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ITIS

PREcision GNSS ON Smartphones & Tablets (PREGON-X) (1)

Almagboul, M.(3), Diekert, J.(2), Janugade S.(3), University of Applied Sciences Karlsruhe

(1) Funded as ZIM Research and Development (RaD) Project by Federal Ministry of Economics and Technology (BMWi)
(2) PhD candidate at HS Karlsruhe (HSKA) and University Tübingen
(3) Scientific assistant at HS Karlsruhe (HSKA)

Overview Project PREGON-X

The Research and Development of the 2 years project PREGON-X comprise mathematical models, algorithms and software for precise positioning and non-contact object geo referencing with smartphones, up to cm level of precision. These basic algorithms will be integrated into innovative apps by Disy, Karlsruhe (www.disy.net). The 3 RaD project milestones include:

Variant 1: External GNSS receiver
Data from an external GNSS will be down-streamed via bluetooth to a smartphone (controller and processing unit), where the SmartphoneRTK-App from HSKA calculates a high precision position with DGNSS or PPP algorithms.

Variant 2: GNSS raw data on smartphones
Since end of 2016 GNSS raw data is available on the newest smartphones. Because of poor signal and antenna technology, innovative approaches to the parameter estimation are needed. The focus is also on GALILEO integration with its more advantageous signal structures compared to other GNSS systems, that will help to reduce initialization time in kinematic PPP measurements and further improve the accuracy.

Variant 3: GNSS + X sensor fusion on smartphones
Tightly coupled GNSS & MEMS sensor fusion in the low-cost domain, is challenging. With the additional integration of optic sensors, i.e. cameras, precise and stable geo-referencing can be achieved. Utilizing a pluggable laser range finder even a non-contact positioning of objects can be achieved.

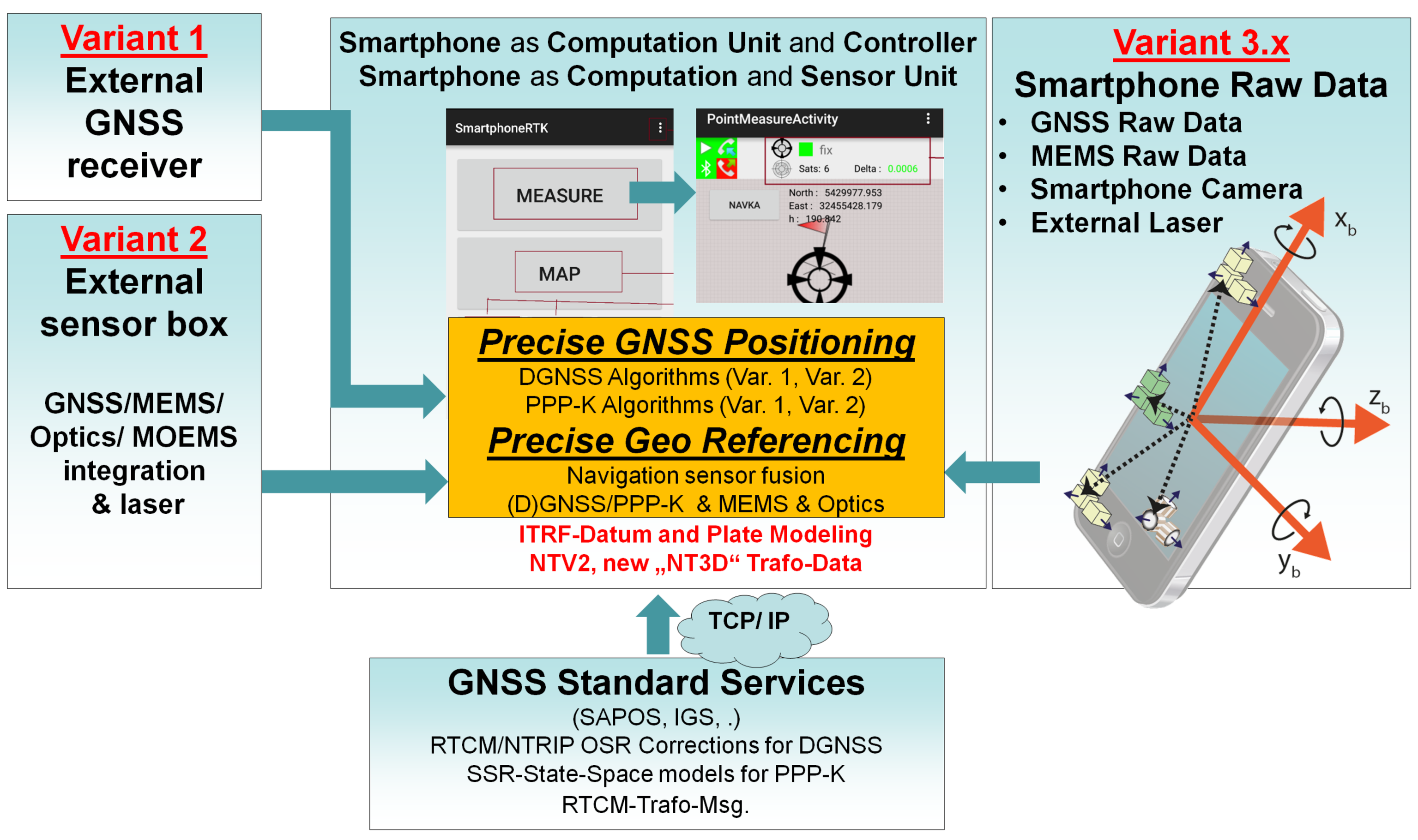

Fig. 1: Developments in PREGON-X

Variants 1.1 und 1.2: External GNSS: Realisation

Data from the GNSS receiver ublox M8T is transmitted to the internal Bluetooth module NINA - B112. The power supply can be provided through the USB port or from a power bank..

