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PIANO NAZIONALE  
DI RIPRESA E RESILIENZA

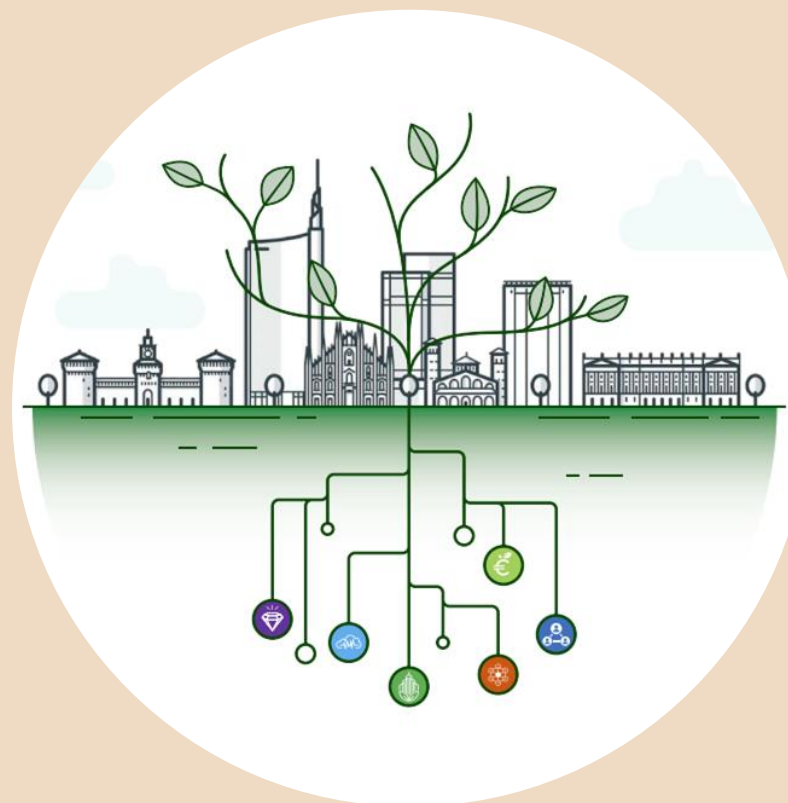


# SPOKE 3

Andrea Sianesi

Second MUSA General Meeting

3.11.2023





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## Dall'idea all'impresa



Applied  
research



Technology  
maturation



Business  
acceleration

Know-how & capability increase in the ecosystem on TT processes and technologies

TTO services to  
SMEs

Entrepreneurship training  
services to local businesses  
and individuals

Venture Building  
services



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## Performance 2023



### Starcup Lombardia

Starcup Lombardia is the competition organized by Lombardy's universities and university incubators, promoted by the Lombardy Region, which fosters the creation of high-potential new ventures born, hosted or connected through collaboration with Lombardy's universities and university incubators.

**+120**

Collected ideas

**6**

PNI Access

**13**

finalists

**10**

Universities involved

**150k€**


Grants provided

**AWARDS CATEGORIES**  
**ICT & SERVICES**  
**INDUSTRIAL TECHNOLOGIES**  
**LIFE SCIENCES & MEDTECH**  
**CLEANTECH & ENERGY**  
**SPECIAL AWARDS**  
**SUSTAINABILITY**  
**SOCIAL IMPACT**



## Premio nazionale innovazione

The **National Innovation Award PNI** is the most important and widespread **Business Plan Competition** in Italy which every year selects the best innovative business projects winners of the regional Start Cups.



MILAN  
NOVEMBER 30  
DECEMBER 2



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## CHIARA LENA

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*Smart endoscope for  
colonoscopy*

## MIRKO SIANO

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*Perspectives in optical and  
radio links for high density  
data transmission*

# AFFAMATI DI FUTURO UNPLUGGED



Inquadra il QR-Code per  
acquistare il biglietto

**13 NOV  
ORE 19.15**

Teatro Franco Parenti  
Via Pier Lombardo, 14 - Milano

Prevendite su:  
[www.teatrofrancoparenti.it](http://www.teatrofrancoparenti.it)

Un evento organizzato da:



Con il patrocinio di:



**POLITECNICO  
MILANO 1863**

Media partner:



**Teatro Franco Parenti**

Dal 1972. Fondato e diretto da Andrée Ruth Shammah



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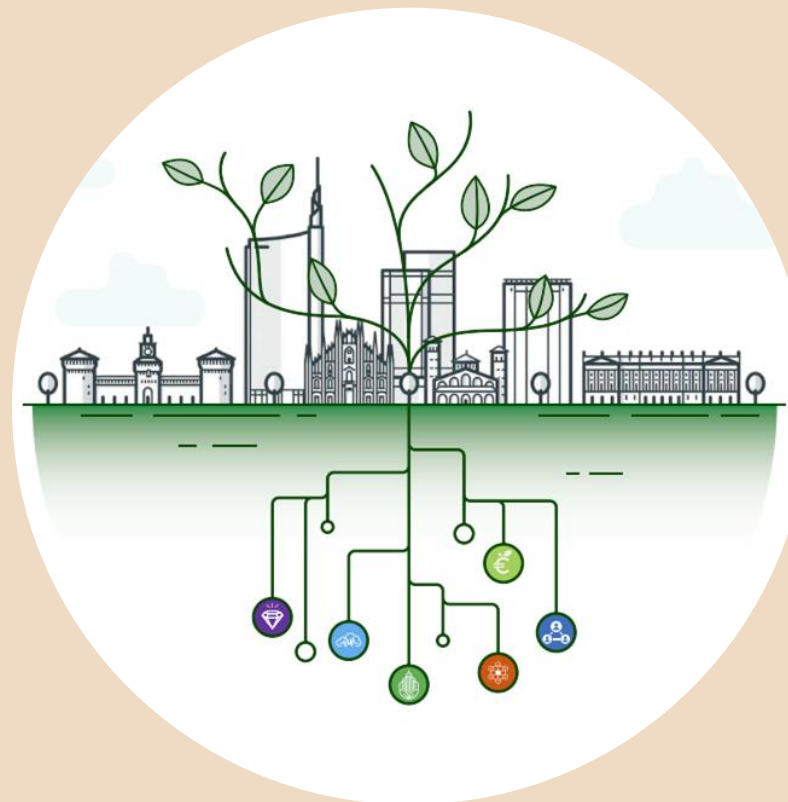
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# Smart Endoscope for Colonoscopy

Chiara Lena, POLIMI

03.11.2023





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# Collaboration

## Politecnico di Milano



Chiara Lena  
*PhD Candidate*



Elena De Momi  
*Professor*



Alberto Redaelli  
*Professor*



Marco Spadaccini  
*MD, PhD Candidate*



Cesare Hassan  
*MD, Professor*



Alessandro Repici  
*MD, Professor*

## Humanitas Research Hospital

## Leeds University



Bruno Scaglioni  
*PhD*



Joseph Norton  
*PhD*



Pietro Valdastri  
*Professor*

Request to Humanitas Ethical Committee  
for collection and annotation of >500  
endoscopic videos

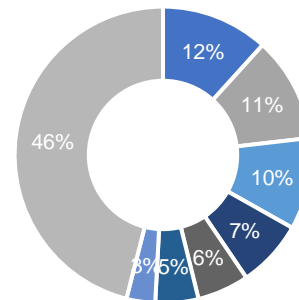




# Clinical Scenario: Colorectal Cancer

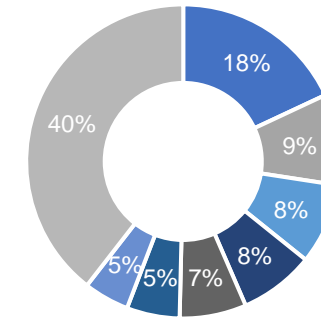
**Third** most common  
**Second** for mortality

Incidence

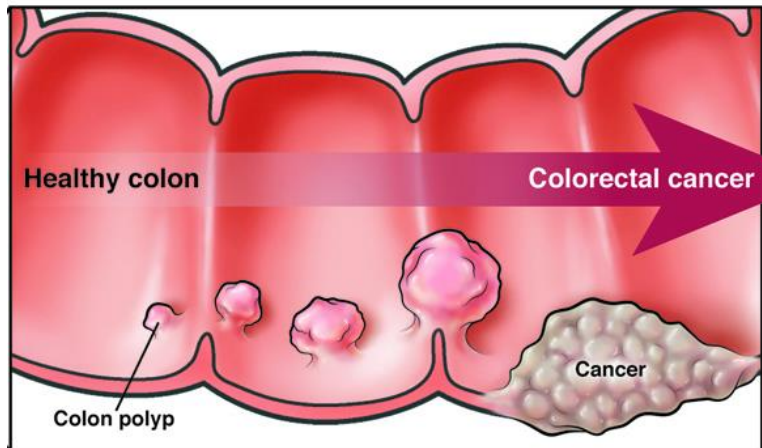


- Breast
- Lung
- Colorectum
- Prostate
- Stomach
- Liver
- Cervix uteri
- Others

