy.**



Open surgery Laparoscopy

Traditional open surgery

Palpation is very useful and often used to identify tumors

Nevertheless if tumor is small in size or does not have hard consistency, palpation can be misleading

Additionally open surgery has several drawbacks:

- **Patient trauma after surgery**
- **Increased health care costs**
- **Slow recovery time**

MIS Laparoscopy - practices

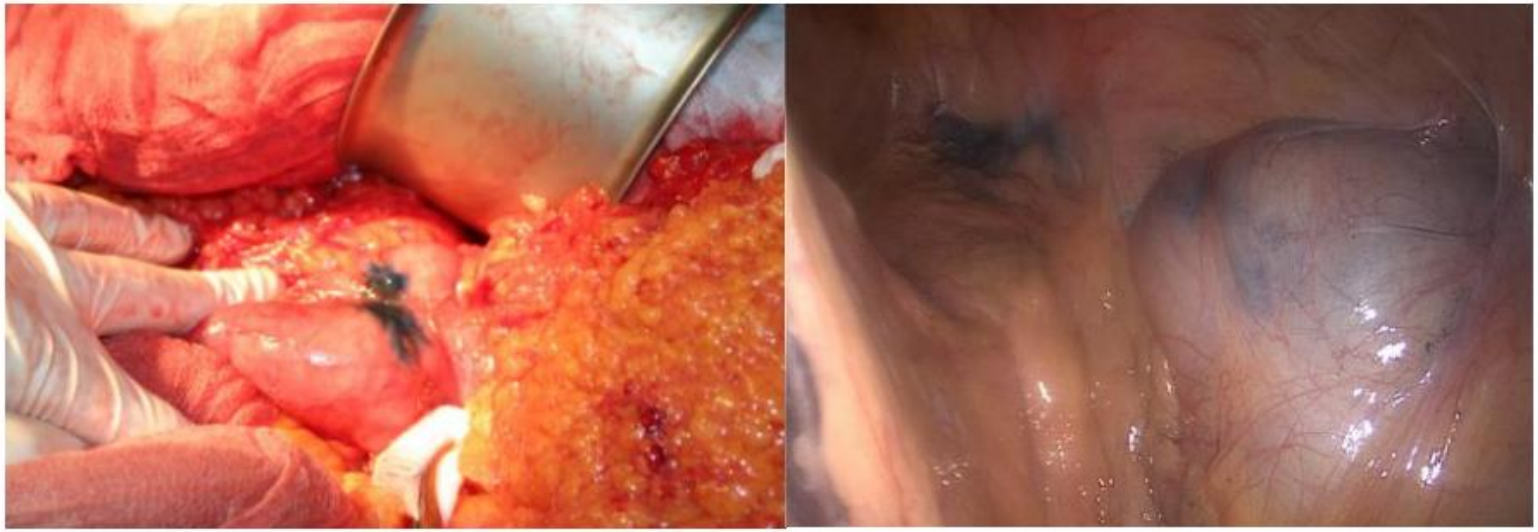
Digestive tumor marking or identification is required:

- **Before surgery dye injecting**

↑ endoscopist not required during surgery.

↓ needle gets contaminated, patient experienced abdominal pain.

↓ injected dye colors proximity tissues.



MIS Laparoscopy - practices

Digestive tumor marking or identification is required:

- **Intra-operatory tumor detection**

endoscopist and logistics are required at surgery time.

reduced working space due to insuflation of gas into the lumen of stomach or colon resulting in a distention of the bowel.

