IAF
Institut für Angewandte Forschung (IAF)

Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

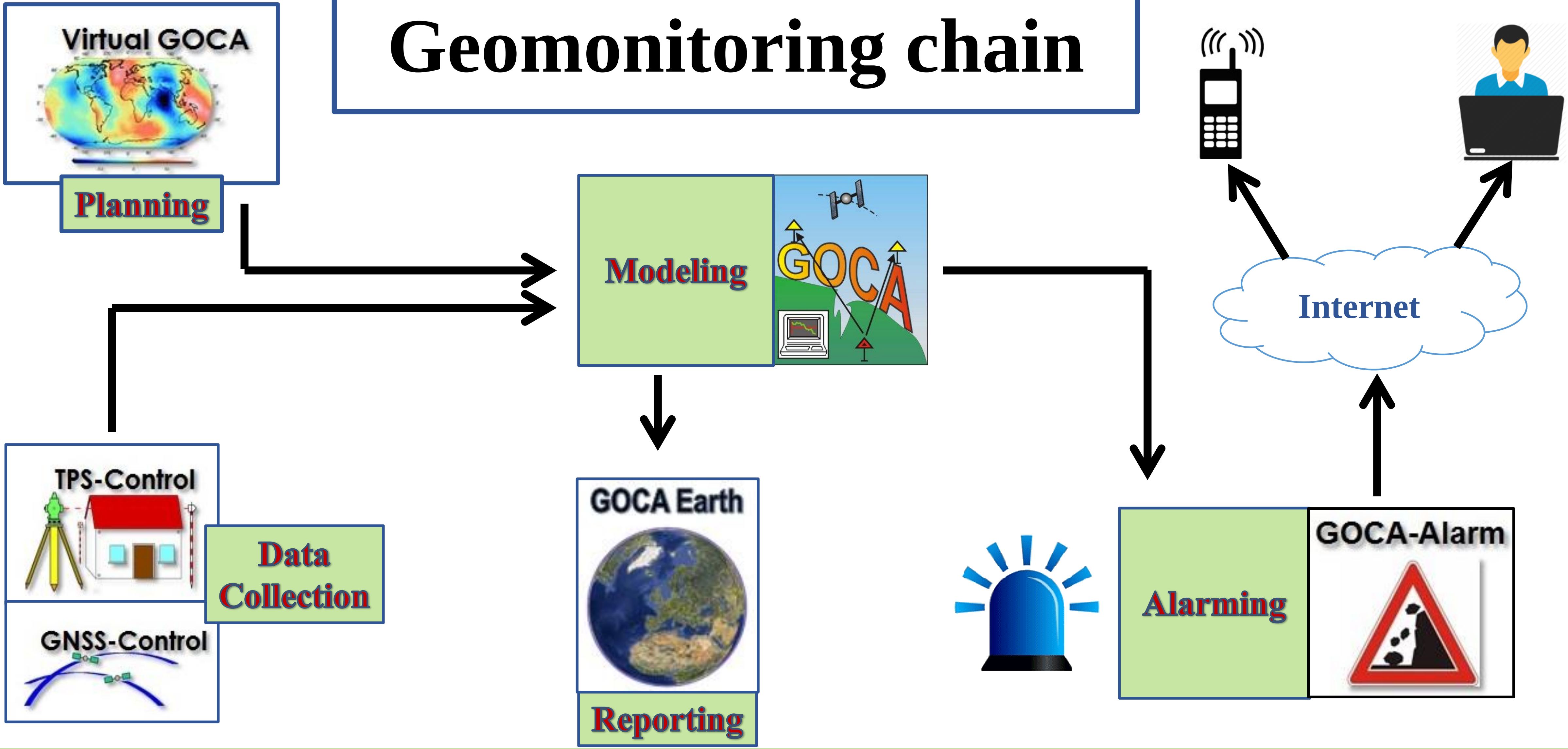
Model- and Sensor-Integration for an Integrated 3D Geomonitoring in a Modern Data Communication Structure with Applications to the Stuttgart TV Tower

„Geodynamics & Geospatial research“ conference, Riga 08.02.2018 GOCA Team, HSKA University of Latvia

Content

1. Introduction to the structure of the deformation analysis software GOCA
2. Integrated & quasi-integrated 3D approach
3. Design of the Stuttgart geomonitoring project from the software point of view
4. Organizational design of the IT architecture in Stuttgart geomonitoring project
5. Further development plans
6. Live demonstration of the running project

Geomonitoring chain



Integrated & Quasi-Integrated Approach

Usage of integrated and quasi-integrated 3D adjustment in order to integrate all sensor data types in geometry and gravity.

$p = \left(C'_{n(k),m}, S'_{n(k),m}\right)$

Direct observation equation in integrated 3D approach

Parametrisation of
GNSS observations in quasi-integrated approach

$$b^T = \left(\Delta x_{ij}, \Delta y_{ij}, \Delta z_{ij}\right)$$
$$\Delta H_{ij} = \left(h(x,y,z)_j - N_j\right) - \left(h(x,y,z)_i - N_i\right)$$

Farther steps of integration:

- Detection of pixels of video tachymeters
- Laser scanner point clouds processing

$$\mathbf{l} = \mathbf{l}\left(\mathbf{x}, \mathbf{z}, \overline{\mathbf{p}}(W(\mathbf{x}, \mathbf{p}, \mathbf{c}))\right), \mathbf{C}_{\mathrm{l}}$$

Quasi-Integrated 3D-Approach

Reparametrization $\overline{\mathbf{p}}$ **and** $\overline{\mathbf{A}}$

Horizonal Component of the Gravity Field

$$\varphi(W(\mathbf{x}, \mathbf{p}, \mathbf{c})) = \arctan\left(\frac{W_z}{\sqrt{W_x^2 + W_y^2}}\right)$$

$$\lambda(W(\mathbf{x}, \mathbf{p}, \mathbf{c})) = \arctan\left(\frac{W_y}{W_x}\right)$$

Vertical Component of the Gravity Field

$$N(W(\mathbf{x}, \mathbf{p}, \mathbf{c})) = \frac{(W - U)_P}{\gamma_{h(x,y,z)-N}}$$

