UNITED NATIONS
Office for Outer Space Affairs

United Nations/Philippines Workshop on the Applications of Global Navigation Satellite Systems
Manila, Philippines, 22 – 26 April 2024

Ambient-Aware Applications-Aligned (AA)² PNT

Prof Dr **Renato Filjar**
Faculty of Engineering, University of Rijeka, Rijeka, Croatia, and
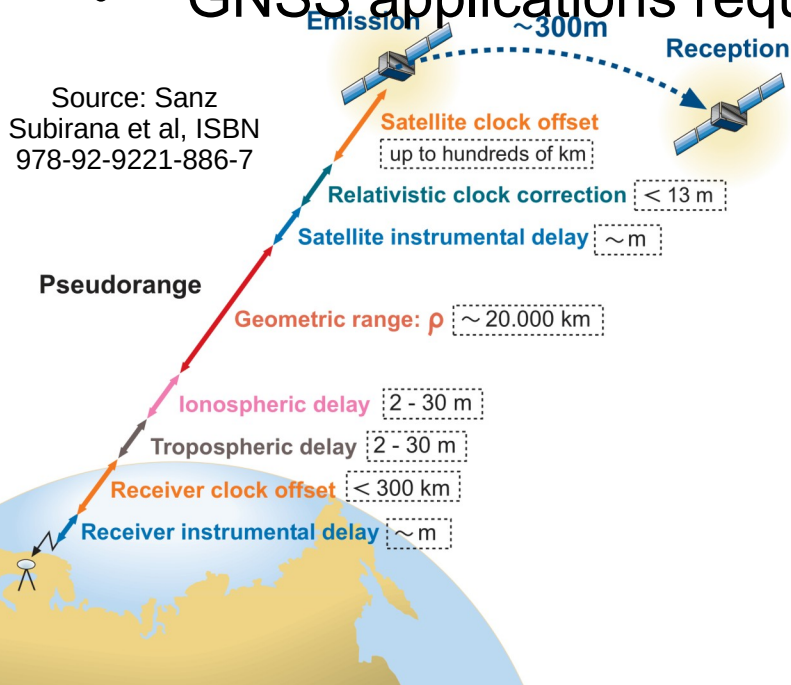Krapina University of Applied Sciences, Krapina, Croatia

- ## PNT = Positioning, Navigation & Timing

- GNSS PNT process is exposed to systematic, natural, and artificial interferences originated in the positioning environment (ambient)

- PNT process associated with a black-box GNSS receiver

- GNSS operators required to guarantee PNT QoS, in the uncontrollable positioning ambient

- GNSS applications require their PNT QoS needs are met

Source: Sanz Subirana et al, ISBN 978-92-9221-886-7

Emission ~300m Reception
Satellite clock offset
up to hundreds of km
Relativistic clock correction < 13 m
Satellite instrumental delay ~m
Pseudorange
Geometric range: ρ ~ 20.000 km
Ionospheric delay 2 - 30 m
Tropospheric delay 2 - 30 m
Receiver clock offset < 300 km
Receiver instrumental delay ~m

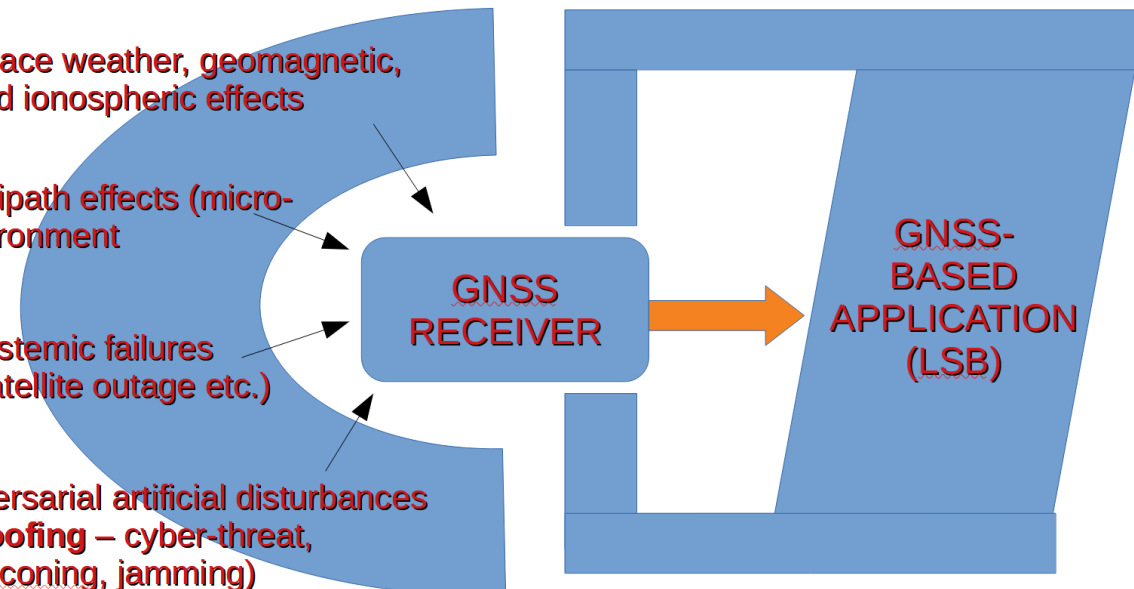Source: Jukić et al, doi 10.1109/TELFOR51502.2020.9306548