Mortality



- Lung
- Colorectum
- Liver
- Stomach
- Breast
- Oesophagus
- Pancreas
- Others



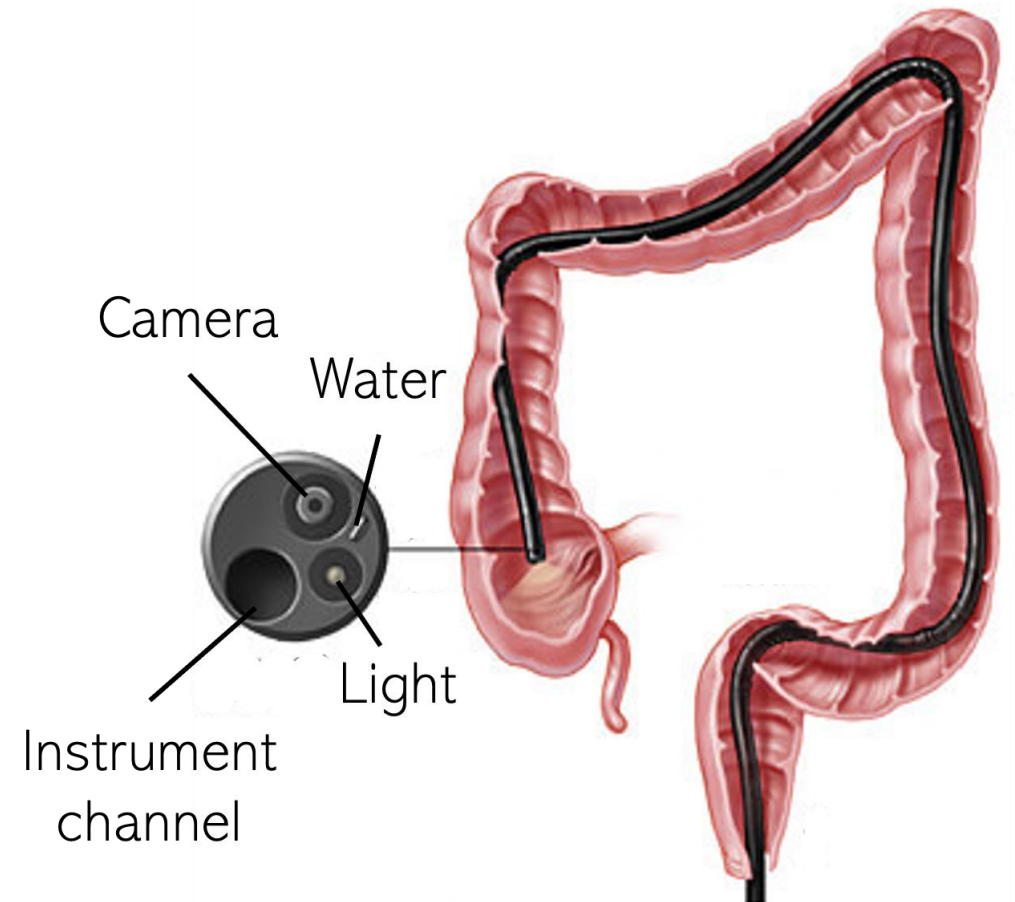
It arises from the malignant transformation of **polyps**

**Early detection and removal** of pre-cancerous polyps is the key to **prevention**. The best screening exam is **colonoscopy**



## Clinical Scenario: Colonoscopy

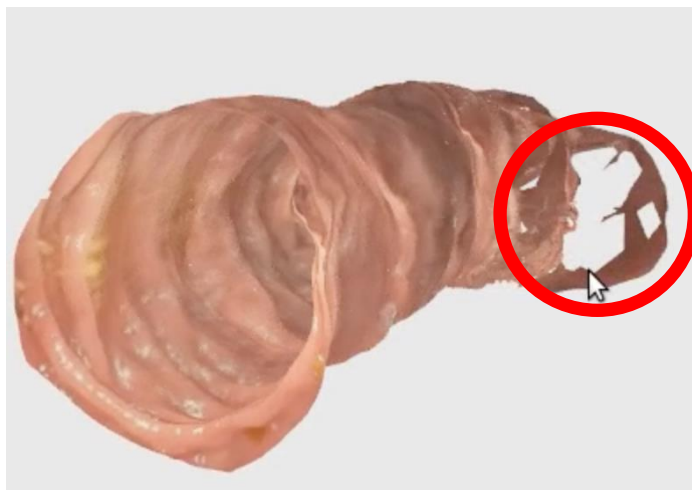
- Lesion **inspection** and **removal**
- **Flexible** endoscope
- **Manual** navigation



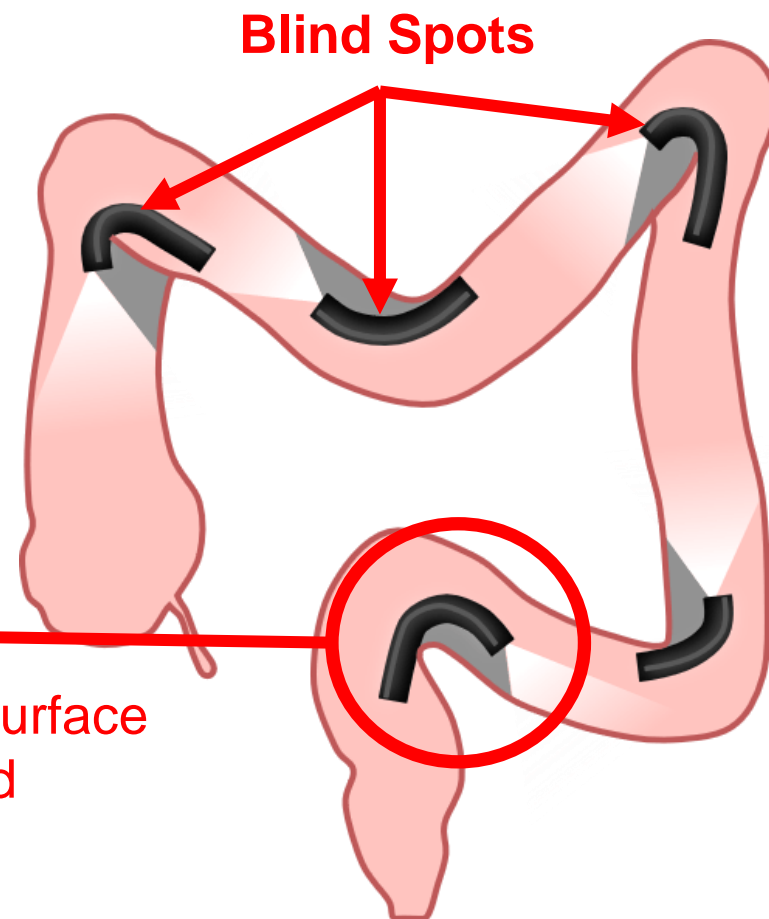
## Clinical Scenario: Challenges

Up to 22% of missed lesions

Blind spots and missed surface



Holes where surface is missed



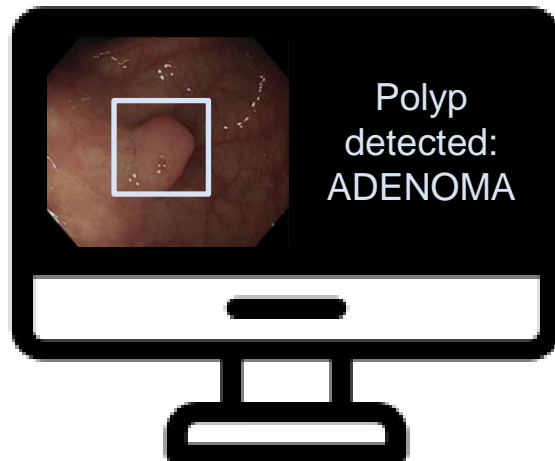


## Aim of the project

Development of a **smart endoscope for colonoscopy** integrating **artificial intelligence** to increase **diagnostic accuracy and quality**.

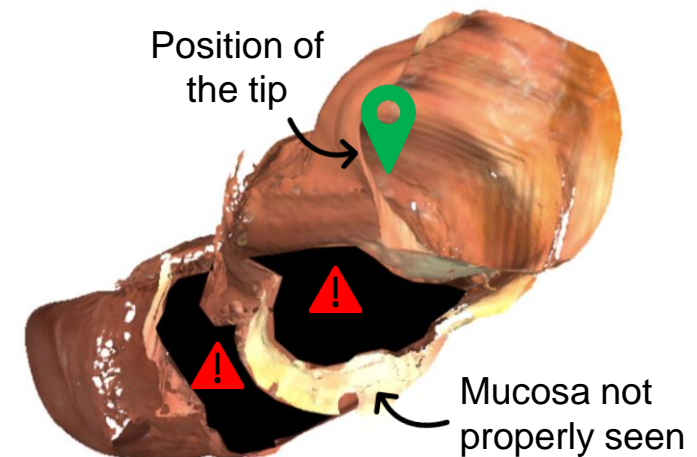
### Lesion detection and virtual biopsy

Computer-aided system for **automatic identification** and **classification of lesions**



### 3D reconstruction and navigation

Automatic **reconstruction** of the **3D model** of the colon and **navigation** of the built model