Transition Quasi-Integrated to Integrated 3D-Adjustment

$$\ddot{\mathbf{U}}(i, j) = \frac{\partial \overline{\mathbf{p}}(\mathbf{p}, \mathbf{c})_i}{\partial \mathbf{p}_j} \qquad \mathbf{A} = \overline{\mathbf{A}} \cdot \ddot{\mathbf{U}}$$

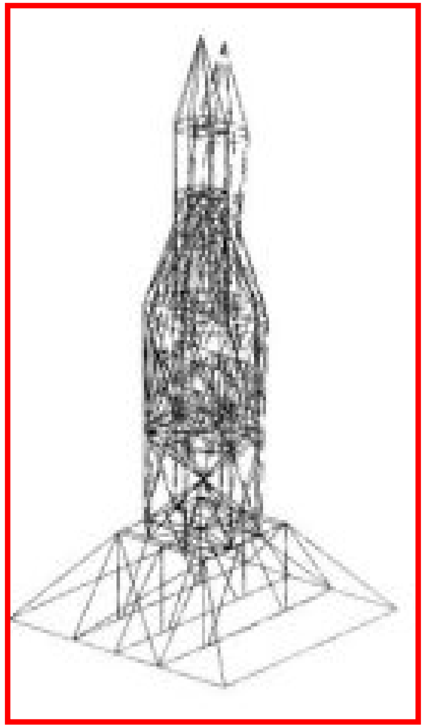
$$y(t) = [x^e\ y^e\ z^e \mid v_x^e\ v_y^e\ v_z^e \mid r^e\ p^e\ y^e \mid\mid \ddot{x}^e\ \ddot{y}^e\ \ddot{z}^e \mid \omega_{eb,x}^b\ \omega_{eb,y}^b\ \omega_{eb,z}^b]^T$$

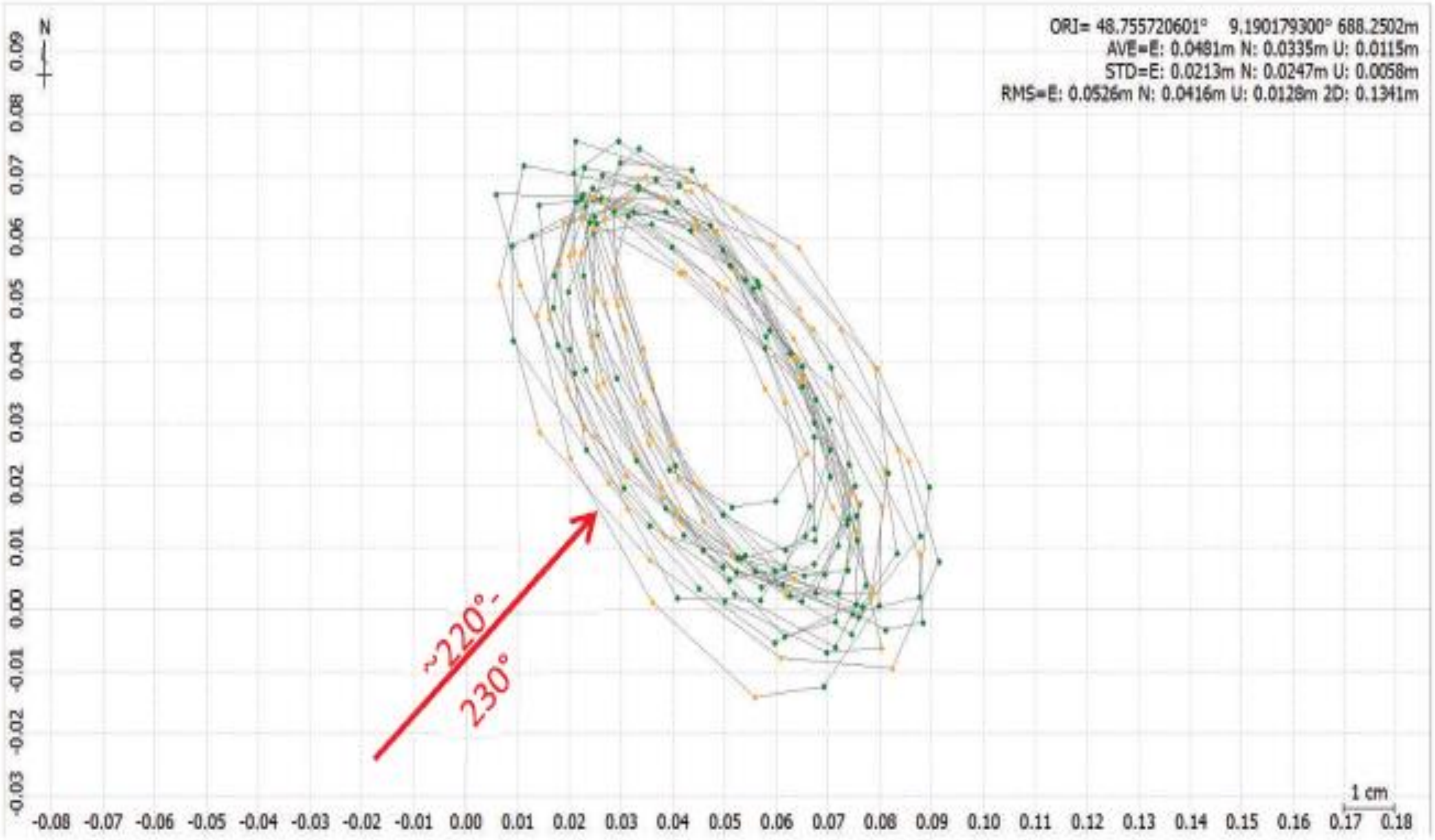
The sensory scanning of objects in a dynamic state, using the FEM-based vibrational equations
Forced damped vibration & free damped eigen-vibration of a structure

$$K(p_K)\cdot u(t) + C(p_C)\cdot \dot{u}(t) + M(p_M)\cdot \ddot{u}(t) = f(t)$$
$$K(p_K)\cdot u(t) + C(p_C)\cdot \dot{u}(t) + M(p_M)\cdot \ddot{u}(t) = 0$$