POSITIONING ENVIRONMENT

Space weather, geomagnetic, and ionospheric effects

Multipath effects (micro-environment

Systemic failures (satellite outage etc.)

Adversarial artificial disturbances (**spoofing** – cyber-threat, meaconing, jamming)

GNSS RECEIVER

GNSS-BASED APPLICATION (LSB)

- **State-of-the-art - GPS/GNSS PNT process**

- Aim: estimation of position and positioning error in the reference framework, based on measurement of satellite signal propagation properties (pseudoranges from visible satellites)

- Essential domains of measurement, analysis, and modelling:
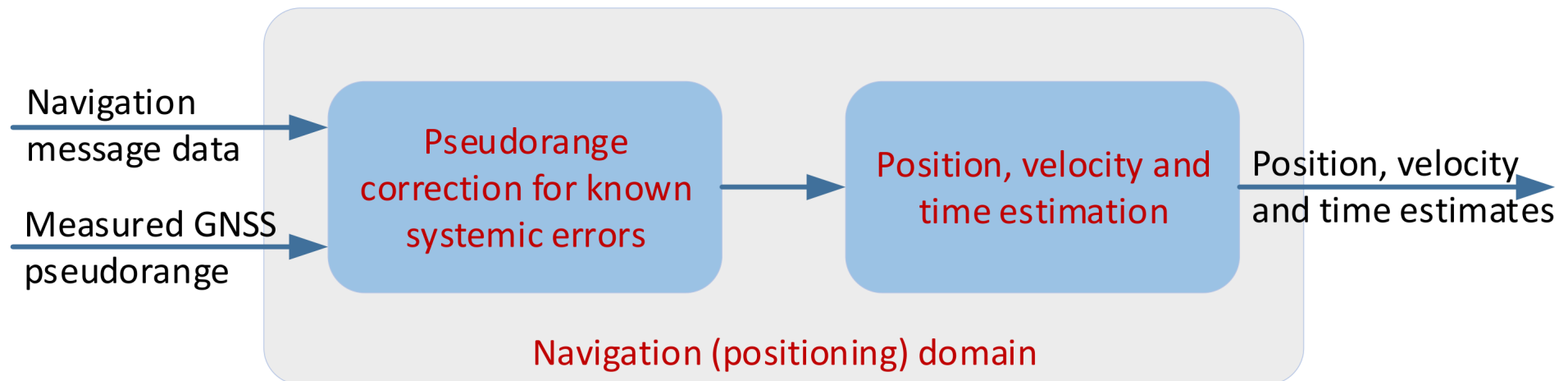
(i) spectrum, (ii) signal, (iii) information
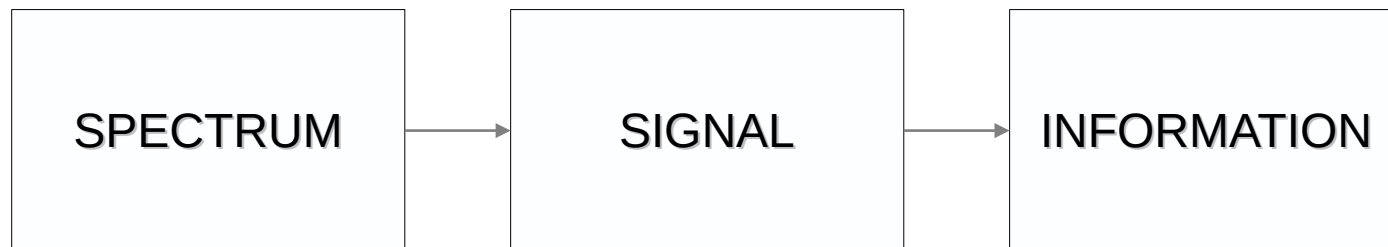
| SPECTRUM | → | SIGNAL | → | INFORMATION |

