Autonomous Indoor Positioning and Navigation with Foot-mounted IMUs

Ulrich Walder
Prof. Dr. Dipl. Ing. ETH
Martin Krammer
Dipl. Ing. TUG

Institute for Building Informatics, Graz University of Technology
www.bauinformatik.tugraz.at

AIONANV Systems Ldt, Berne, Switzerland
www.aionav.com

Content

- Introduction
- Actual Developments in Indoor Positioning and Navigation
- Inertial Measurement Units (IMU)
- Foot-mounted IMU
  - Theoretical Background
  - Practical Problems with Sensors and Environments
- Results
- Applications
- Further Developments

Introduction

Motivation and Goal of this Session

- Indoor positioning and navigation systems for pedestrians are getting ready to be used in practice
- Scientific publications are getting more and more specialized
- Potential, non-academic users miss state of the art summaries of the different technologies and their reliability for different applications
- Discussion with other specialists without time pressure to improve the own developments and learn from other experiences

Graz University of Technology

Graz University of Technology
Founded 1811

Faculty of Civil Engineering Sciences

TU Graz – Civil Engineering Sciences

Graz University of Technology:

- Founded 1811
- 7 faculties
- 12500 students
- 1400 scientific staff

Institute for Building Informatics belongs to the **Faculty of Civil Engineering Sciences**

- 16 institutes
- 5 laboratories

1 bachelor and 4 master studies:

- Structural Engineering
- Geotechnics and Hydraulics
- Environment and Transportation
- Construction Management

1550 students (190 beginners)

Institute for Building Informatics

Founded in 2004 with 2 collaborators

Today:

- 1 professor
- 5 scientific assistants
- 5 scientific project collaborators
- 1 secretary
- 12 tutors

from Austria, Switzerland, Germany, Slovenia and China

Research Activities

The research topics are based on experiences during my professional life.

The main research is in the field of
- building information modelling
- facility management
- location based services
- desaster and security management in urban areas.

An indoor positioning and navigation system was needed to combine these topics and to add real-time processes.

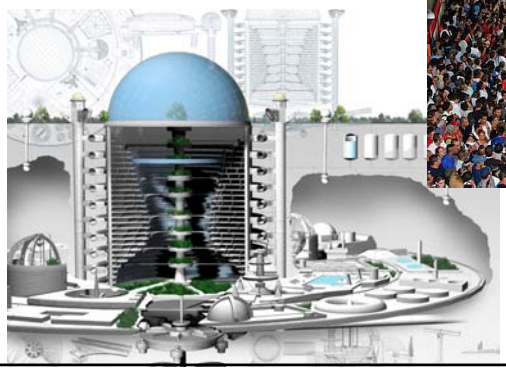
Motivation and Goal of our Research

- Combine the knowledge in different fields to find new solutions for practical problems many people and organizations are waiting for
- Teamwork with scientists of different disciplines
- In our case:
  - Civil engineers and architects for environmental and building modeling
  - Geodesists for GIS and mapping
  - IT engineers for a complex software system
  - Electronic engineers for sensors and radio transmission

Actual Developments in Indoor Navigation

Urban development

- 50% of the world's population lives in cities
- Higher density ► large roofed areas
- Underground cities and transport systems



11

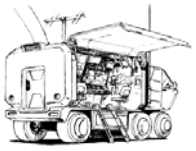
Orientation and Security Problems

Buildings and Underground Structures

- Difficult orientation, especially for handicapped people
- Difficult overview and access in case of fire, flood, terror, etc.
- Difficult to protect against threads of all kind

Desaster Management

- Real-time information about the affected areas and situation of deployed rescue teams is needed
- Secure communication enables efficiency
- Data must be available at the front and in the back
- C³I-Military systems not suited for civil applications
  - Too complicated
  - Too expensive
  - No indoor tracking

