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Development and Application of IATS for Structural Health Monitoring

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CONTENT OF THE PAPER

1. Introduction
2. Development and application of IATS
    - 2.1 Technological development from 2000s until today
    - 2.2 Application of IATS
3. **Experimental testing in the laboratory**
4. **Application in the field**
5. **Discussion and conclusions**

Read in the paper ☺

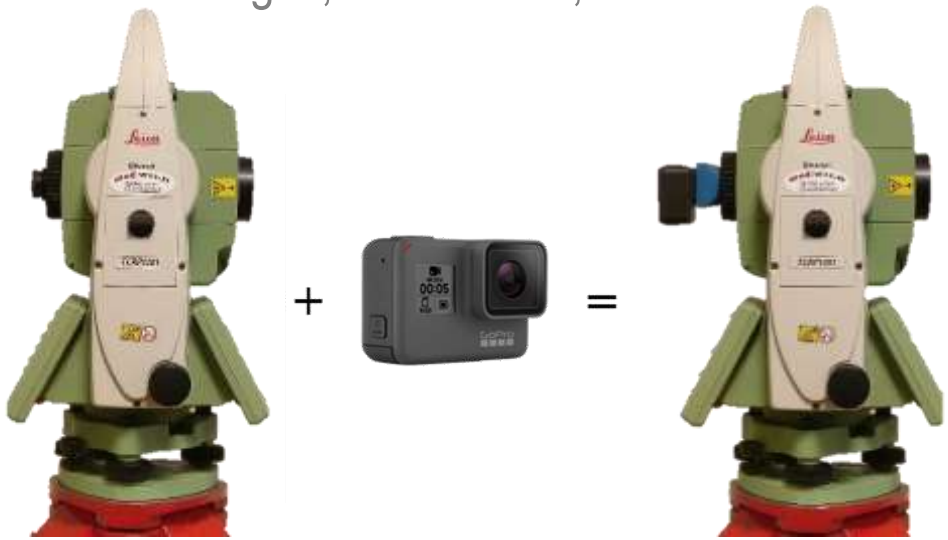
Will be presented now…

Not in the paper, but it will be presented now ☺

APPLICATION OF IATS & WHAT HAVE WE DEVELOPED?

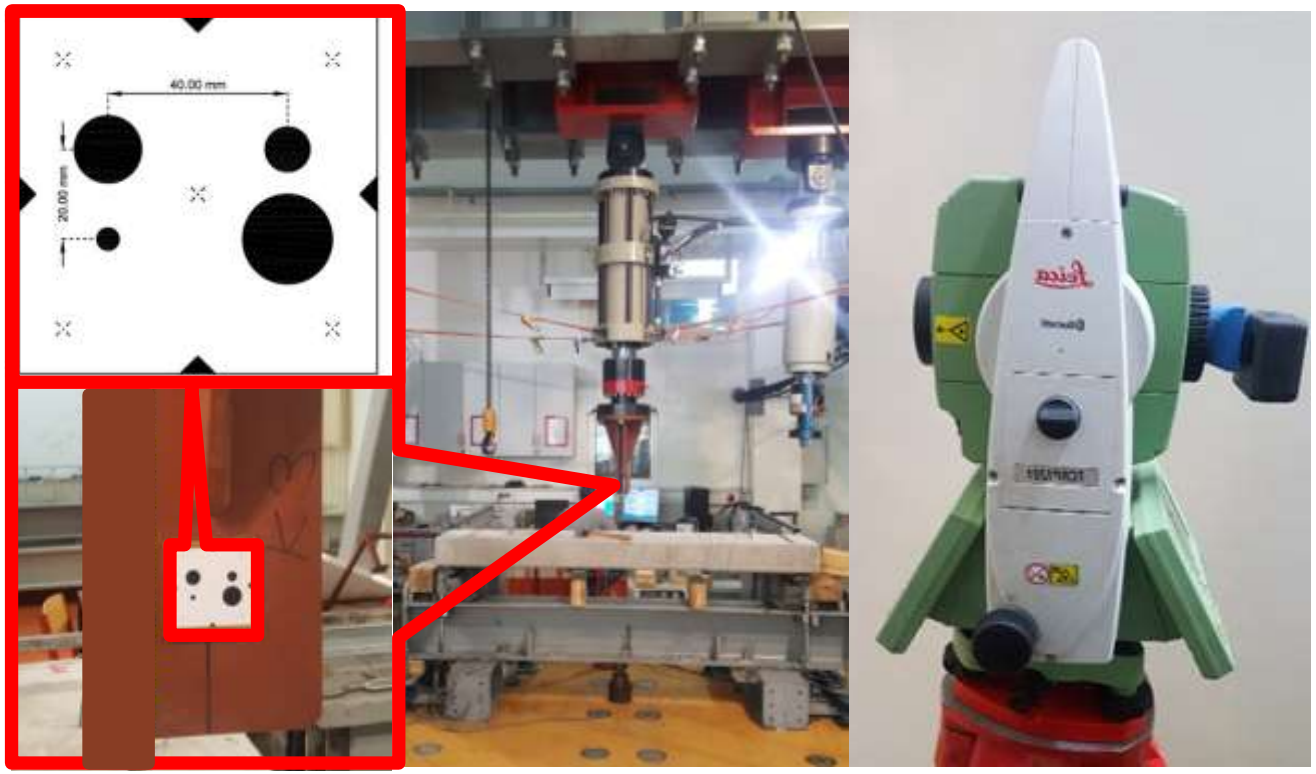
1. **Structural health monitoring (SHM)** refers to the measurement and evaluation of civil engineering structures such as bridges, tunnels, dams, railways, towers, or skyscrapers, i.e., generally manmade objects.
2. **Geo-monitoring** in contrast, is used as a term for the determination of changes, movements, or deformation of natural structures, such as landslides and slopes.