Problem statement

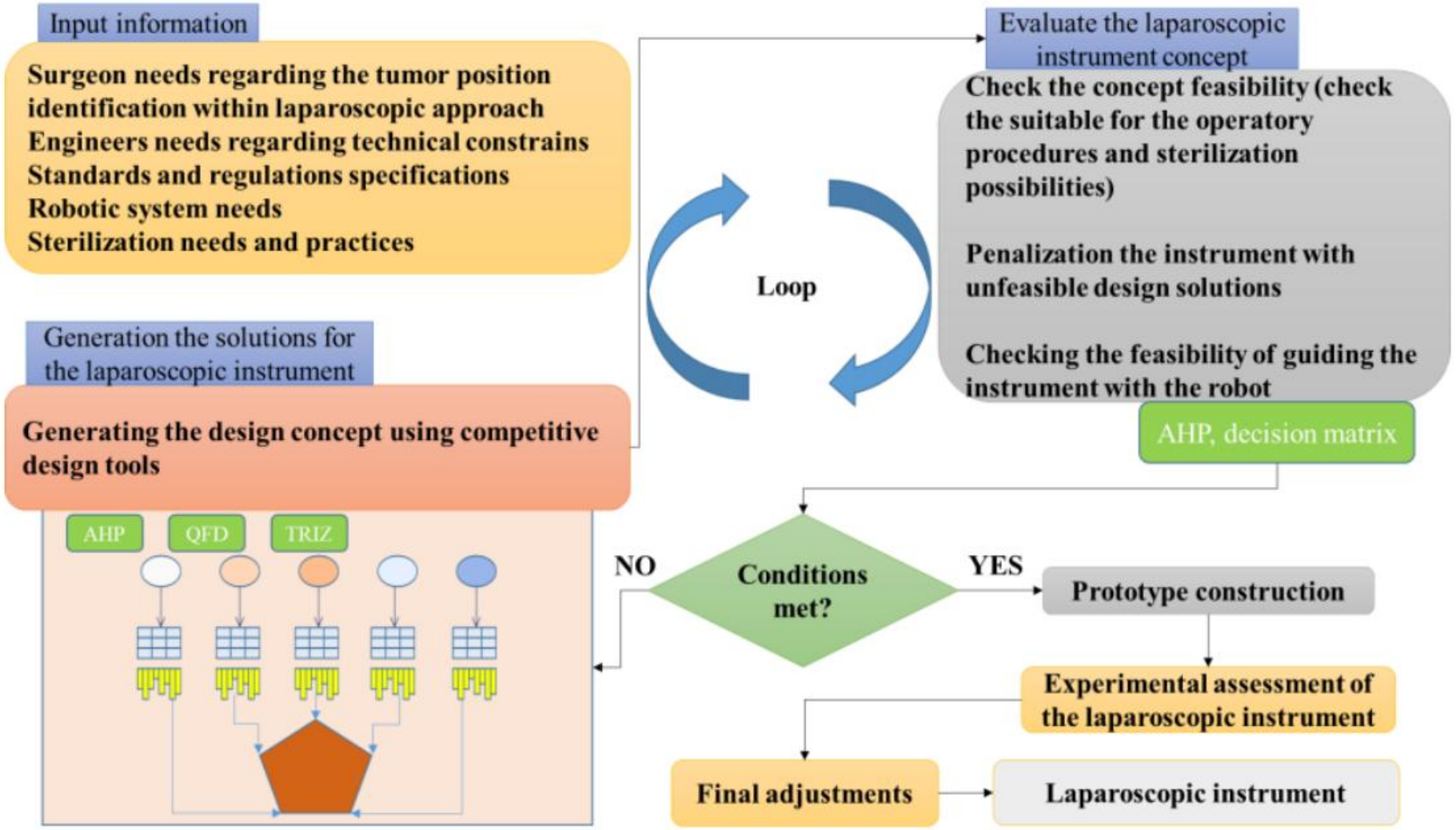
Precise localization of small size digestive tumors within a surgery

Proposed solution

Based on a pre-surgery endoscopic evaluation and tumor marking with metal clips

A laparoscopic instrument with an inductive proximity sensor on top of it able to detect tumor marking metal clips

Methodology – design framework



Methodology – target functions (TF)