Basic equation for the SHM modeling

$$\begin{bmatrix} u_O(t+\Delta t) \\ \dot{u}_O(t+\Delta t) \\ \ddot{u}_O(t+\Delta t) \end{bmatrix} = \begin{bmatrix} I & [\Delta t] & \left[\frac{1}{2}\Delta t^2\right] \\ 0 & I & [\Delta t] \\ 0 & [-M(p_M)^{-1}\cdot K(p_K)\cdot \Delta t] & [I - M(p_M)^{-1}\cdot C(p_C)\cdot \Delta t] \end{bmatrix} \cdot \begin{bmatrix} u_O(k) \\ \dot{u}_O(k) \\ \ddot{u}_O(k) \end{bmatrix}$$





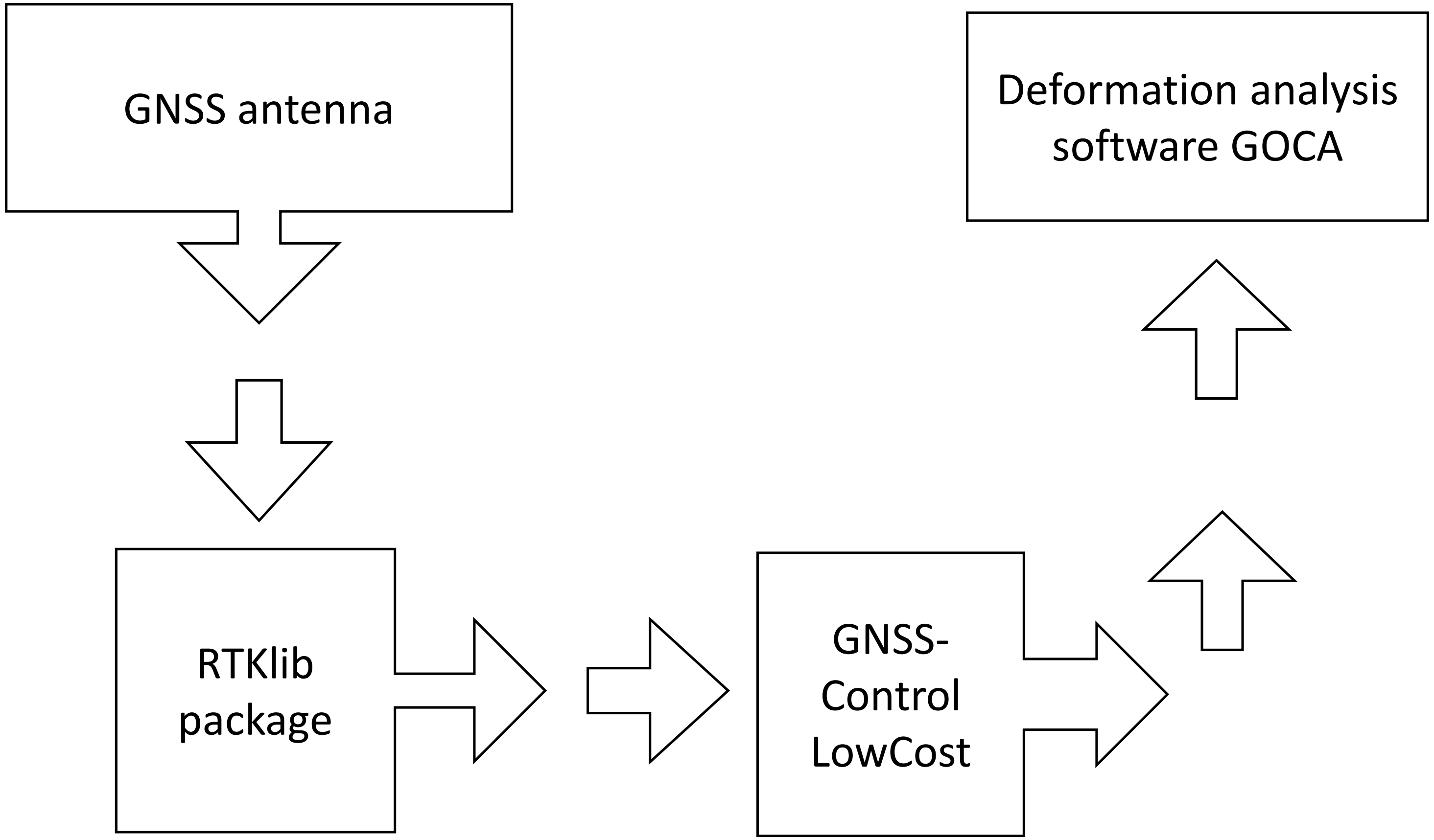
ORI= 48.755720601° 9.190179300° 688.2502m
AVE=E: 0.0481m N: 0.0335m U: 0.0115m
STD=E: 0.0213m N: 0.0247m U: 0.0058m
RMS=E: 0.0526m N: 0.0416m U: 0.0128m 2D: 0.1341m
N
~220°-
230°
1 cm

Definition of the project task

Usage of reference object for implementation of innovative methods for the early detection of hazard potentials of structures (SHM) by new algorithms, sensor systems and information technologies

As a reference object Stuttgart TV tower is used. The popularity of the object among the citizens allows to increase the visibility of the idea of geomonitoring.

The intercation of the individual chain elements from the software modules point of view