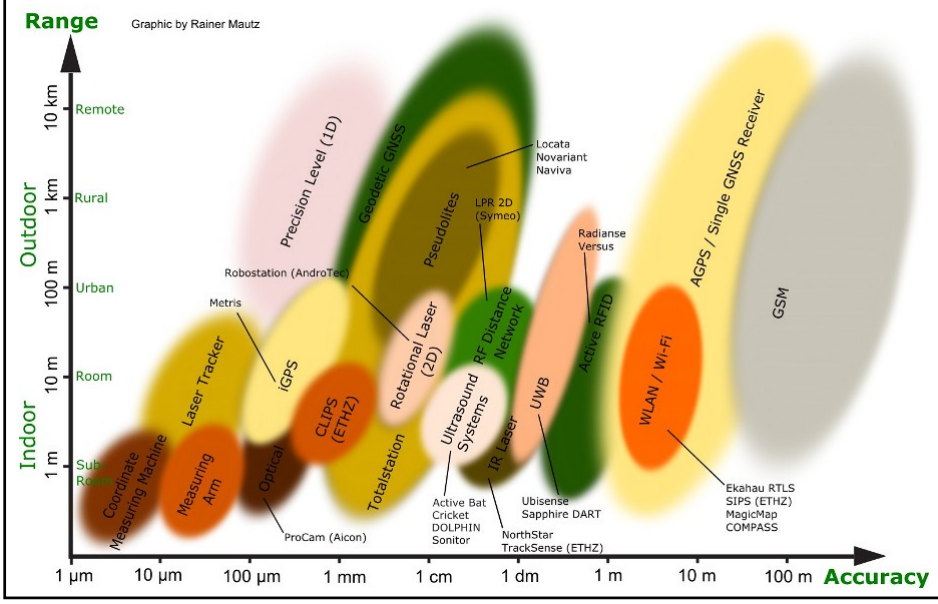


13

Indoor Positioning Technologies

- Based on preinstalled infrastructure
  - HS-GNSS (GPS)
  - Wireless LAN (fingerprint)
  - Ultra Wide Band
  - RFID
  - Cameras
- Dead reckoning systems
  - Repeated distance measurement
  - Inertial systems
- Assistance for visually impaired people
  - Blind men stick and floor guidance system
  - Blind men dog

Indoor Positioning Technologies



Indoor Positioning Technologies

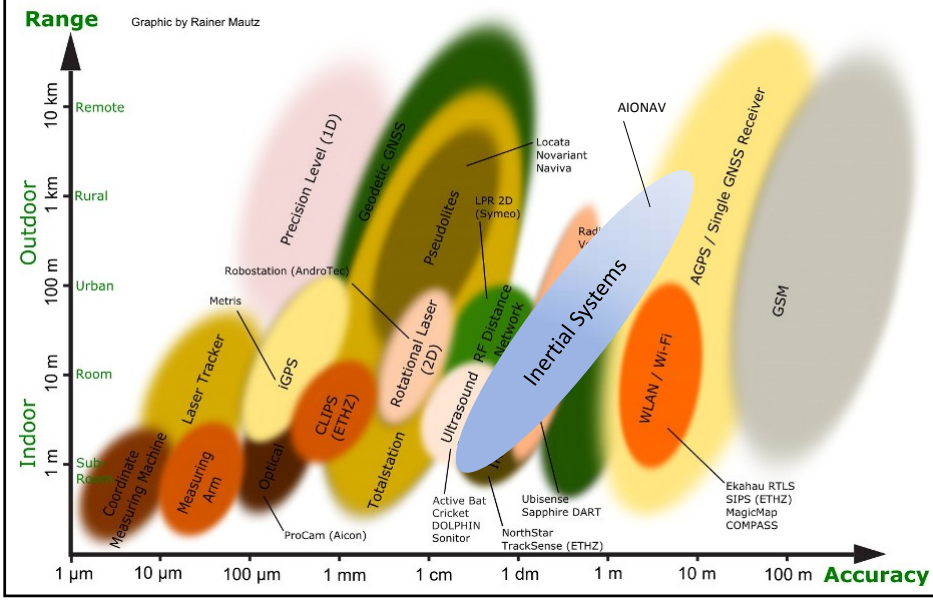
Requirements for pedestrian navigation and disaster management:

- Must work in all environments (indoor and outdoor)
- Low price
- **Autonomous (no additional infrastructure)**
- Accuracy < 3 – 5 m
- Simple to use and immediately available
- High reliability and security
- Small dimension
- Minimum weight