- What have we developed? **IATS prototype**. It consist of:
  - Leica TPS1201 (1”, 2 mm + 2 ppm , 10 Hz, 30x) and
  - GoPro5 Hero camera (1080P, 30 fps, linear)



EXPERIMENTAL TESTING IN THE LABORATORY

- The experimental testing was carried out in the:
  - **Structural Testing Laboratory of Civil Engineering Faculty, University of Zagreb**.
- The dynamic displacements were simulated by:
  - **Multi-purpose universal testing machine** *intended for static and dynamic testing* of mechanical properties of building materials and constructions.
- AIM & SCOPE:
  - Simulate and determine with IATS prototype very small and very fast dynamic displacements;
  - **A** = **0.2**, 0.5, **1.0**, 2.0 and **5.0** mm at **F** = 0.5, **1.0**, 2.0 and 5.0 Hz.



EXPERIMENTAL TESTING IN THE LABORATORY - RESULTS

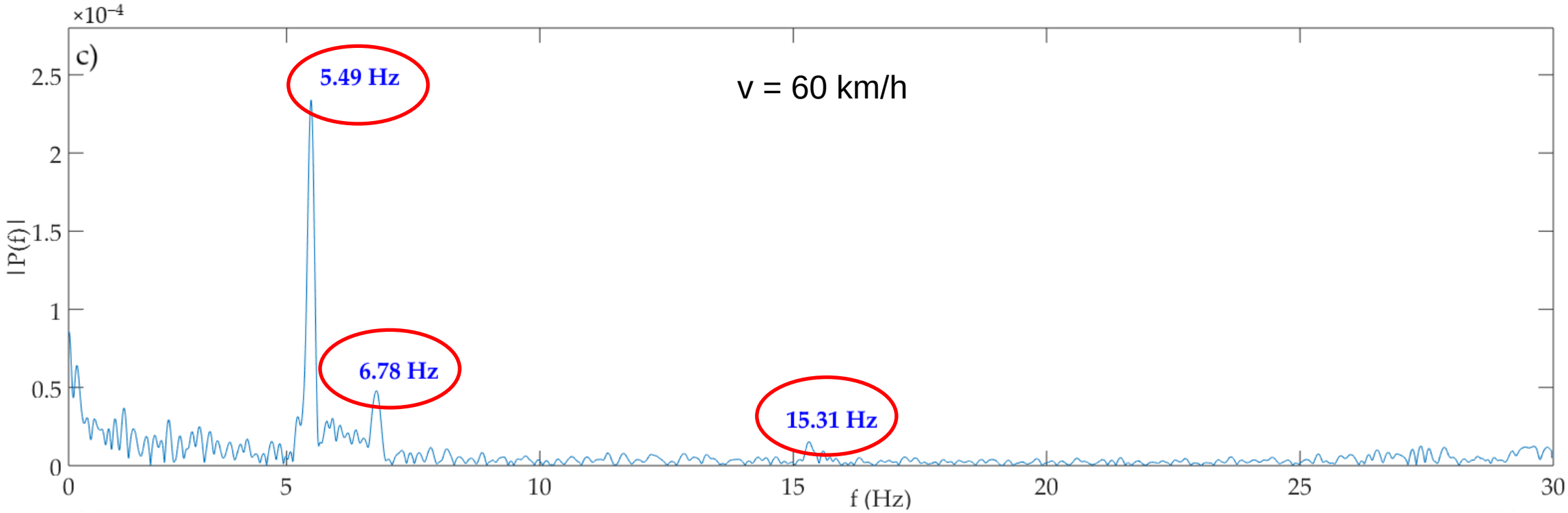
Test F = 1.0 Hz	A = 0.2 mm		A = 1.0 mm		A = 5.0 mm	
	Testing machine	IATS	Testing machine	IATS	Testing machine	IATS
Min (mm)	0.170	0.172	0.980	0.923	4.977	4.923
Max (mm)	0.170	0.182	0.994	0.970	4.989	5.025
Average (mm)	0.170	0.177	0.987	0.947	4.983	4.974
St. dev. (mm)		0.029		0.045		0.111
RMS (mm)		0.029		0.052		0.122