Procedure of data collection and processing

1. Computation of exact object’s position based on the raw GNSS data

2. Data collection based on the fixed solution in respect to the object point positioning

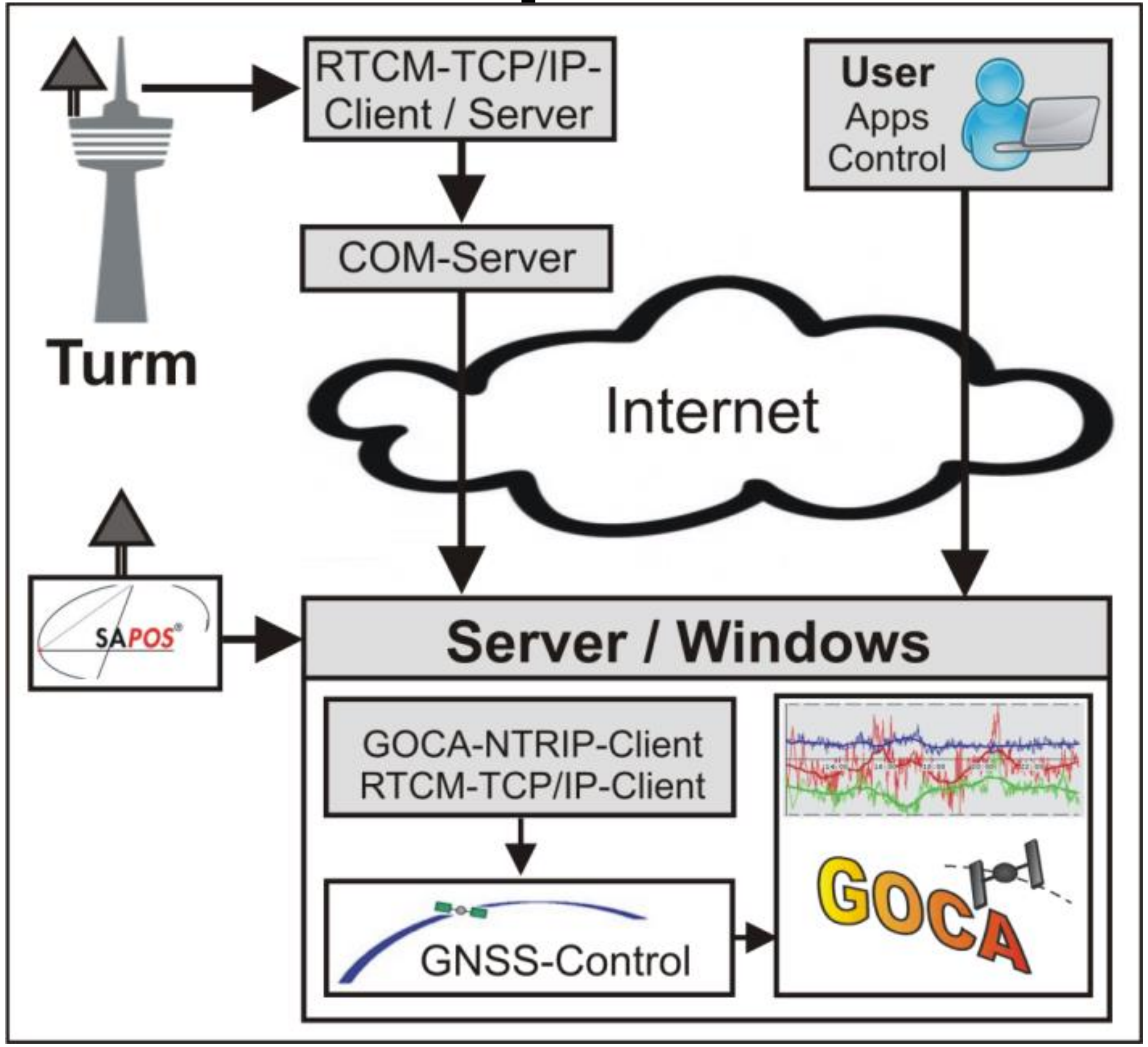
3. Creation of GKA interface with accurately precomputed object coordinates.

4. Visualization of time series for TV tower’s rotations in deformation analysis software GOCA

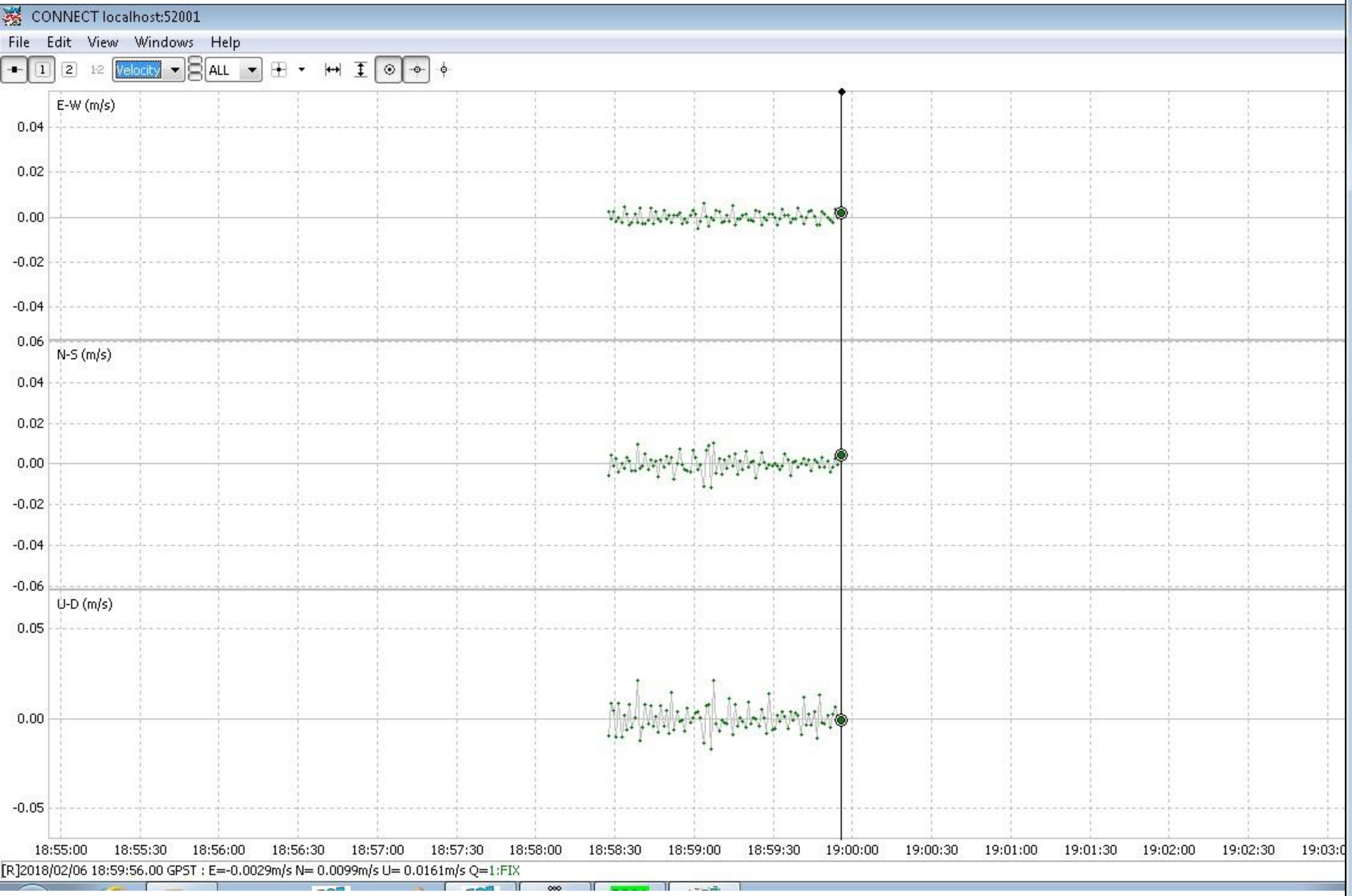
System organizational design in respect to the relationship between different parts of the complete chain