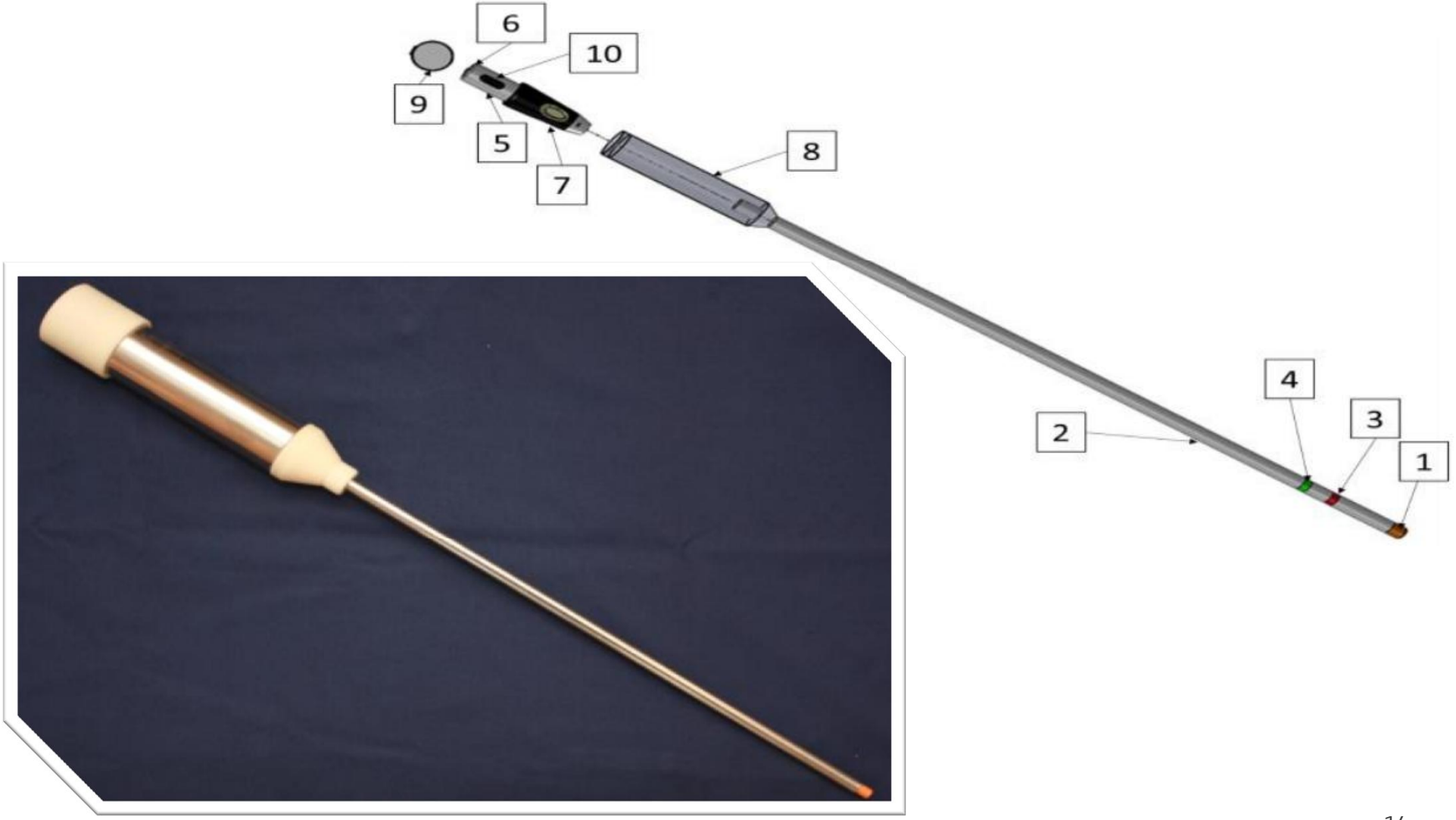
TF1: High quality						
TF2: Affordable costs						--
TF3: High efficiency					++	++
TF4: High precision				-	++	++
TF5: Easy to handle by surgeon & robot			++	++	++	++
Optimization trend			↑	↑	↑	↓	↑
Requirements	Importance	TF5	TF4	TF3	TF2	TF1
MR1: sterilization by standard methods	10%		*		o	o
MR2: usage in laparoscopic and classic procedures	25%	*	*	o	o	
MR3: Identification of tumors extremely accurate	65%	●	●	●		●
Value weight [%]		24.0	25.9	23.6	8.1	18.4

Methodology – solving TF conflicts

1. Cost minimization vs. high quality
2. Increasing efficiency vs. precision

1. Change density or physical state, make immovable parts movable; Use composite materials, etc.
2. Replace mechanical means with sensory means, use electric, magnetic fields to interact with object, etc.