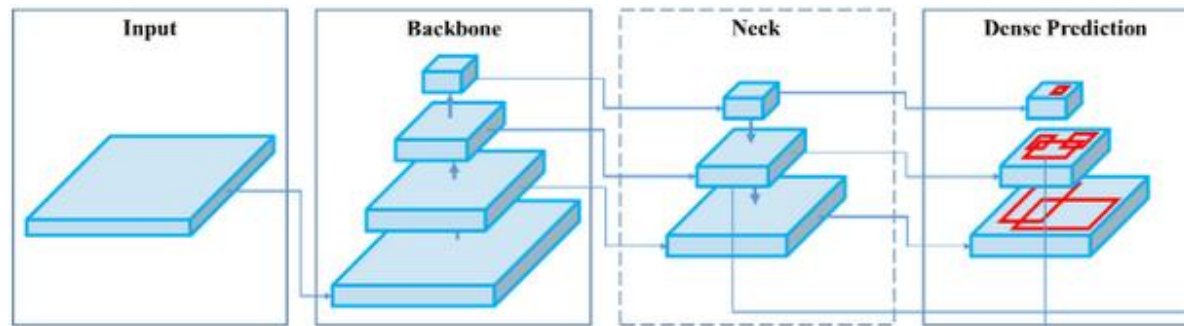




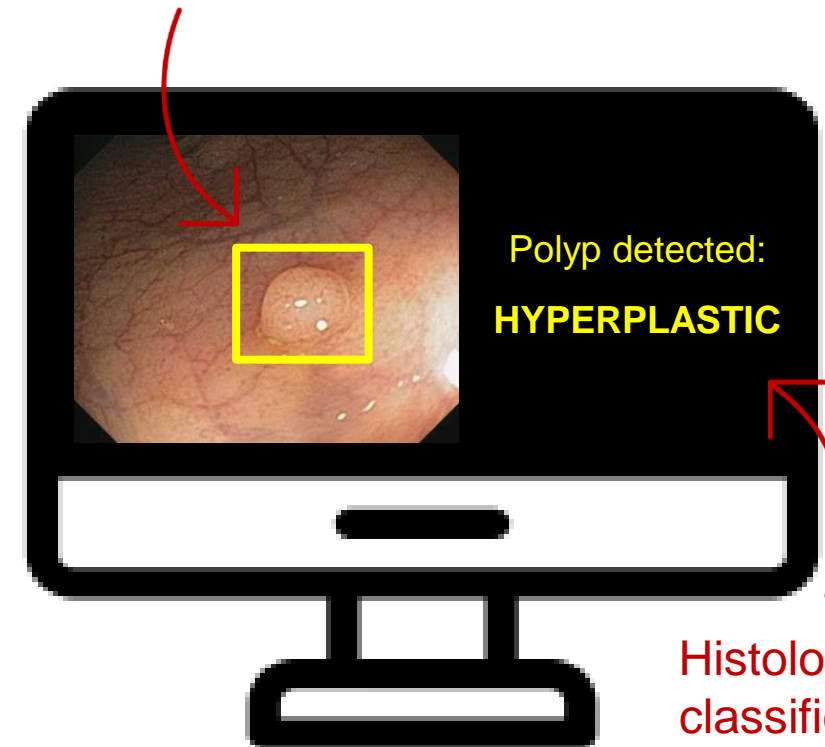
## Lesion detection and virtual biopsy

Prediction of the **presence, location and histological classification** of polyps in a frame

Fully supervised approach with YOLOv5, a convolutional neural network known for good accuracy and speed.



Polyp Location

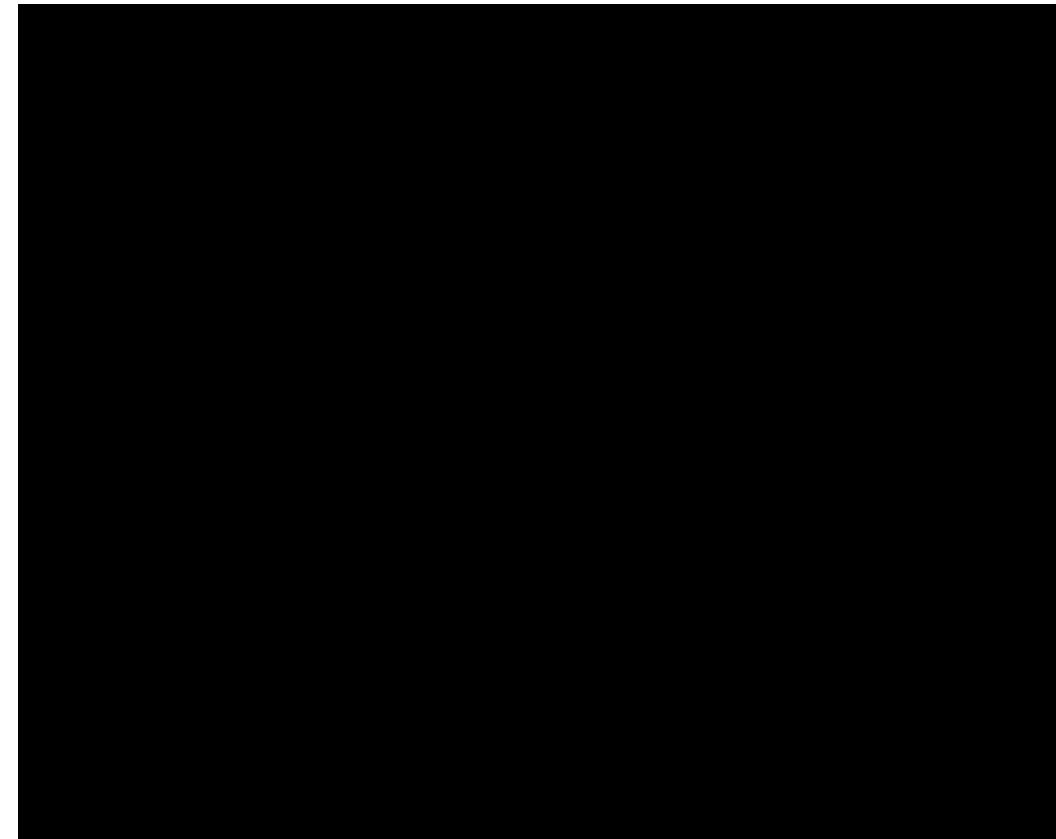




## Lesion detection and virtual biopsy

Very promising results: **> 95% accuracy**  
for each histological class

Class	P	R	mAP50
All	0.97	0.948	0.971
Adenoma	0.971	0.958	0.987
Hyperplastic	0.975	0.943	0.967
Serrated	0.978	0.931	0.977
Non-epithelial neoplastic	0.936	0.943	0.957
Invasive	0.989	0.967	0.965



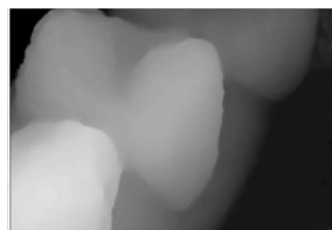
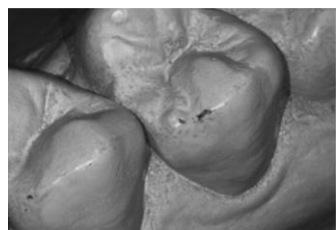
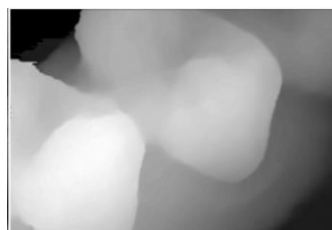
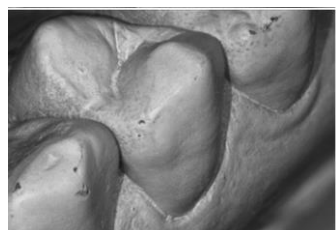
# 3D Reconstruction and Navigation

Multiple views of the same scene

Depth maps: images are colored based on distance from the camera

Camera poses and orientations

3D reconstruction and navigation



+

+



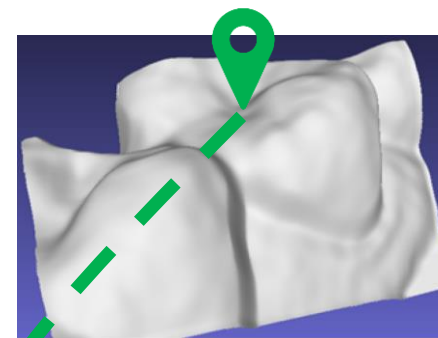
Closer objects

Further objects

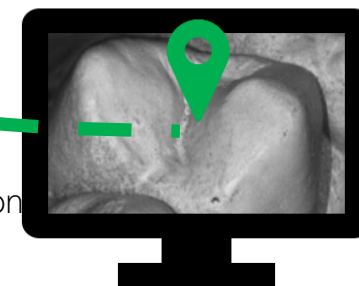
Camera pose 1

Camera pose 2

Camera pose 3



Position and motion awareness

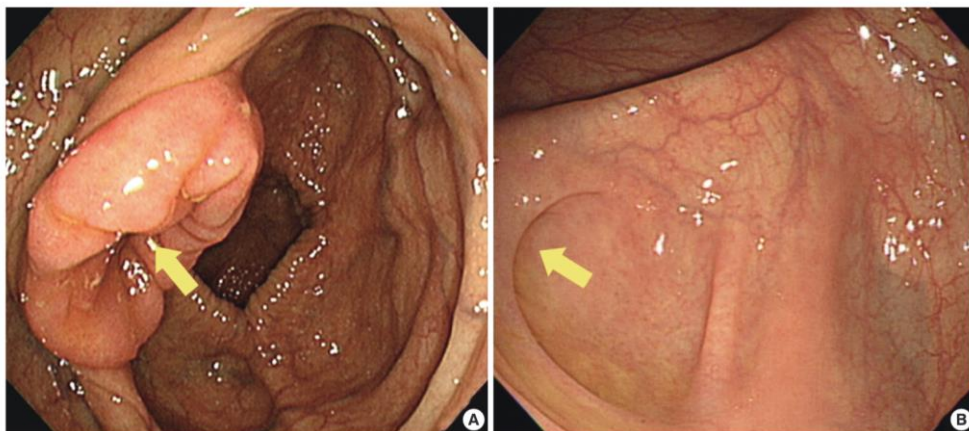
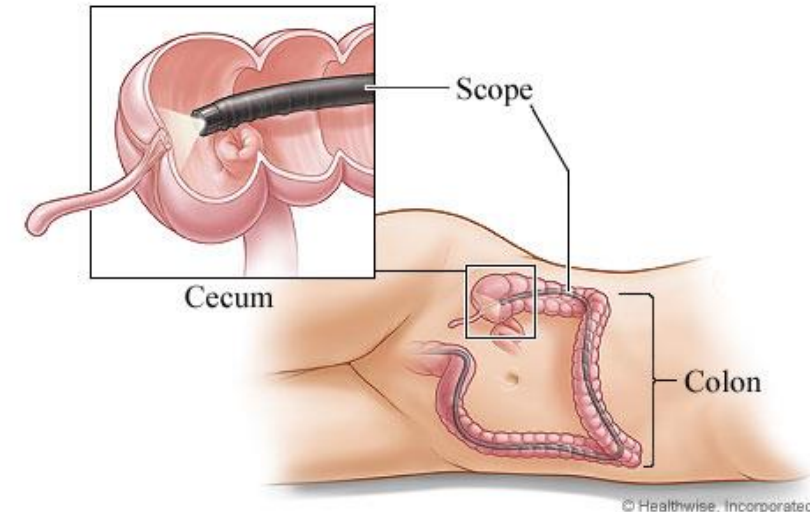