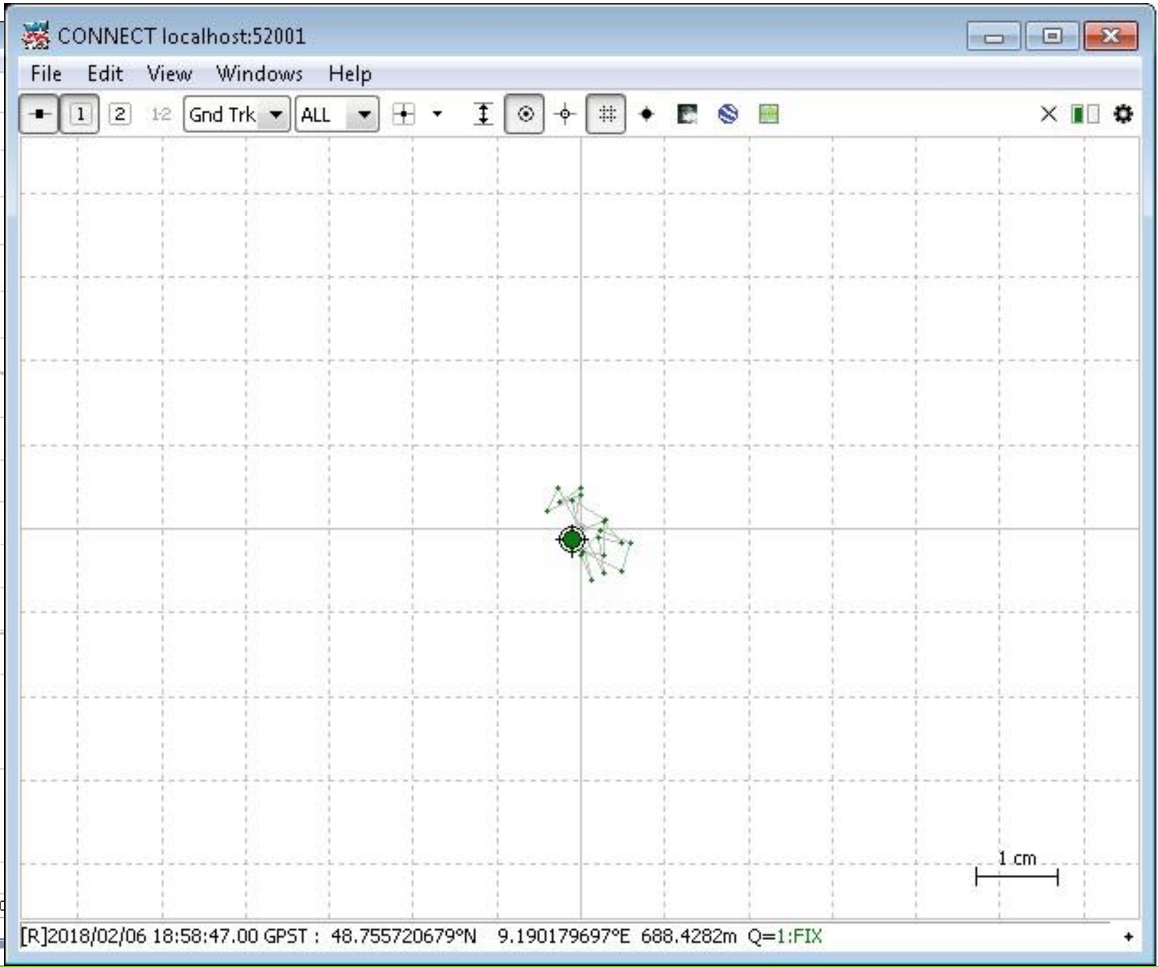
Support of object's monitoring from 3 sides:

1) Provision of the IT service
2) Provision of the spatial reference
3) Provision of the complete geodetic solution & mathematical algorithms for data processing