Instrument – design & prototype



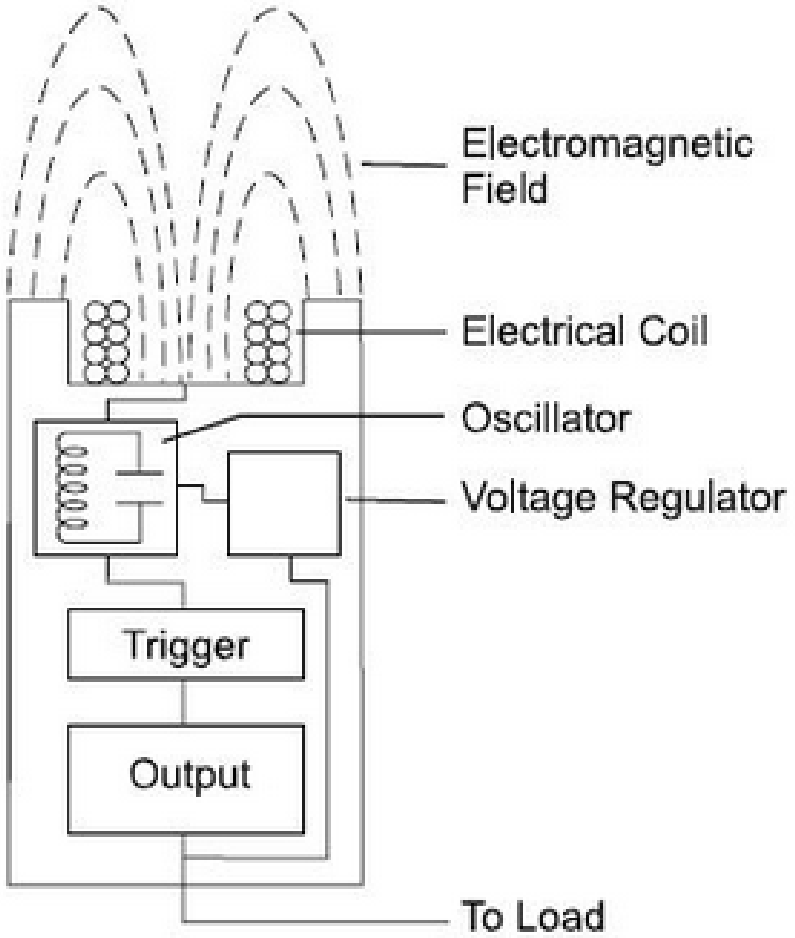
Instrument – sensing element

Sensor used:

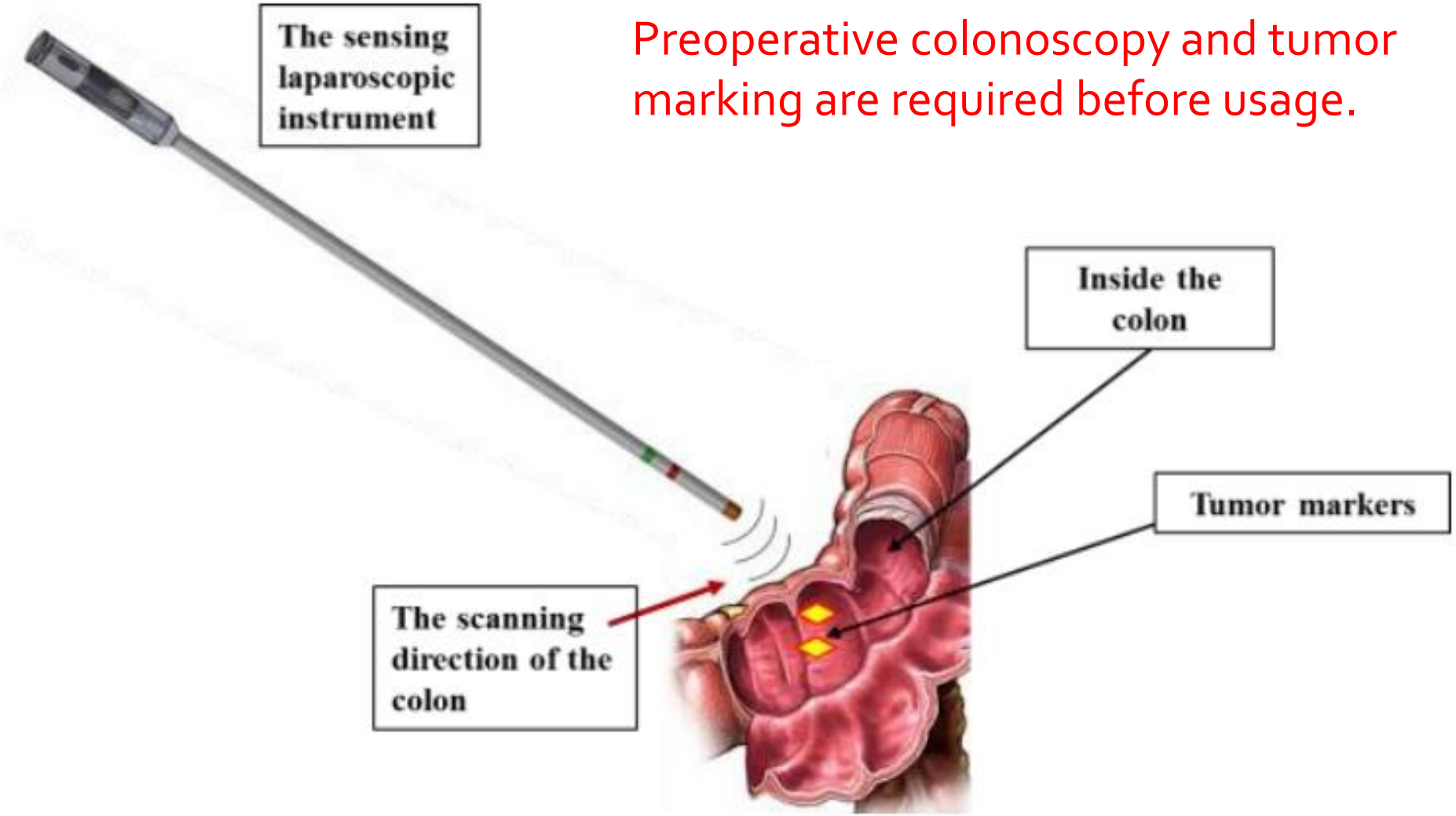
- IFM IE5352

Sensor characteristics:

- Operating voltage: 10-30 VDC
- M8 body size.
- Normal open transistor output
- Non-flushable



Instrument – usage example



Preoperative colonoscopy and tumor marking are required before usage.

Instrument – usage & testing

a) handled by a surgeon

b) handled by a robotic system

Instrument – experiment

Within a bowel wall of 20 cm tumor marking clips were applied.

Each marking elements were applied with a Karl Stroz applier.

Experiment goal:

- Evaluate detection accuracy at different:
  - Motion curves
  - Orientations angle
  - Velocity

Instrument – validation

titanium	steal ϕ 0.4 mm	cooper ϕ 0.3 mm	cooper ϕ 0.5 mm	Stain. steal ϕ 0.2 mm	Stain. steal ϕ 0.4 mm
					
60% at 1.15mm	85% at 2.9 mm	70 % at 2.0 mm	75 % at 2.4 mm	80 % at 2.5 mm	85 % at 3.5 mm

Conclusions

- A methodology for concurrent planning and design of surgery products considering both medical and performance requirements is introduced.
- Developed laparoscopic sensing instrument is adaptable to be used in both open and laparoscopic surgery.
- At this stage the instrument can be used by surgeon or by a guided industrial robot system.

Questions?

Acknowledgement: Support within the project Research Grant no. 1495/5/28.01.2014 offered by the University of Medicine and Pharmacy Cluj-Napoca for the study of "Non-invasive intraoperative detection of small endoluminal digestive tumors and their margins using proximity sensors" is acknowledged with gratitude

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