APPLICATION IN THE FIELD – SHM OF RAILWAY BRIDGE KLOŠTAR OVER RIVER DOBRA , IN VRBOVSKO, CROATIA

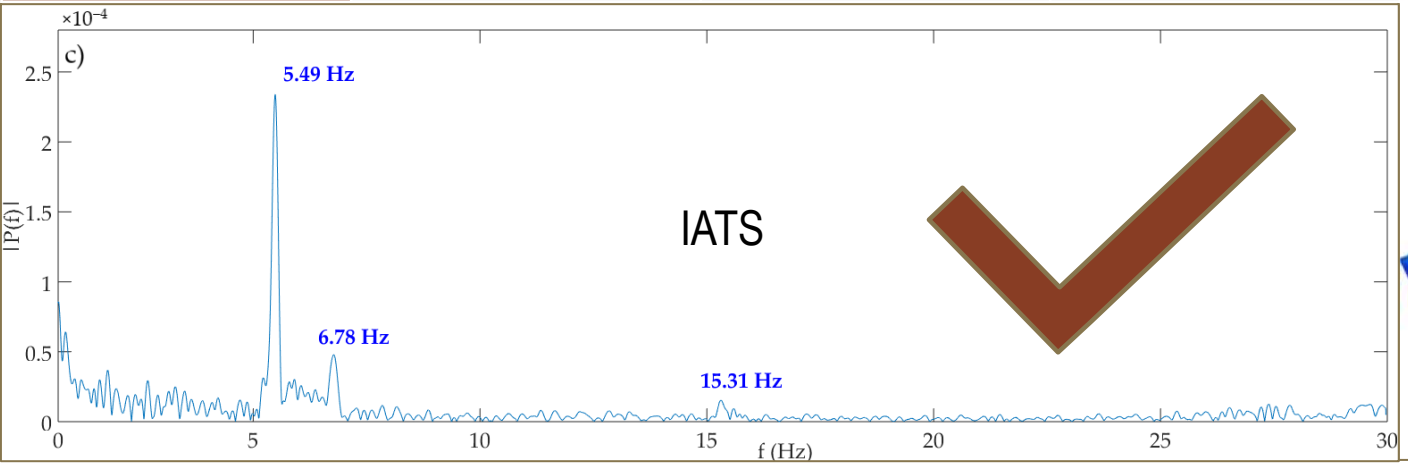
APPLICATION IN THE FIELD – SHM OF RAILWAY BRIDGE KLOŠTAR OVER RIVER DOBRA, IN VRBOVSKO, CROATIA

	F2 (1)		F3 (1)		F4 (1)	
Measuring point	Load		Load		Load	
	A	B	A	B	A	B
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1	0.2	0.3	0.3	0.3	0.0	0.0
2	6.9	6.4	6.6	6.1	0.2	0.2
3	**8.8**	**8.1**	**8.5**	**7.8**	**0.2**	**0.2**
4	6.8	6.6	6.9	6.4	0.1	0.2
5	0.2	0.2	0.3	0.2	0.0	0.0