Object point positioning based on the raw data





Initialization of raw data in deformation analysis software GOCA

Init_Plane - Notepad

File Edit Format View Help

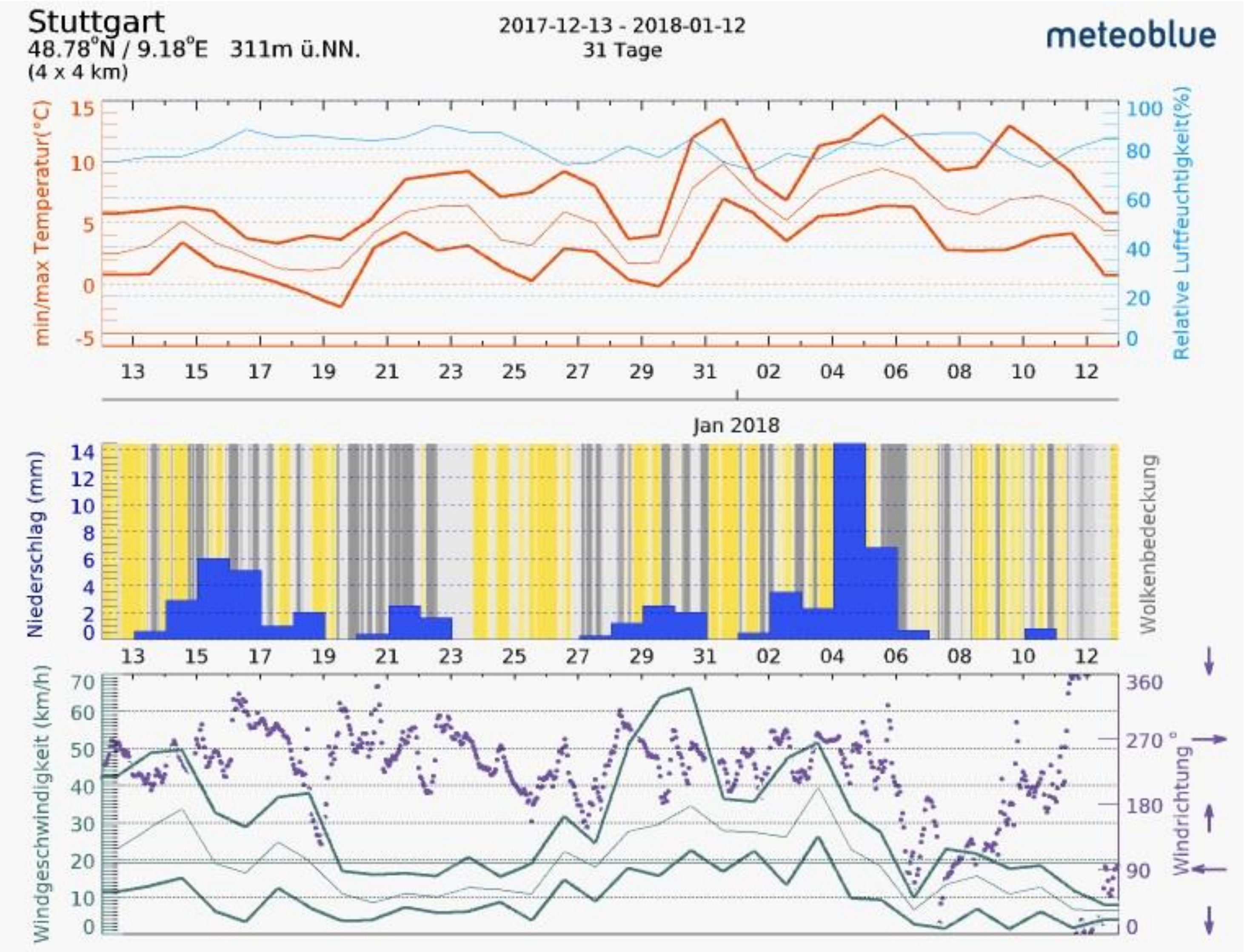
```
***********************************************************************
***                                                                 ***
***               GOCA   -   A D J U S T M E N T                    ***
***                                                                 ***
***                      PLANE COMPONENT                            ***
***                                                                 ***
***********************************************************************

Computation Time: 07.02.2018 22:07:06
Network Design:
===========

Stable-/ Reference Points (Number = 1):
Sapos

Object Points (Number = 1):
Turm


Used Epoch:
Start Date: 03.01.2018 21:54:03
End Date  : 03.01.2018 23:59:59
-----------------------------------------------------------------------
Number of Observations: 11278
-----------------------------------------------------------------------

***********************************************************************
***                                                                 ***
***              ITERATIVE  DATASNOOPING                            ***
***                                                                 ***
***********************************************************************
```

Init_Plane - Notepad

File Edit Format View Help

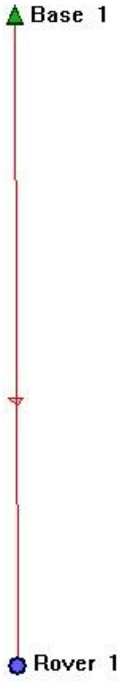
```
ADJUSTMENT NO: 11
-----------------------------------------------------------------------

Number of Observations: 11258
Number of Unknowns: 4
Redundancy (n-u+d): 11256

Statistical Parameters:
Alpha-NV [%]                    =        1.0
Matched Error Probability:
Alpha-Plane [%]                 =        2.3
Crit. Value Plane               =      3.762
Alpha-Height [%]                =        1.0
Crit. Value Height              =      2.577

No Observation was rejected in this Run!

***********************************************************************
***                                                                 ***
***                   FINAL   -   ADJUSTMENT                        ***
***                                                                 ***
***********************************************************************

s0 priori                       =          0.0050
s0 posteriori                   =          0.0050

Global test (test value)        =          1.0000
Global test (critical value)    =          0.9788

Mean Point Error                =          0.0029

Redundancy r = (n-u+d)          =           11256


***********************************************************************
                 GNSS - Observations - relative
***********************************************************************
```