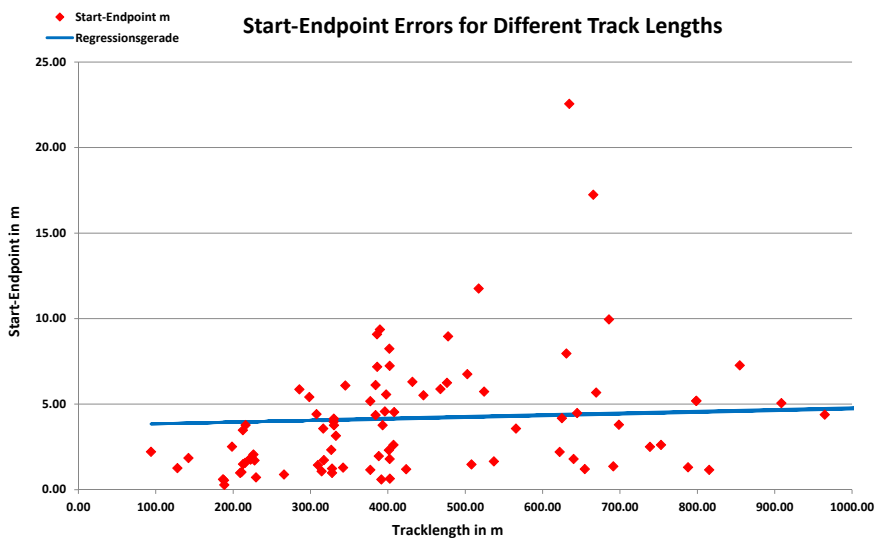
⇨ Best solution with **Dead reckoning (inertial) system**

16

Indoor Positioning Technologies



Indoor Positioning with Inertial System



Autonomous Indoor + Outdoor Navigation

Positioning Equipment

Hardware
- inertial measurement unit (foot or body mounted)
- additional sensors (GPS, barometer, RFID)
- lightweight wearable computer / smart phone

Software
- motion pattern analysis
- intelligent sensor fusion and mapping
- intuitive user interaction

Command Station (optional)

Hardware
- computer / notebook

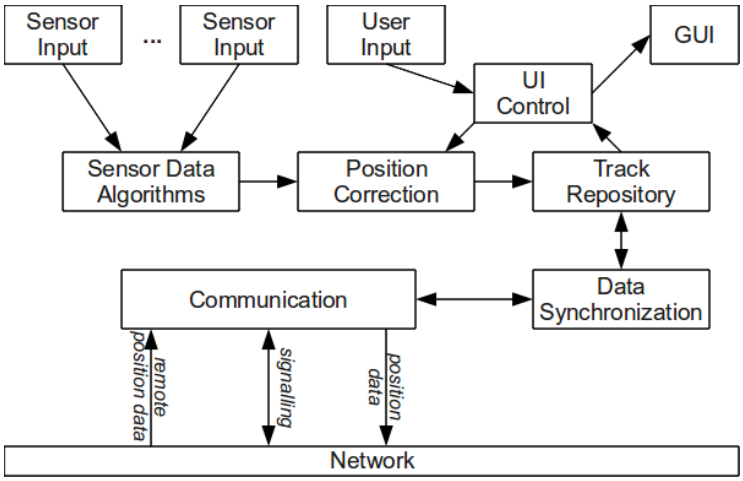
Network
- WLAN, UMTS or radio

Software
- operation command and control system
- database
- location based service (LBS) tools