- ## State-of-the-art - GPS/GNSS PNT process

- Input: raw GPS/GNSS pseudorange measurements, corrected for known systemic errors (bias, trend, seasonality) using globalised correction models (Klobuchar, NeQuick, standard atmosphere-based Saastamoinen); navigation message data

- Various position estimation algorithms based on different optimisation approaches

Navigation message data →

Measured GNSS pseudorange →

Pseudorange correction for known systemic errors → Position, velocity and time estimation → Position, velocity and time estimates

Navigation (positioning) domain

Source: GPS-X-02007-C, http://www.u-blox.com/

- ## Related technology developments

- Transition to transparent Software-Defined Radio (SDR) platform

PRN SCREENSHOTS

GNSS PSEUDORAN-GES, NAV MESSAGE

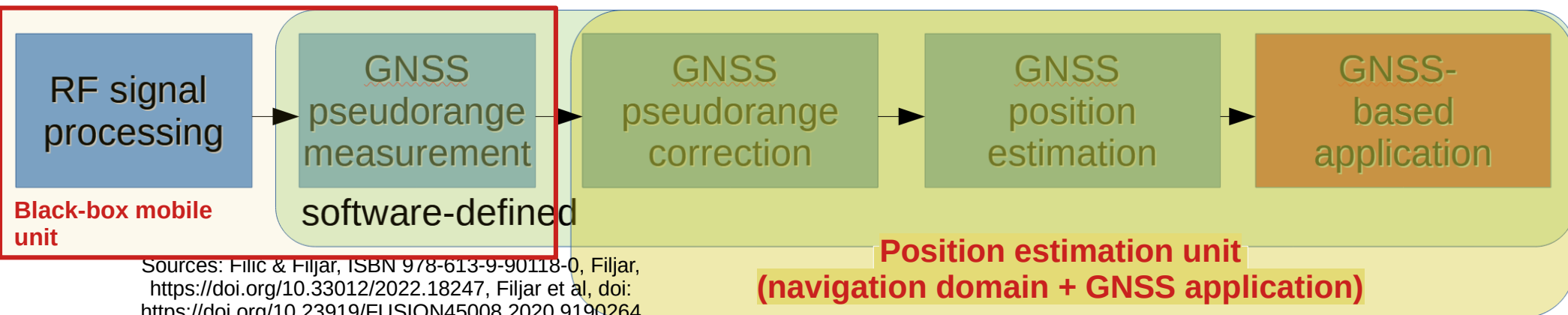| GNSS SDR RECEIVER	RF DOMAIN	BASE-BAND DOMAIN	NAVIGATION (POSITIONING) DOMAIN	PNT, PNT QoS

- Availability of the positioning environment-related observations, real-time and archived (space weather, geomagnetic, ionospheric, and tropospheric conditions)