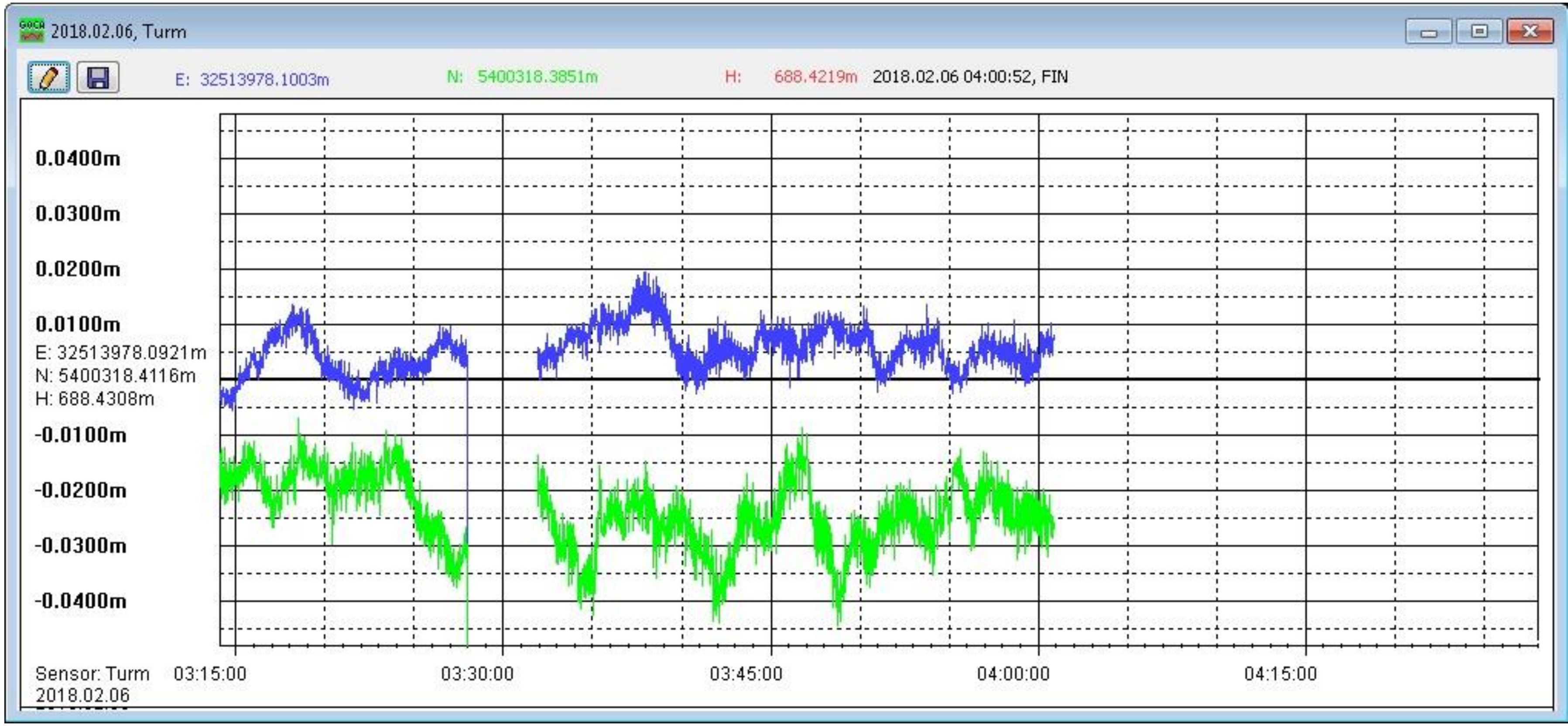
Meteodata for the area of Stuttgart city in January 2018



Visualisation of Stuttgart TV tower point time series for deformation state estimation and analysis

Name Stuttgart_Fernsehrturm_03-Januar-2018, Projection UTM, Dimension: Plane+Height (2D+1D), Sensors GNSS
2018.01.03 21:54:03, Initialisation