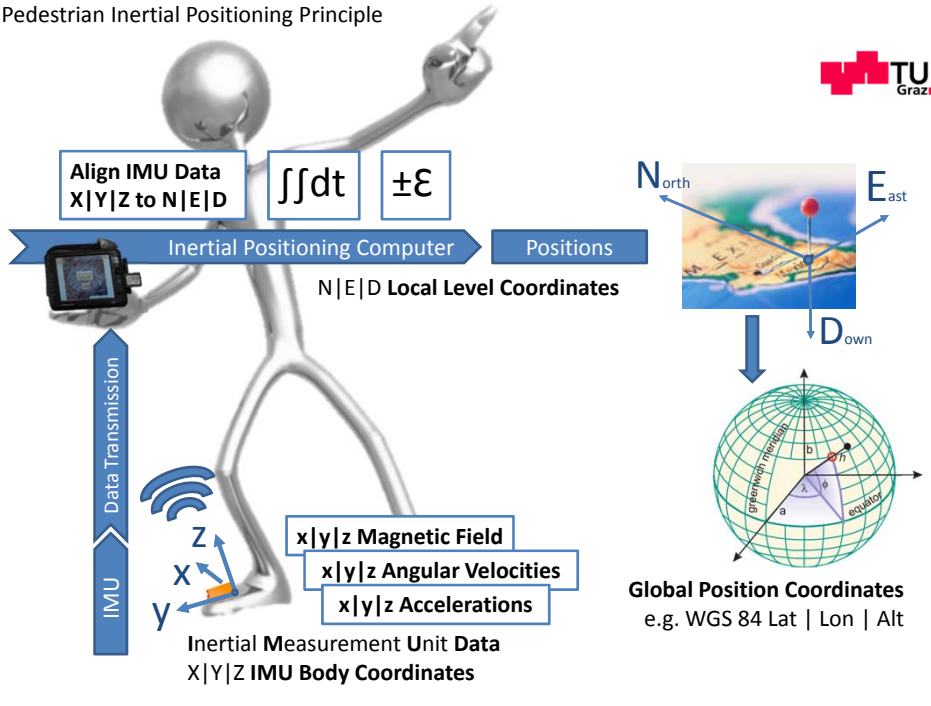
AIONAV Minimum Equipment

Sensor is integrated into the shoe shaft

System Architecture



Pedestrian Inertial Positioning Principle



Properties of an **Inertial Measurement Unit** (IMU)

- A lot of **Measurements** – i.e. 100 [Hz]

Measurement Interval
Δt i.e. 0,01 [s]

- For „inertial positioning“ one IMU measurement **sample contains at least**:

3 Accelerations
ax, ay, az [m/s2]

3 Angular Velocities
ωx, ωy, ωz [rad/s]

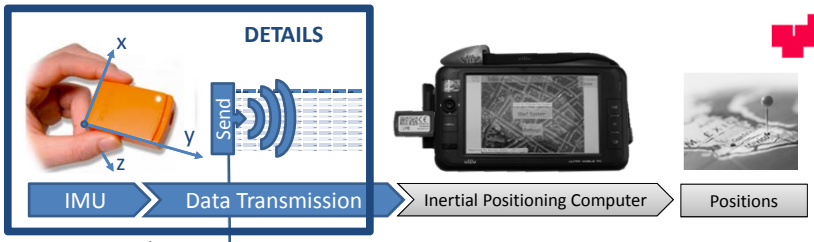
3 Magnetic Field
mx, my, mz [Gauss]

- And **accuracy** of „inertial positioning“ **increases**, with other sensors:

Atmospheric Pressure [Pa]
for Height Corrections [m]

Global Navigation System Position
e.g. GPS, Galilleo, GLONASS [m]
for Position Correction [m]

IMU Data Generation and Transmission



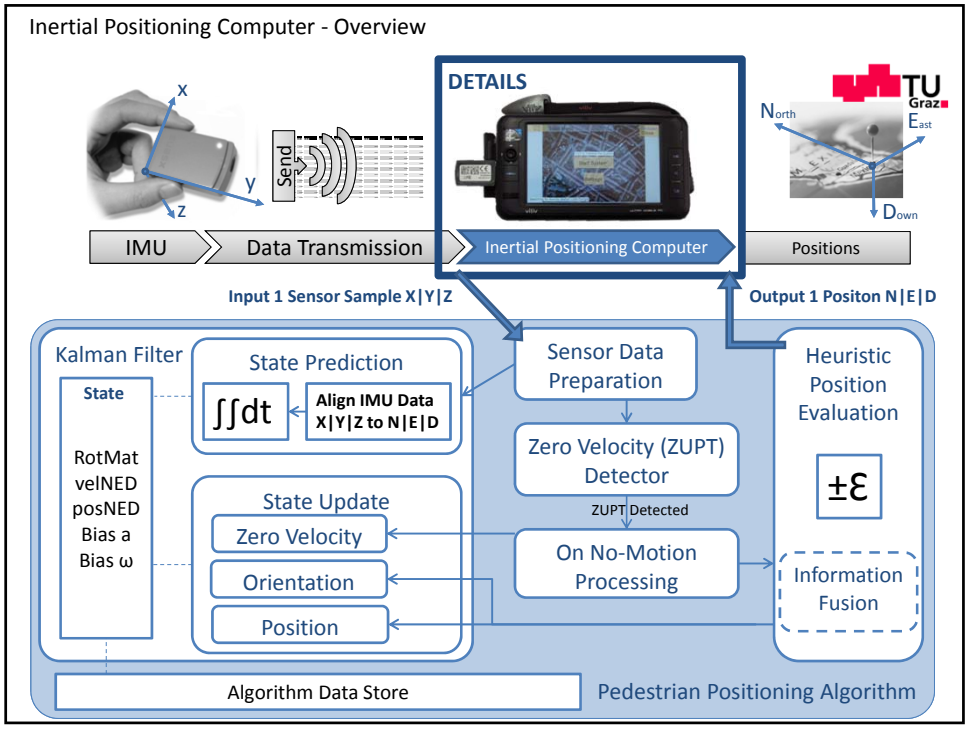
Measurement Sampling
X|Y|Z – Body Coordinates