## 3D Reconstruction and Navigation: Cecum Identification

Clinical relevance:

- Starting point of the real exam
- Starting point of 3D reconstruction
- Quality measure

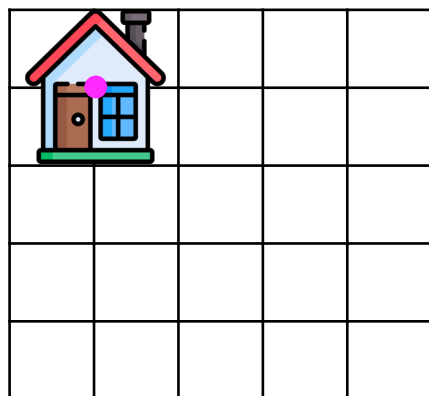


New approach based on **the identification of the two main landmarks of the cecum**

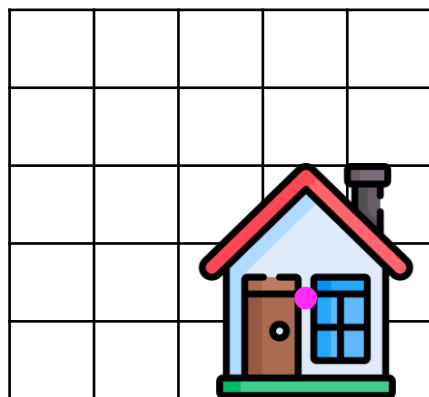
- Appendiceal orifice
- Ileocecal valve



## Depth Estimation with Optical Expansion

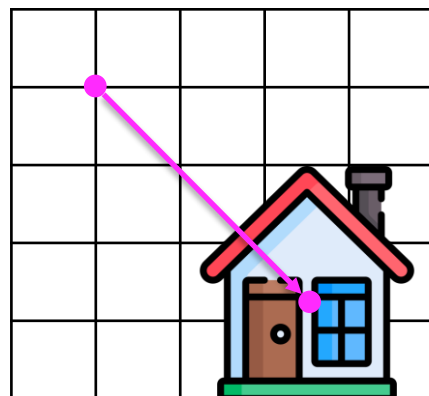


Frame T



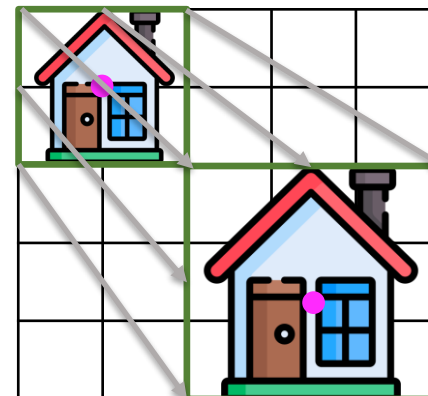
Frame T+1

**Optical Flow**



**Vector representing 2D movements**

**Optical Expansion**



**Provides scale changes "expanding" 2D flow in 3D**

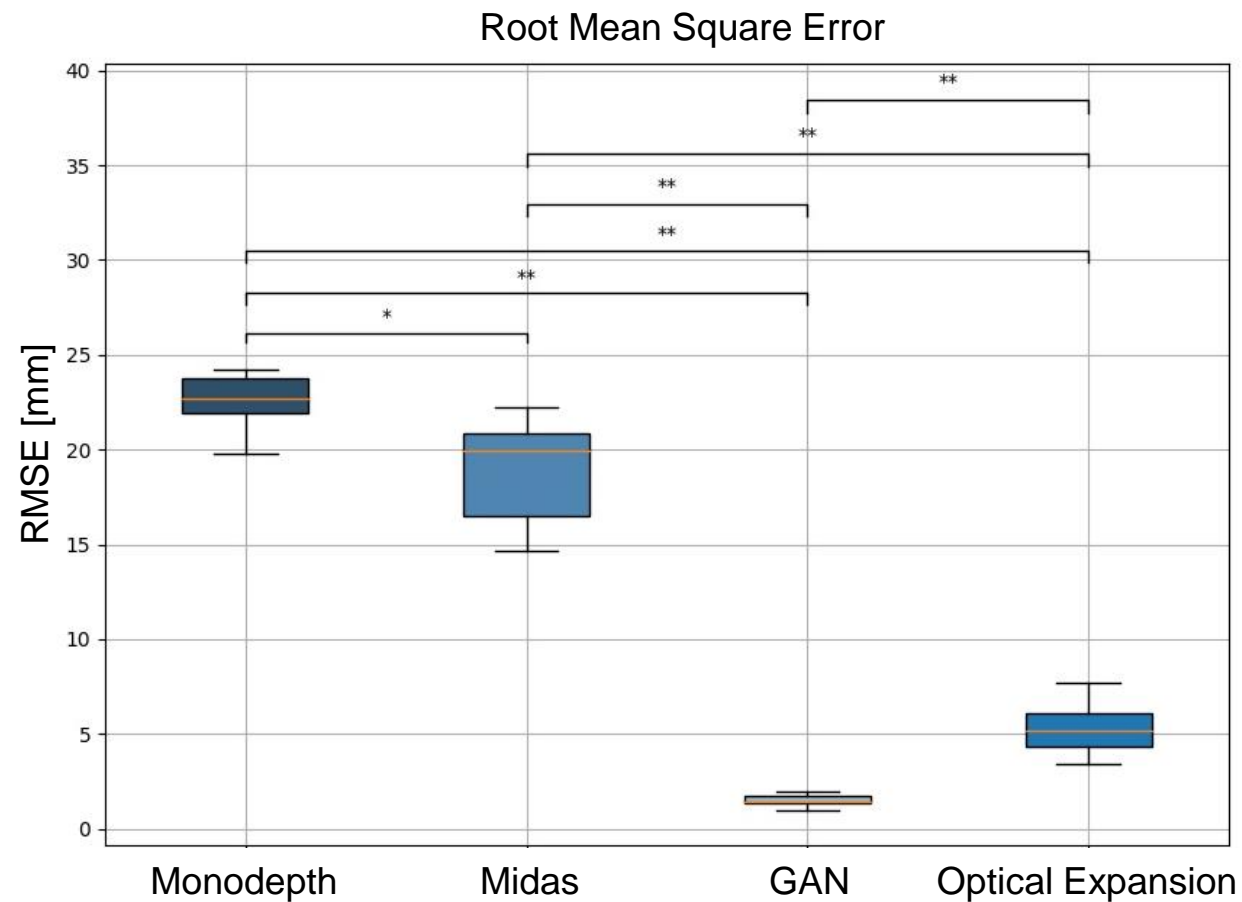
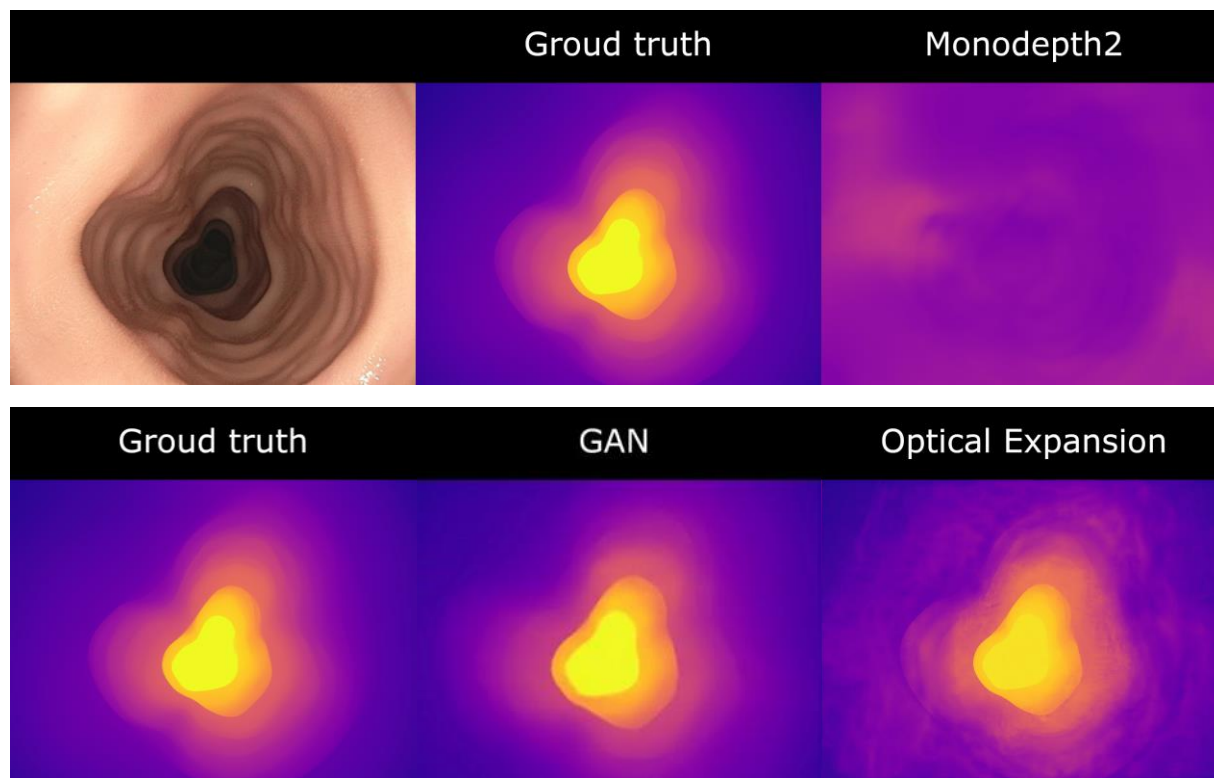