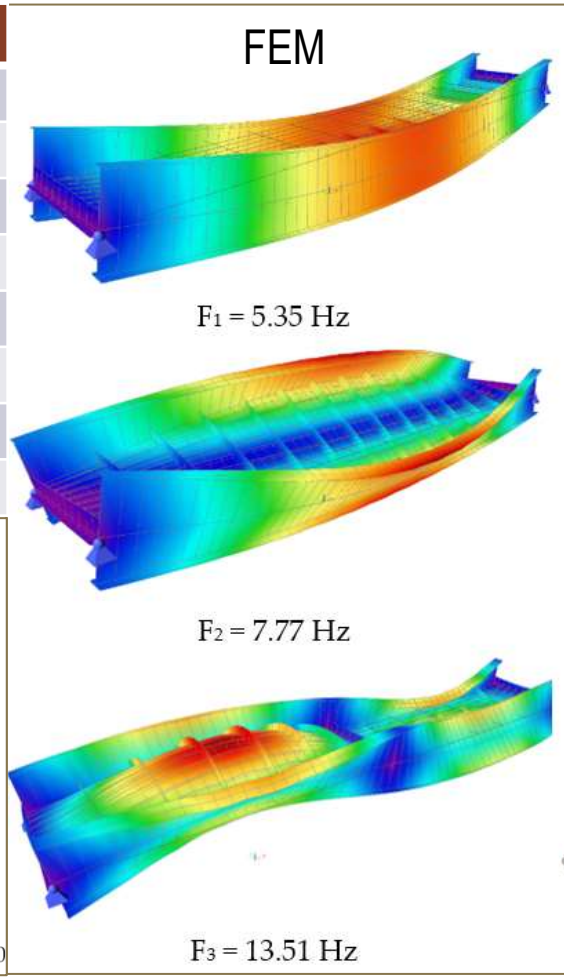
APPLICATION IN THE FIELD – SHM OF RAILWAY BRIDGE KLOŠTAR OVER RIVER DOBRA, IN VRBOVSKO, CROATIA – RESULTS



	F_1	F_2	F_3
FEM	5.35 Hz	7.77 Hz	13.51 Hz
OMA	5.49 Hz	6.85 Hz	15.24 Hz
	20 km/h		
IATS	/	/	/
	40 km/h		
IATS	5.49 Hz	6.78 Hz	/
	60 km/h		
IATS	5.49 Hz	6.78 Hz	15.31 Hz



IATS



DISCUSSION AND CONCLUSIONS

- **The results from the experimental testing conducted in the laboratory showed that with IATS prototype mm and sub mm displacements can be detected with a high level of precision, as well as determined frequencies.**
  - The displ. errors and the differ. between simulated by the TM and by the IATS are from **σ = −0.057 mm to 0.12 mm**.
  - The accuracy measure **RMS** was **0.029**, **0.052** and **0.122 mm** for corresponding amplitudes.
  - The simulated frequency by the **TM of F = 1.00 Hz** was detected by the **IATS prototype** as **F = 1.00 Hz**.
- The successful application of IATS prototype for measuring dynamic displacements and natural oscillation frequencies of the bridge have been also presented and shoved that our **low-cost IATS prototype can be used for vibration monitoring, i.e, for SHM.**
- **Contactless methods have distinct advantages over contact methods**, and minor disadvantages over contact methods that can be overcomed. We managed to overcome this lack of precision by combining the GoPro5 camera with the high-quality optics 30× magnification of the RTS Leica TPS1201.

Thank you for your attention!

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WHAT CAN BE FOUND IN THE PAPER? IN INTRODUCTION

- **Structural health monitoring** (SHM) of engineering structures besides physical sensors (accelerometers, LVDT, encoders) can be performed by geodetic instruments and is usually done by **GNSS** in combination with **Robotic Total Stations** (RTS). **Image Assisted Total Stations** (IATS) – **total station** (TS) with integrated **image sensor**.
  - Due to the **rapid technological development**, these different sensor classes, each with their specific advantages, can be unified, utilized, and are fused as one single (nearly) **universal instrument**.
  - different geodetic tasks can be resolved much quicker, easier and more precise in comparison with classical geodetic methods and instruments.
  - some tasks that were not possible to be done in the past with the usage of classic TS can be accomplished today.
  - an appropriate system calibration provided, these images and video frames are accurately geo-referenced at any time. They are particularly suitable for deformation monitoring of civil engineering structures, i.e., for SHM and geo-monitoring of hazardous areas, which are very hard to approach.