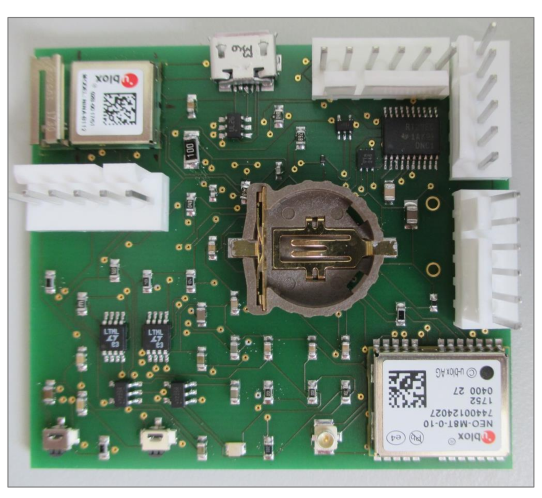

Fig. 2: External GNSS OEM board with bluetooth

DGNSS and PPP-K Algorithms

The GNSS measurement model for code measurements, carrier phase and Doppler includes multiple corrections for the various errors on GNSS signal propagation:

$$P_i = \rho + c(dt^{Rec}(P_R) - dT^{Sat}(P_S)) + I_i + T + m_{Pi} + \Delta Tides + DCB + \varepsilon_{Pi}$$
$$\phi_i = \rho + c(dt^{Rec}(P_R) - dT^{Sat}(P_S)) - I_i + T - N \cdot \lambda_i + m_{\phi_i} + \Delta Tides + \Delta PWD + \varepsilon_{\phi_i}$$
$$D_i = \dot{\rho} + c(\dot{dt}^{Rec}(P_R) - \dot{dT}^{Sat}(P_S)) - \dot{I}_i + \dot{T} + \varepsilon_{Di}$$

with $\rho(t_i) = \left| \vec{x}_{Rec}(t_i) - \vec{x}_{Sat}(t_i - \frac{\rho(t_i)}{c}, o) \right|$

$dt^{Rec}(P_R)$	Receiver clock , different parametric models	P_i	Code measurement
$dT^{Sat}(P_S)$	Satellite clock, different parametric models	ρ_i	Carrier phase measurement
I_i	Ionospheric delay	D_i	Doppler measurement
T	Tropospheric delay	$N \cdot \lambda_i$	Ambiguity N multiplied by wavelength
m_i	Multipath	c	Speed of light
ε_i	Additional random errors	$\Delta Tides$	Earth Tides and Ocean Tide Loading
ρ	Geometric distance	DCB	Differential Code Biases
		ΔPWD	Phase Windup

Most systematic errors and delay models will cancel out in differential GNSS (DGNSS), since they affect the base station in nearly the same amount as the (moving) rover. In PREGON-X a **DGNSS** system was realized with a physical NTRIP-caster base station. It transmits OSR RTCM-corrections by TCP/IP adressing via WLAN (or Internet) to multiple NTRIP-client rovers. For the DNSS accuracy studies (Tab. 1) the NAVKA Smartphone-RTK was using SAPOS VRS -based NTRIP RTCM OSR correction data.

Measurement	(E)	(N)	(h)	Fix solution time	Accuracy-H/V
Static L1/L2	32455531.261	5429509.066	190.467	6-7 min	1 cm / 2 cm
Kinematic L1/L2	32455531.238	5429509.042	190.441	6-7 min	1 cm / 3 cm
Static L1	32455531.246	5429509.048	190.415	10-12 min	2 cm / 3cm
Kinematic L1	32455531.253	5429509.085	190.490	10-12 min	1 cm / 4 cm

Table 1: DGNSS-Tests and accuracy of NAVKA Smartphone RTK

In contrast to DGNSS, algorithms for **PPP-S** and **PPP-K** (Precise Point Positioning, Static and Kinematic) have to account for each error, as an example the modelling of the ionospheric delay is included here with first and second order for code and phase delay:

$$I1_{phase,f} = -\frac{40.3}{f^2} TEC \qquad I2_{phase,f} = -\frac{7527c}{2f^3} \int_{rec}^{sat} TEC\ B\ cos\theta\ dl$$
$$I1_{code,f} = \frac{40.3}{f^2} TEC \qquad I2_{code,f} = 2 \cdot I2_{phase,f}$$

TEC	Total Electronic Content
B	Magnetic field
θ	Angle between the magnetic field vector and signal direction

As can be seen in the above equation, the ionospheric delay can be mitigated by a linear combination of two frequencies to a so-called ionosphere-free combination. A second approach for single frequency lowcost GNSS is combining code and phase measurements in a common adjustment. First RaD results show, that an accuracy of 20 cm can be achieved after 15 min convergence time for the static PPP case, and submeter accuracy for kinematic PPP with a lowcost L1 receiver (Tab. 2). But with the announcements of smartphones with two frequency L1/L5 GPS + E1/E5a GALILEO boards for 2018, better results can be achieved.

Static PPP L1/L2	Kinematic PPP L1/L2	Static PPP Lowcost L1	Kinematic PPP Lowcost L1
20 cm	30 – 40 cm	20 cm	70 cm

Table 2: Accuracy of PPP (GPS only) after 15 min convergence time

Kontakt
Center of Applied Research (CAR)
University of Applied Sciences Karlsruhe
Prof. Dr.-Ing Reiner Jäger
Tel ++49 721 925 2592
Mail reiner.jaeger@hs-karlsruhe.de
URL www.navka.de

Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

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