Objects approaching the camera will appear larger



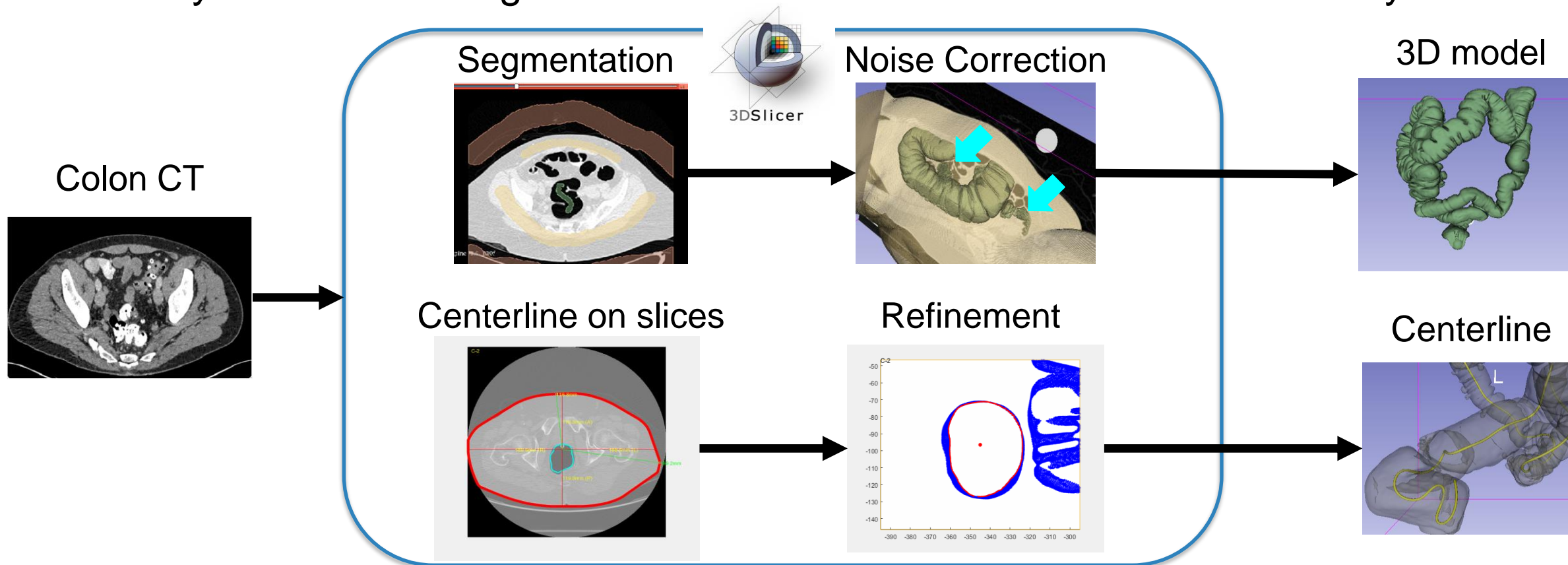
Depth estimation is based on motion, not on image visual characteristics

# Depth Estimation with Optical Expansion



# 3D Synthetic Dataset Generation

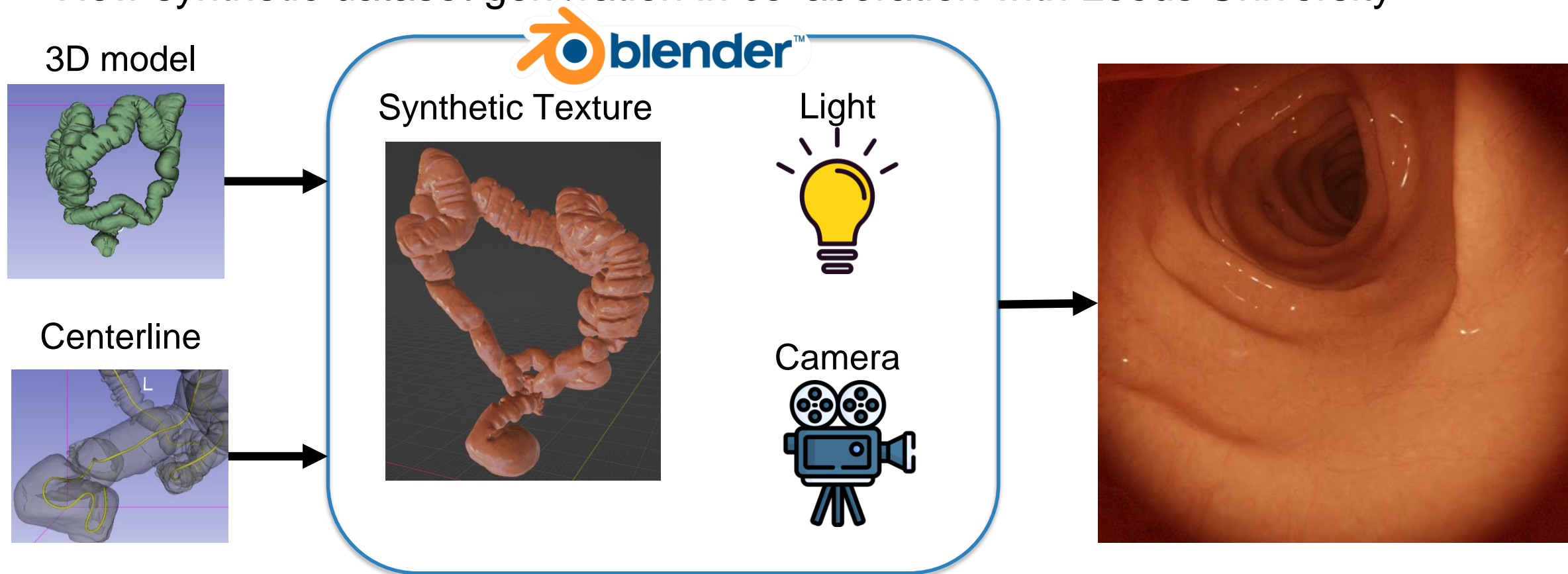
New synthetic dataset generation in collaboration with Leeds University