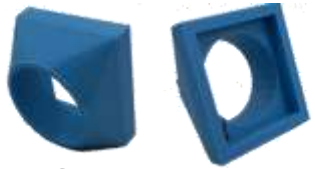
WHAT CAN BE FOUND IN THE PAPER? APPLICATION OF IATS

- Monitoring of artificial or natural structures is one of the key tasks in engineering geodesy, next to site surveying and setting out. Geodetic monitoring is one aspect of monitoring systems in general. There are two subtypes of geodetic monitoring:
  - **Structural monitoring** refers to the measurement and evaluation of civil engineering structures such as bridges, tunnels, dams, railways, towers, or skyscrapers, i.e., generally manmade objects.
  - **Geo-monitoring** in contrast, is used as a term for the determination of changes, movements, or deformation of natural structures, such as landslides and slopes.
- …

WHAT CAN BE FOUND IN THE PAPER?
IATS PROTOTYPE – DEVELOPMENT AND SPECIFICATIONS

- Leica TPS1201:
  - 1" (ISO 17123-3)
  - 2 mm + 2 ppm (ISO 17123-4)
  - 10 Hz
  - **30x telescope magnification**
- GoPro5 Hero camera:
  - ultra-wide angle all-glass lens with reduced distortion
  - different FOV offered; narrow, **linear**, medium, wide and super view
  - videos from:
    - WVGA resolution at max 240 fps,
    - 720P resolution at max 240 fps,
    - 960P at max 120 fps,
    - **1080P from 30-**120 **fps**,
    - 1440P at max 80 fps,
    - 2.7K at max 60 fps to
    - 4K at max 30 fps

- For fitting the GoPro5 to TPS1201 adapter was made with 3D printer;
  - it offers the possibility to directly attached the camera on the ocular of the telescope of Leica TPS1201.