- Motion and environment sensors availability in users devices

- Raising computational capacity of user devices

- A wide-spread use of statistical learning methods

- Availability of efficient methods for sensor information fusion

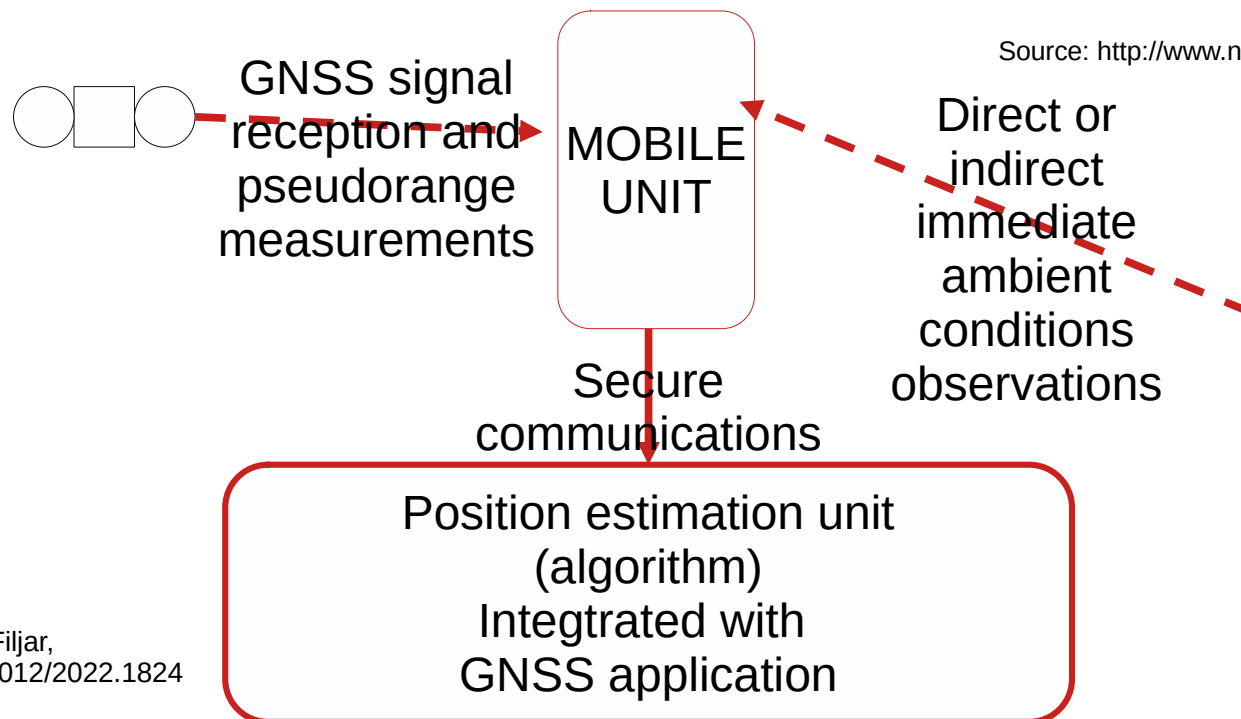- Advanced computational architectures and services (cloud, mist, advanced encryption and authentication etc.)

- **Ambient-Adaptive Applications-Aligned (AA)² PNT**

- GPS/GNSS application manages autonomously the QoS (selection of suitable GPS/GNSS position estimation method and error correction procedures based on real-time positioning environment conditions, scalable GPS/GNSS positioning performance) → alignement to application

- GPS/GNSS operator remains responsible for the matters of GPS/GNSS spectrum and signals

- Positioning to become expandable towards context recognition

RF signal processing → GNSS pseudorange measurement → GNSS pseudorange correction → GNSS position estimation → GNSS-based application

Black-box mobile unit

software-defined

Position estimation unit (navigation domain + GNSS application)

- ## <u>Ambient-Adaptive Applications-Aligned (AA)² PNT</u>

- Mobile unit as pseudorange and positioning environment conditions observations device

- **Autonomous adaptation of position estimation algorithm to immediate real-time ambient conditions**

GNSS signal reception and pseudorange measurements

MOBILE UNIT

Source: http://www.nasa.gov/mission_pages/sunearth/news/M11-125-swef.html

Direct or indirect immediate ambient conditions observations

Secure communications

Position estimation unit (algorithm) Integtrated with GNSS application

- **Ambient-Adaptive Applications-Aligned (AA)2 PNT with mitigation of ionospheric effects**

- GPS/GNSS Software-Defined Radio empowered with mitigating position estimation algorithms, real-time space weather observations, and statistical learning-based correction models

- ## <u>The role of Artificial Inteligence/Machine Learning</u>

- Observation/data-based automated identification of pattern, dynamics, knowledge hidden to human mind with uncertainty, complexity of phenomena addressed

- Knowledge extraction through advanced utilisation of statistical analysis and modelling, advanced computer science algorithms, related massive data sets availability

- Availability of open-source AI/L platforms → R, Python

- Demonstrated achievements, future developments:

  - AI/ML for personalised SW/ionospheric correction model development

  - Advanced AI/ML-based optimised PNT estimation algorithms (position estimation, positioning error estimation)

  - Detection of natural (ionospheric, geomagnetic, space weather, multipath) and artificial (jamming, spoofing) effects on GNSS PNT performance degradation, in reverse engineering PNT-manner

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Ambient-Adaptive Applications-Aligned (AA)2 PNT (Prof Dr Renato Filjar, Croatia)

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with the invitation to participate in:
BAŠKA SIF FORUM
Baška, Krk Island, Croatia
16 – 18 June, 2024

Professor Dr **Renato Filjar**, *FRIN MION*
Faculty of Engineering, University of Rijeka, Croatia, and
Krapina University of Applied Sciences, Croatia
E-mail: renato.filjar@gmail.com