## 3D Synthetic Dataset Generation

New synthetic dataset generation in collaboration with Leeds University





## 3D Synthetic Dataset Generation

New synthetic dataset generation in collaboration with Leeds University



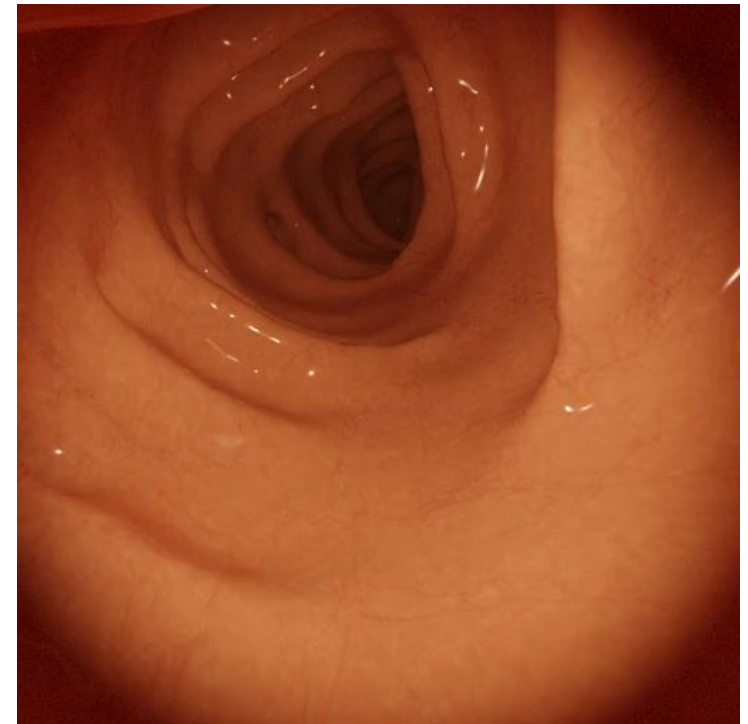
### Highly realistic

- Shape
- Texture
- Movements



### Ground truth

- Depth maps
- Camera poses
- Optical flows

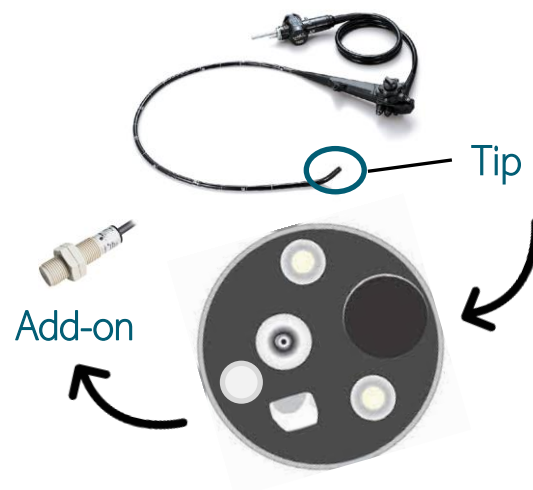




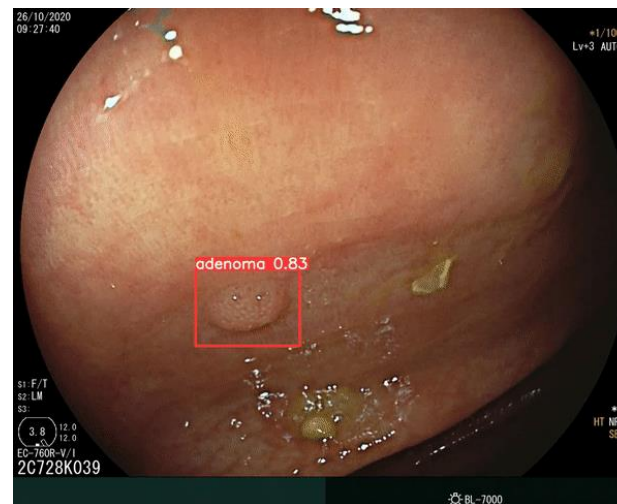
## Switch2Product: INSIGHT

# INSIGHT

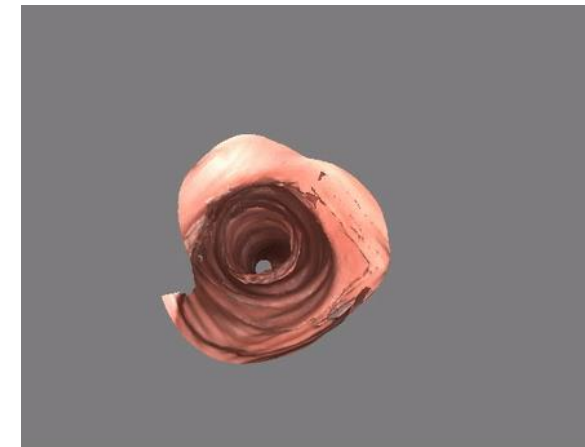
**INSIGHT** is an endoscopic add-on that can be easily integrated into existing devices.  
**The projects passed the first and second selections of the Switch2Product.**



**Sensorized add-on** mounted on the tip of the endoscope



**AI module** for lesion detection and virtual biopsy



**AI module** for 3D reconstruction and navigation



## Next Steps: Roadmap

**FINAL AIM:** Development of a **smart endoscope** integrating **Artificial Intelligence algorithms** to **improve diagnostic accuracy**

### Outreaching to other MUSA projects

- The aim is to create a strategy to increase accuracy of diagnosis and treatment of colorectal cancer

### Lesion detection and Virtual biopsy

- Additional tests to improve robustness
- Weakly supervised approaches to avoid large annotated datasets

### 3D Reconstruction and Navigation

- Additional tests to improve robustness
- Focus on pose estimation
- Alternative approaches based on SLAM and learning-based keypoints

### Device integration and certification

- Integration of the artificial intelligence algorithm into a commercial device
- Device and algorithms certification with proper clinical trials



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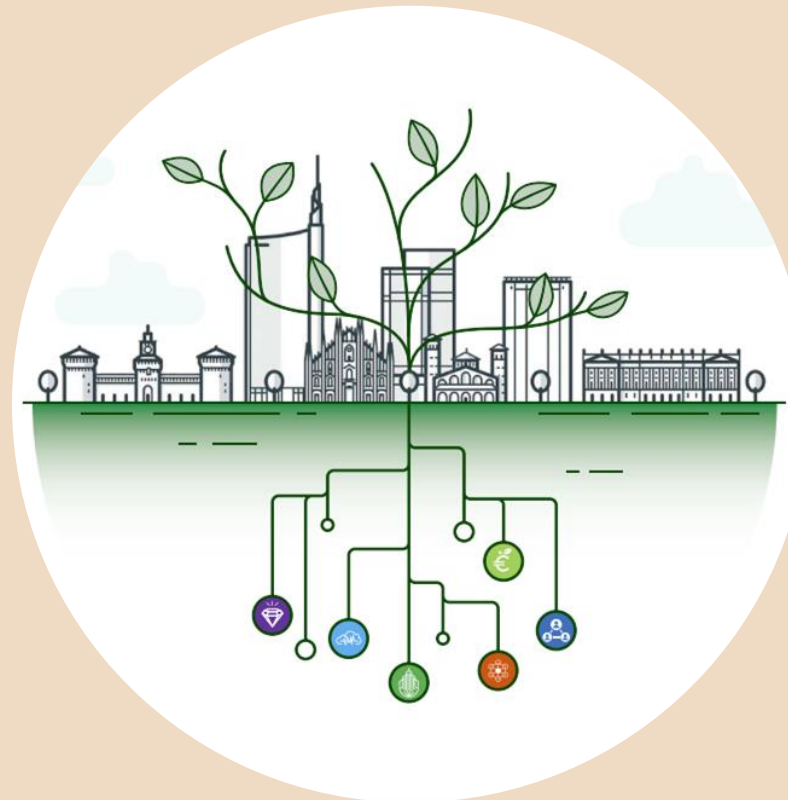
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# Perspectives in optical and radio links for high density data transmission

Mirko Siano, UNIMI

3 November 2023







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## Optical links for data transfer

Recently, high-throughput optical data transmission has been achieved:

1 Tbit/s – 53 km

Potential 40 Tbit/s reachable

Resilience to atmospheric turbulence



Y. Horst *et al.*,

Light: Science & Applications **23**, 153 (2023)

<https://ethz.ch/en/news-and-events/eth-news/news/2023/06/lasers-enable-internet-backbone-via-satellite.html>