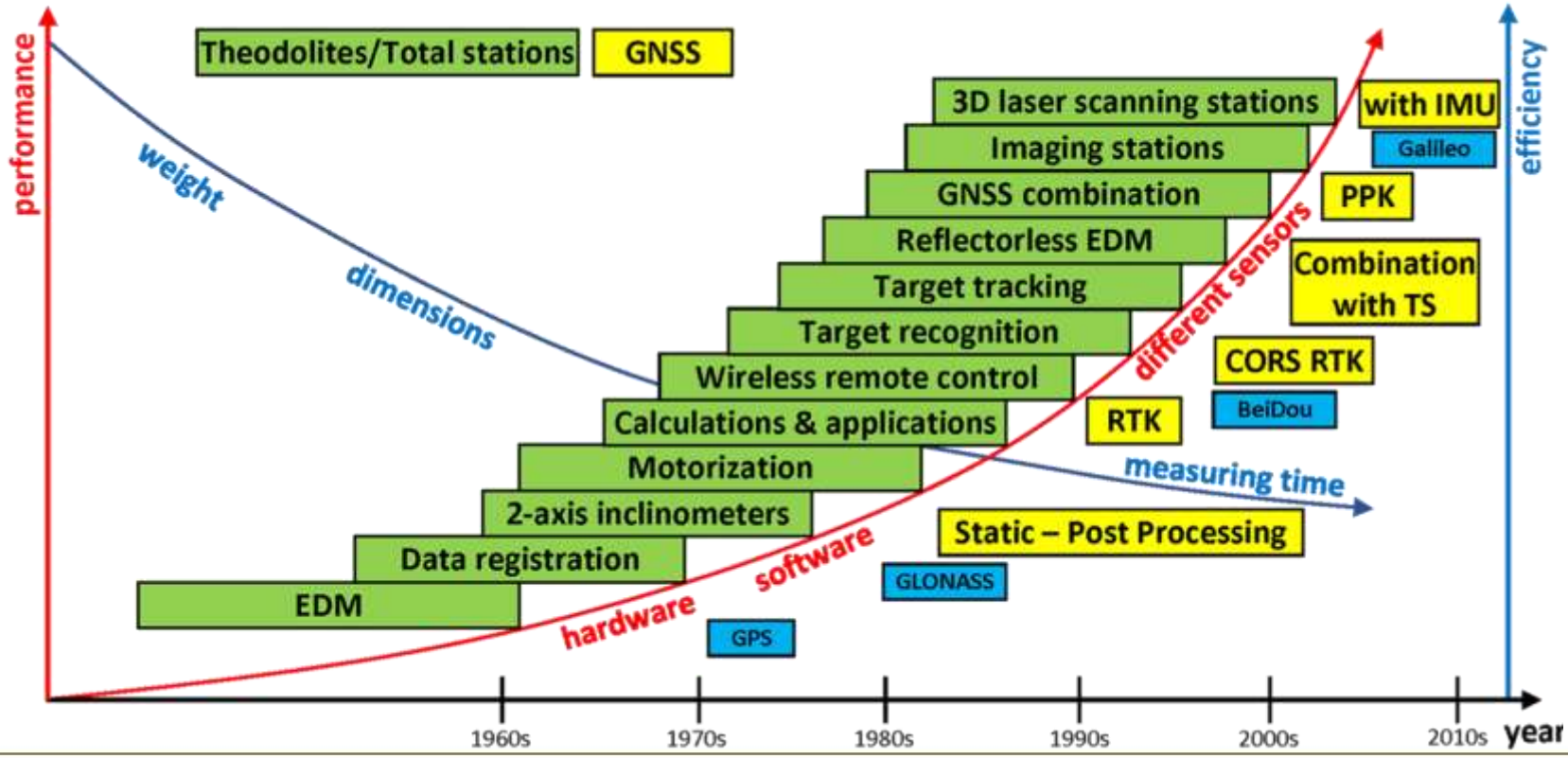


- **Stability examination of the telescope** in vertical direction have been performed:
  - **no movements** of the telescope has been detected.

- IATS prototype offers the possibility to manage:
  - the camera by smartphone application,
  - the instrument via laptop computer.