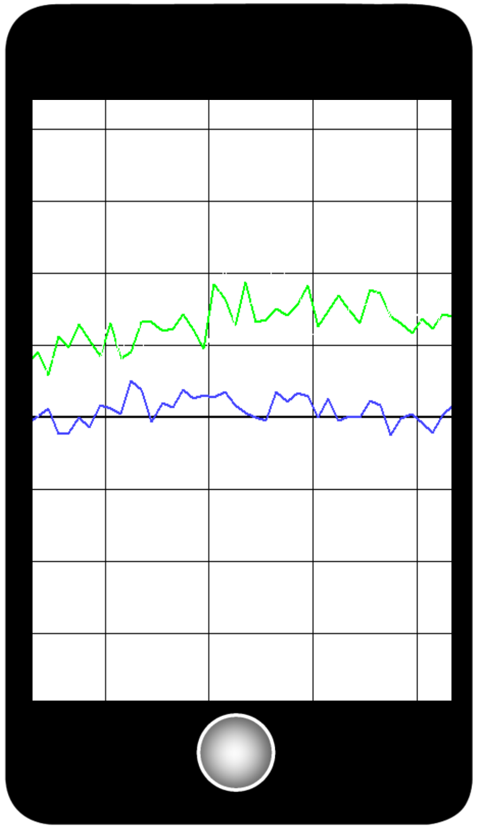




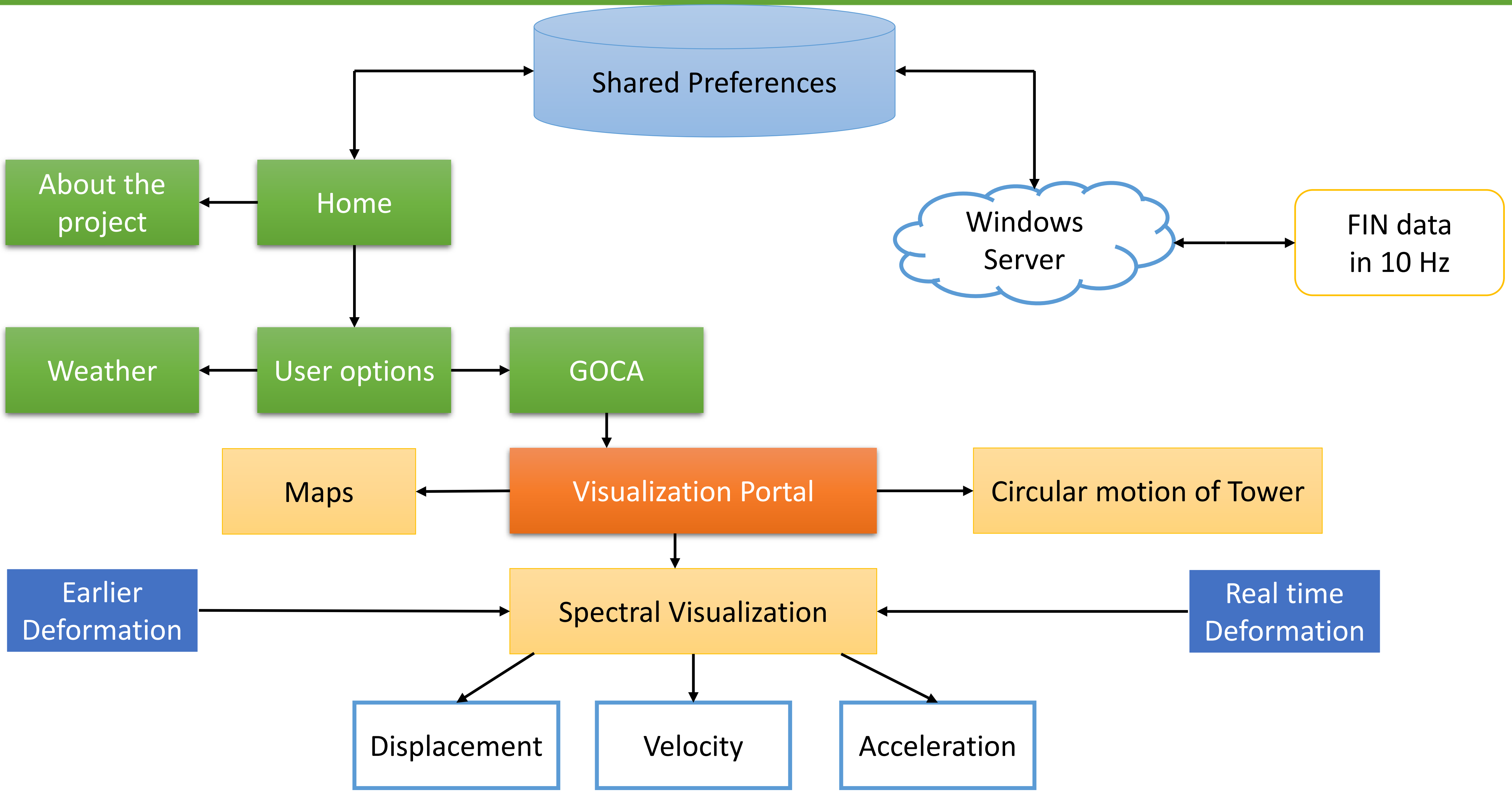
Android application for external use

Further project development based on the Android system in order to provide the continuous access to the visualization results of the monitoring for citizens and tourists.

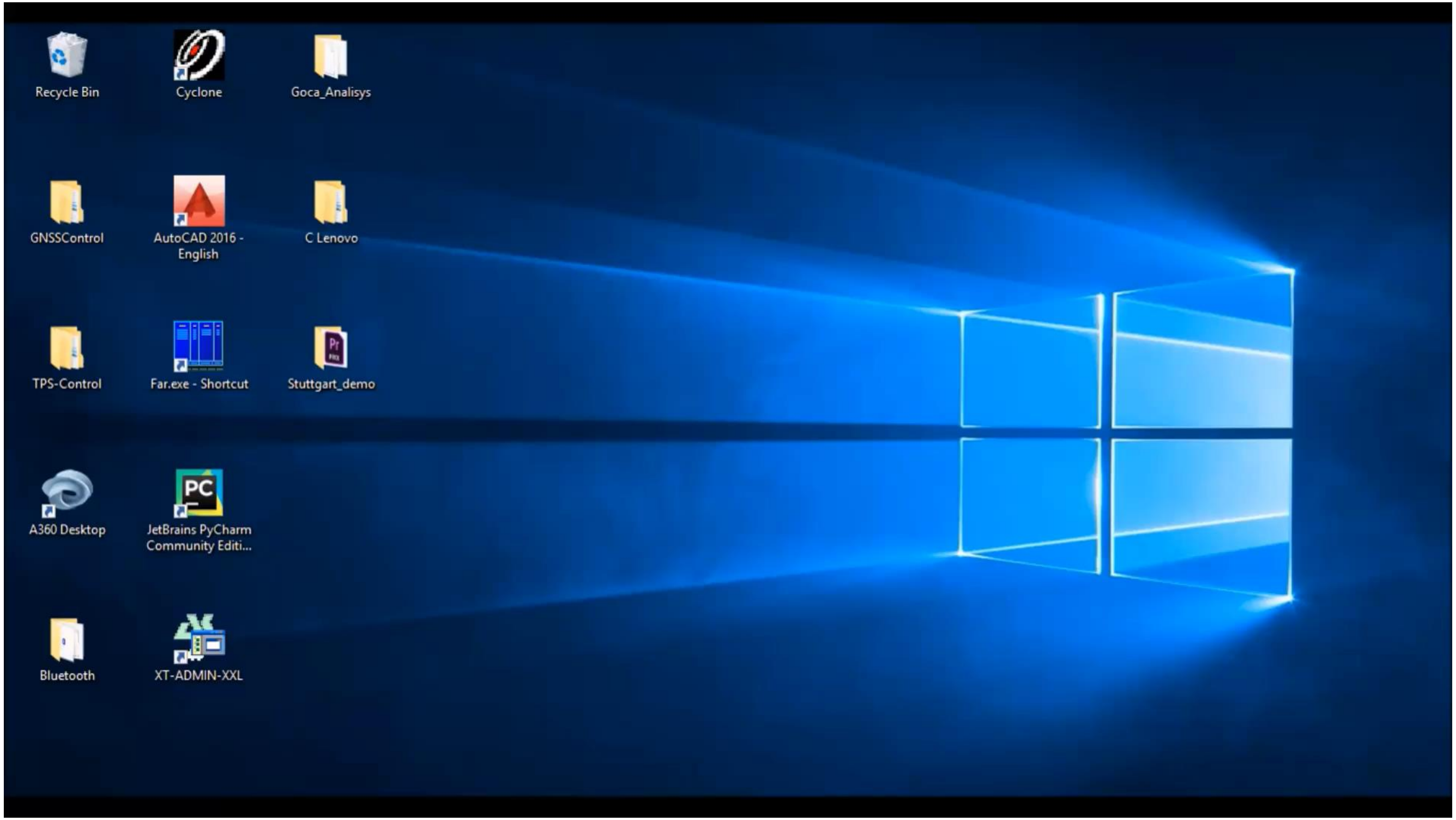
- Algorithmic conversion of 1Hz FIN data to 10 Hz
- Development of the data management system, based on the object server, for access to the data from any Android system compatible devices



App architecture


Shared Preferences
About the project
Home
Windows Server
FIN data in 10 Hz
Weather
User options
GOCA
Maps
Visualization Portal
Circular motion of Tower
Earlier Deformation
Spectral Visualization
Real time Deformation
Displacement
Velocity
Acceleration

Instead of live demonstration



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Thank you for your attention!