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## Space-based internet

INTERNET ACCESS  
DEMAND vs TIME

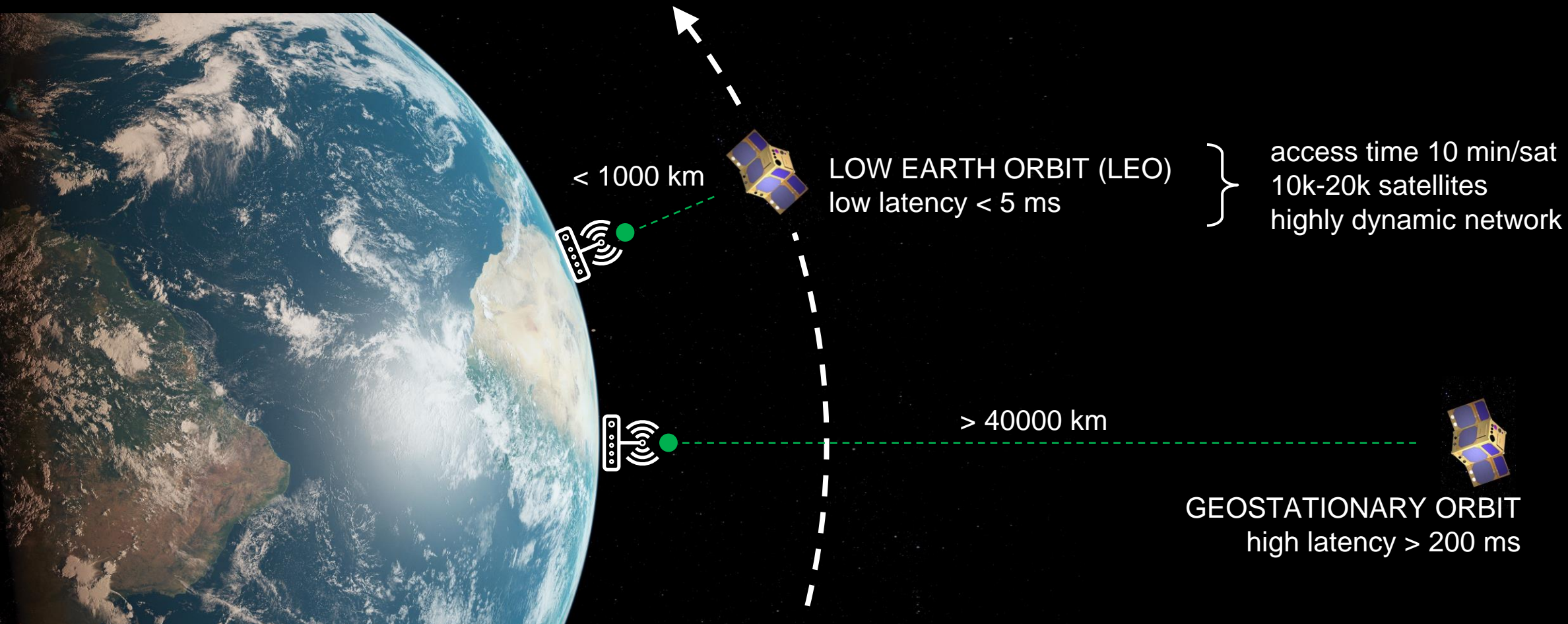


SATELLITE LAUNCHING  
COST vs TIME



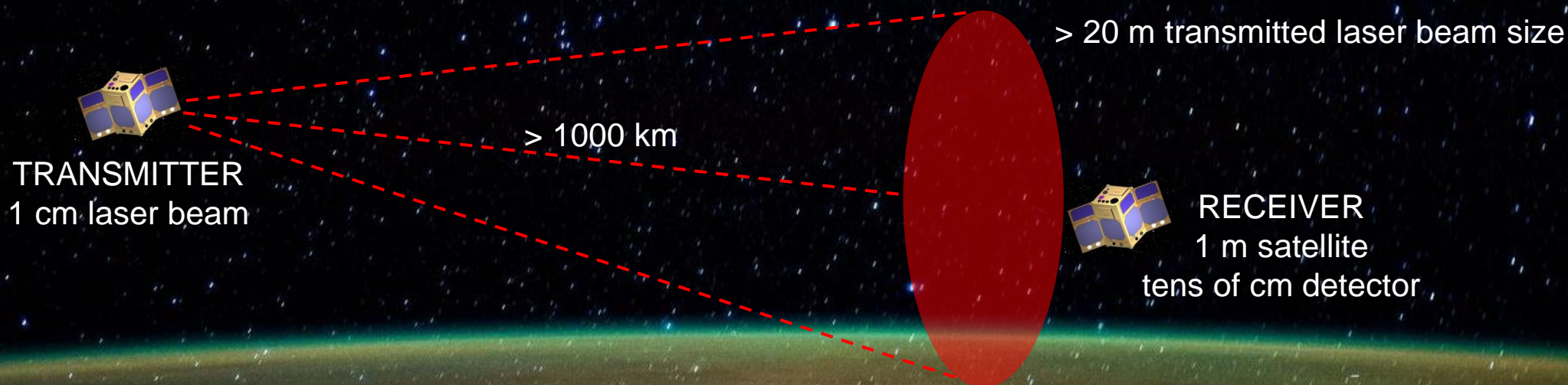
In the forthcoming years, more constellations of satellites will be implemented and will form the backbone of space-based internet

## Space-based internet: challenges



## Space-based internet: challenges

Deep space propagation calls for local detection  
(satellite-satellite distance  $> 1000$  km)





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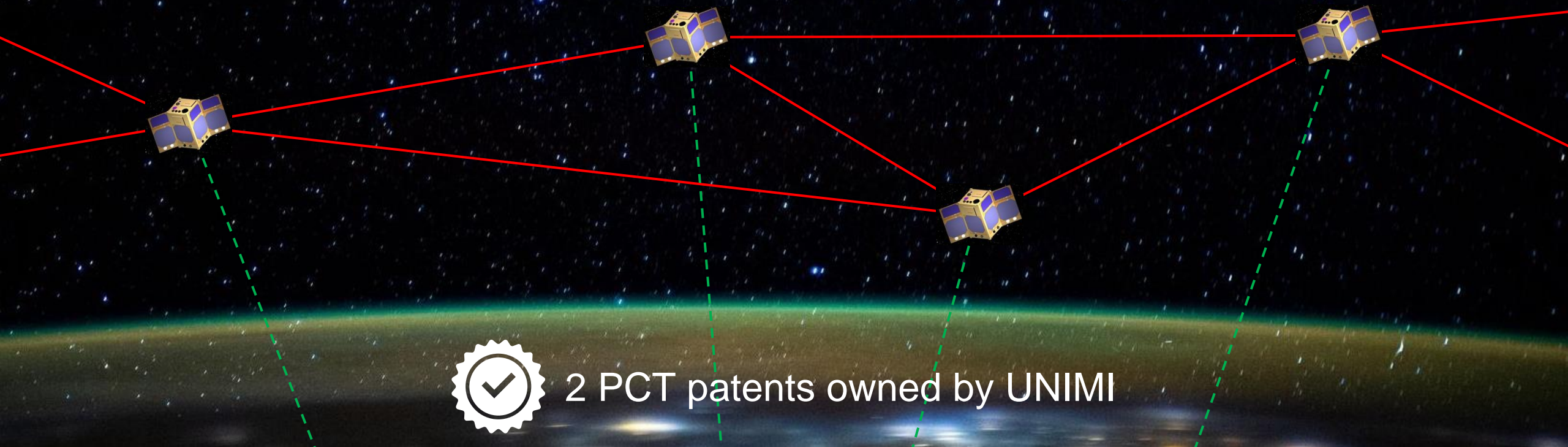


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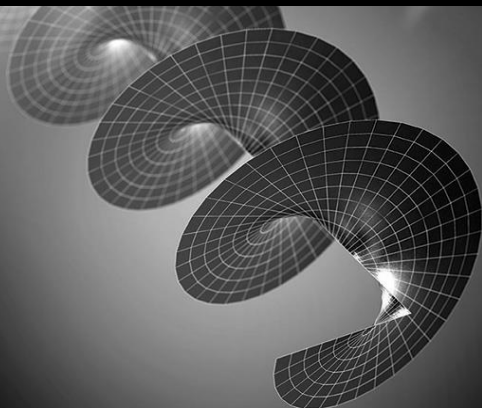


## UNIMI unique solution

Multiplex-demultiplex the information transferred per orbiting unit (satellite-satellite and satellite-ground) with disruptive laser beam shaping, control and detection

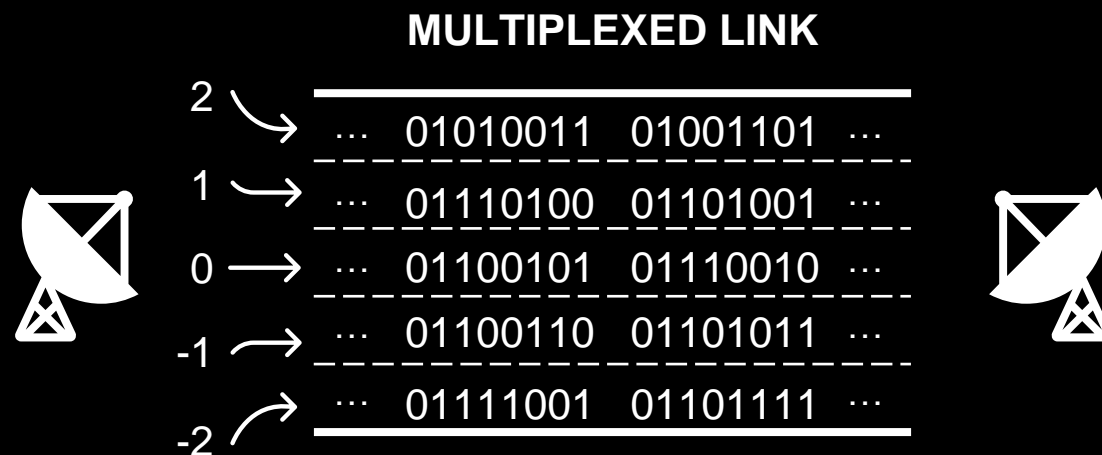


# Optical vortices



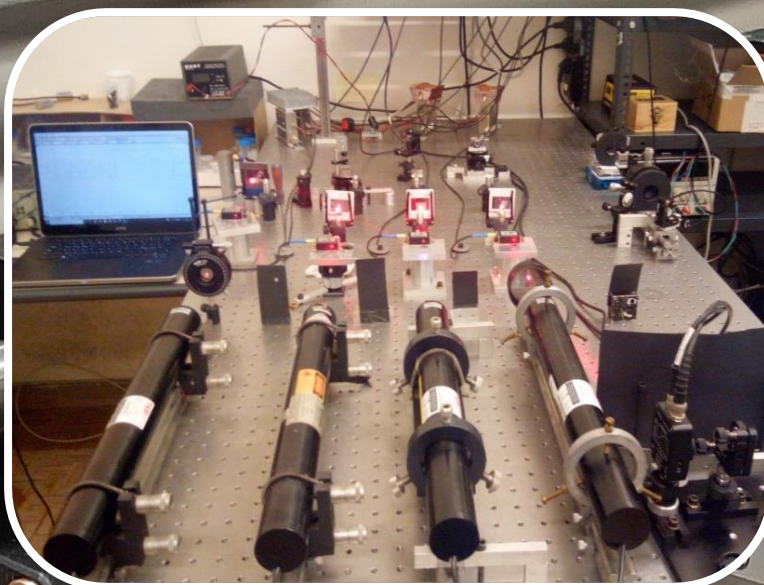
We transform standard laser beams into optical vortices, namely laser light “rotating” around the propagation direction

Multiple parallel communication channels are then realized with optical vortices with different “rotation speed”



## Results and ongoing activities

STRINGS	Transmitted	Received	Parity error	Code error
U, O	55, 4F	55, 4F	none	none
N, /	4E, 2F	4E, 2F	none	none
I, A	49, 41	49, 41	none	none
M, /	4D, 2F	4D, 2F	none	none
I, M	49, 4D	49, 4D	none	none