WHAT CAN BE FOUND IN THE PAPER?
TECHNOLOGICAL DEVELOPMENT FROM 2000s UNTIL TODAY

Image Assisted Scanning Total Station



WHAT CAN BE FOUND IN THE PAPER?
TECHNOLOGICAL DEVELOPMENT FROM 2000s UNTIL TODAY

Topcon GPT-7000i

Trimble VX Spatial Station

Leica Viva TS11, TS15

Topcon DS-200i

Leica Nova TS60/MS60

Topcon GTL-1000

Sokkia SET3110MV

Topcon GPT-9000Ai

Pentax R-400VDN

Leica Nova TS50/MS50

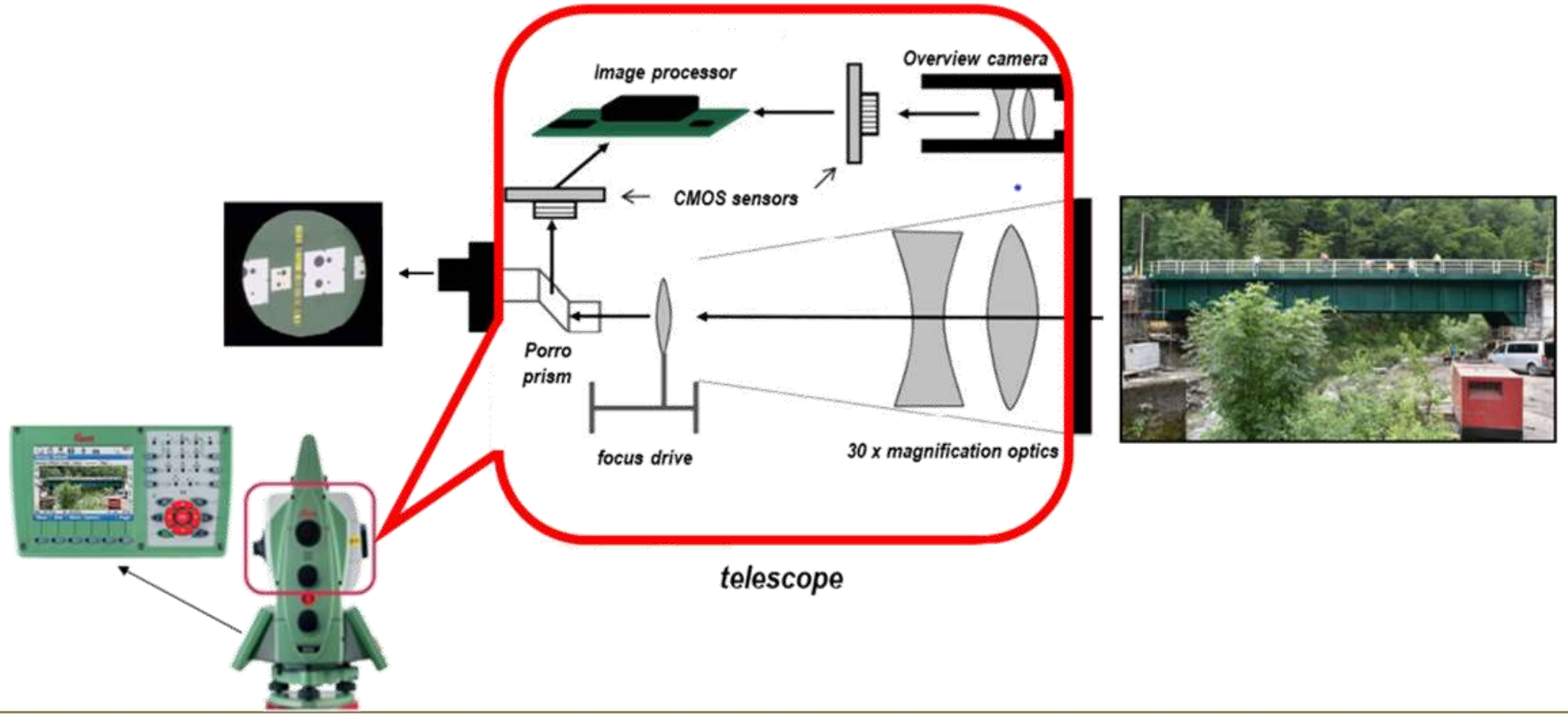
Trimble S9

Trimble SX10

Trimble SX12

2002. 2005. 2007. 2009. 2010. 2013. 2014. 2015. 2016. 2019. 2021.

WHAT CAN BE FOUND IN THE PAPER?
IATS – SCHEMATIC CROSS-SECTIONAL VIEW OF THE TELESCOPE



WHAT CAN BE FOUND IN THE PAPER? MORE DETAILED DISCUSSION AND CONCLUSIONS…

- The paper deals with the technological development of IATS from the early 2000s and with the determination of dynamic displacements and natural oscillations frequencies in the laboratory with developed low-cost IATS prototype.
- The results from the experimental testing conducted in the laboratory showed that with IATS prototype mm and sub mm displacements can be detected with a high level of precision.
- The displacement errors that occurred and the differences between simulated displacements by the TM and those detected by the IATS prototype are in a range from σ = −0.057 mm to 0.12 mm.
- The accuracy measure RMS was 0.029, 0.052 and 0.122 mm for corresponding amplitudes.
- The simulated frequency by the TM of F = 1.00 Hz was detected by the IATS prototype in every test as F = 1.00 Hz, i.e., with 100 % overlap.
- The successful application of IATS prototype for measuring dynamic displacements and natural oscillation frequencies of the bridge have been also presented.

WHAT CAN BE FOUND IN THE PAPER? DISCUSSION AND CONCLUSIONS…

- **The achieved precision and accuracy of measured displacements are at a high level, as well as determined frequencies.**
- Contactless methods have distinct advantages over contact methods:
  - they generally measure visible light,
  - can be easily set up,
  - measure a large scene of interest as every pixel collects a time series,
  - IATS does not need to be placed on the object, and it is not necessary like with contact methods.
- Contactless methods have minor disadvantages over contact methods that can be overcomed:
  - the trade-off is less precise data compared to contact techniques.
- We managed to overcome this lack of precision by combining the GoPro5 camera with the high-quality optics 30× magnification of the RTS Leica TPS1201
- The conducted study showed that our low-cost IATS prototype can be used for vibration monitoring.

Thank you for your attention!

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