1 laser  
2 strings in parallel  
Speed: kbit/s

4 lasers  
16 different states  
Speed: Mbit/s

WORK IN PROGRESS



Transmission protocols  
Air turbulence  
Speed: Gbit/s



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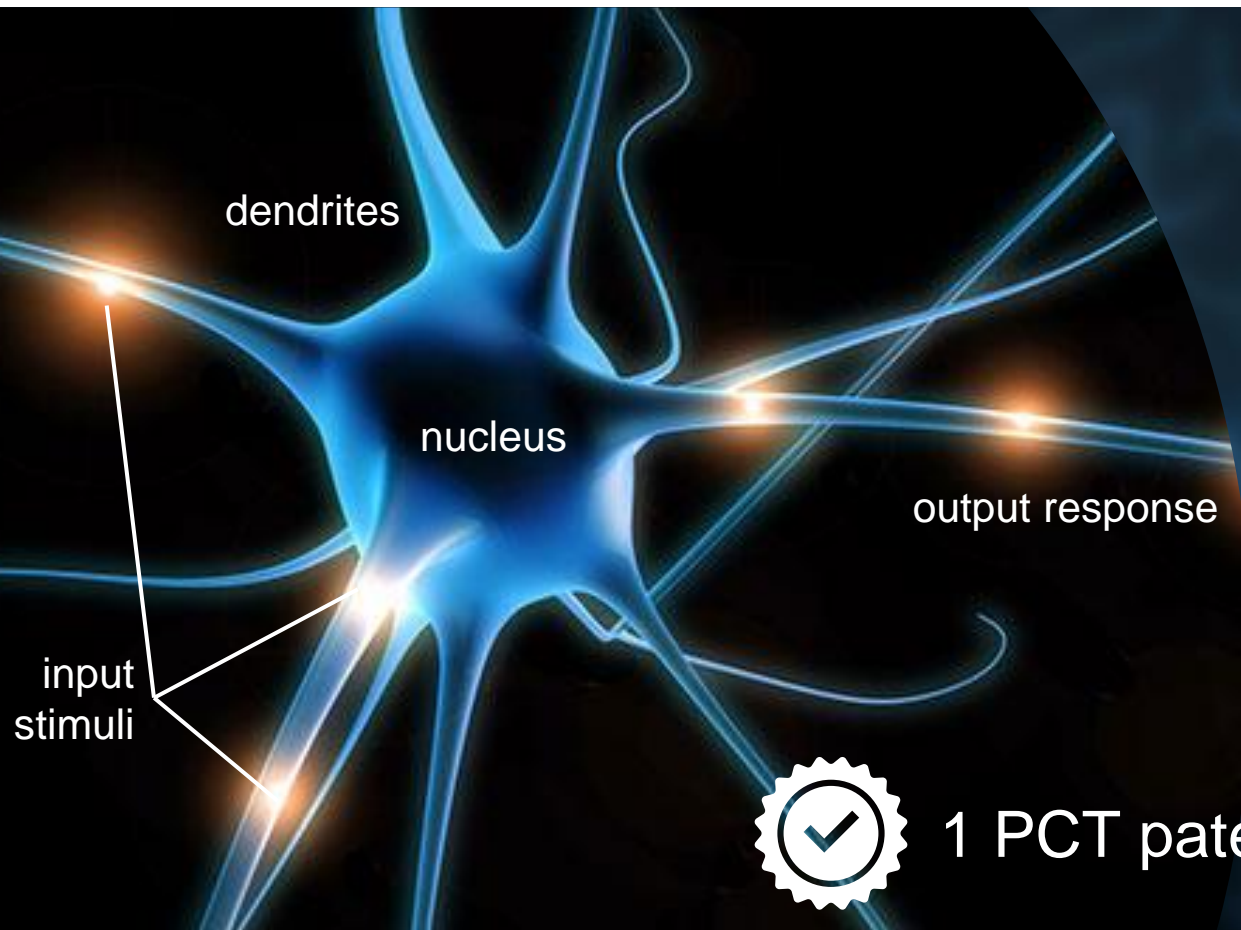
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## All-optical neuromorphic computation



Electrical stimuli from dendrites propagate through the neuron, which in response generates an output pulse.

Depending on the incoming stimuli, the output response is different.

The internal processes of the neuron are not known: the neuron acts as a black box.

Key aspects: redundancy, causality



1 PCT patent owned by UNIMI





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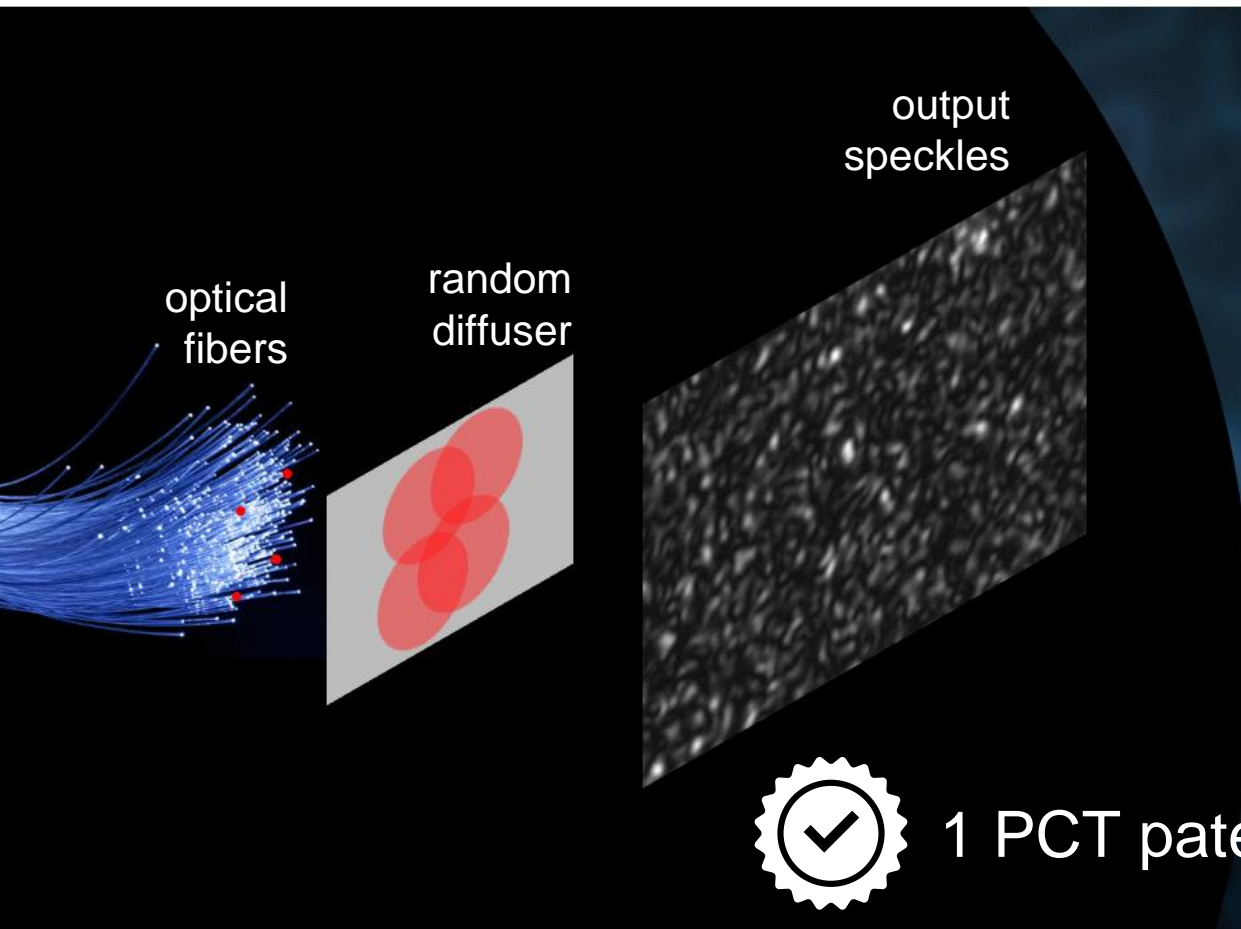
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# All-optical neuromorphic computation



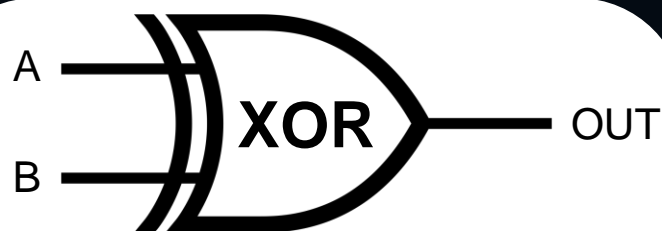
Light stimuli from optical fibers propagate through a random diffuser, which in response generates a random speckle pattern.

Depending on the incoming stimuli, the output speckle pattern is different.

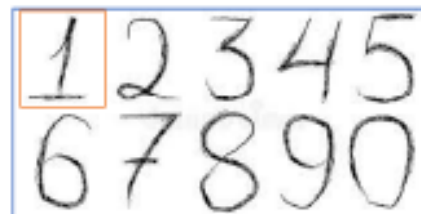
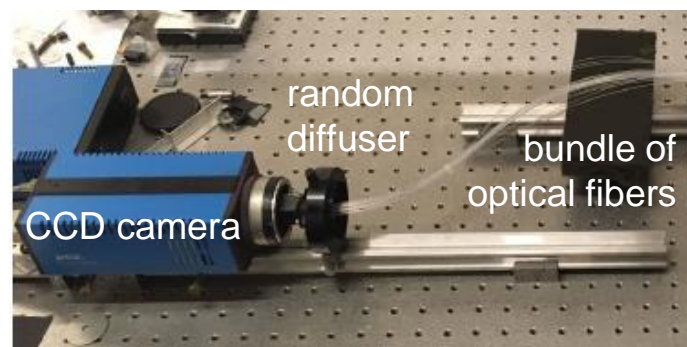
The detailed structure of the diffuser is not known: the diffuser acts as a black box.

Key aspects: redundancy, causality

## Solving tasks with light



A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	0



WORK IN PROGRESS



Simple logic operations  
Logic gates

Pattern recognition  
100% successful

Process fast ethernet  
(100 Mbit/s) signal



## Conclusions and perspectives

Development and integration of novel, disruptive optical technologies for high-density data transmission:

- intersatellite connections and downlink (satellite-ground)
- all-optical neuromorphic edge computing

@ UNIMI we have (patented):

- new technologies for multiplexing/demultiplexing optical vortices
- novel paradigm for non-conventional (electrical/optical) computing

**Building a space-compliant, fully integrated device in collaboration with Optec SpA**