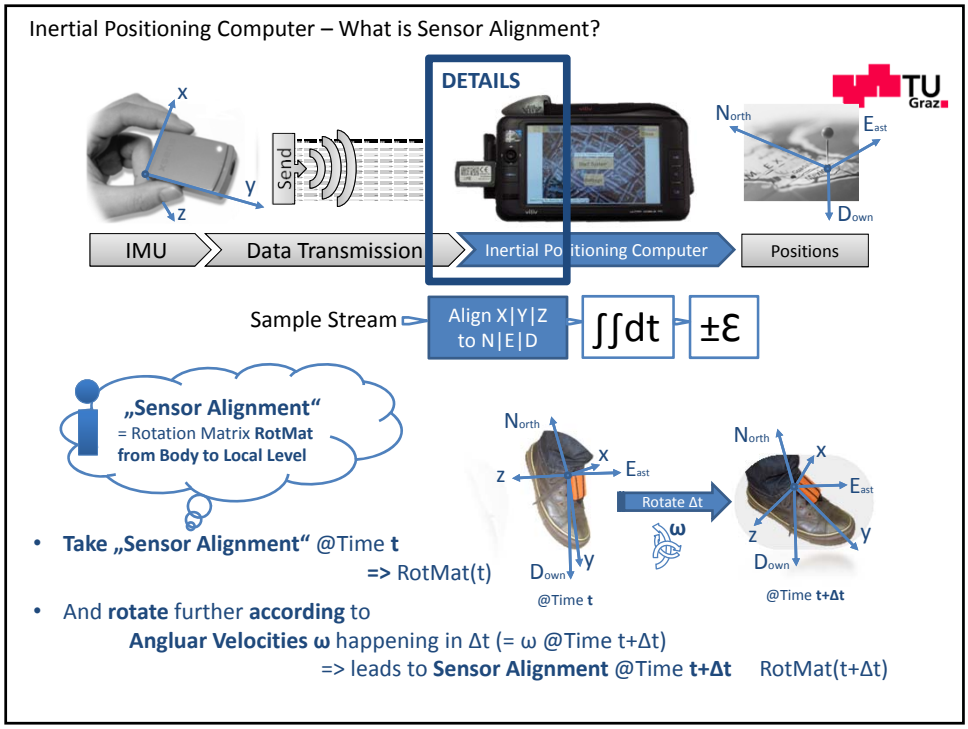
IMU Samples
Data Stream for all Δt

t [s]	ax [m/s2]	ay [m/s2]	az [m/s2]	ωx [rad/s]	ωy [rad/s]	ωz [rad/s]	mx [gauss]	my [gauss]	mz [gauss]
...	...	...	...	...	...	...	...	...	...
t= 212,160	-7,0068	0,9338	9,8389	-0,9253	0,0870	-0,5837	0,5042	-0,5435	-0,6201
+Δt 212,170	-6,4638	-1,4626	9,5151	-0,5589	-0,0902	-0,4761	0,5083	-0,5371	-0,6233
212,180	-5,4932	2,3132	8,9905	-0,3920	-0,0488	-0,3532	0,5103	-0,5308	-0,6265
...	...	...	...	...	...	...	...	...	...

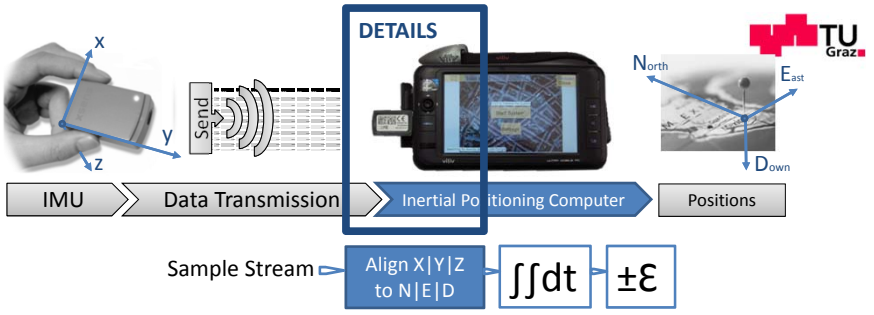
Send all Samples

IMU Sample (t+Δt)

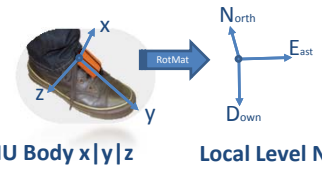

Inertial Positioning Computer - Overview
DETAILS
IMU
Data Transmission
Inertial Positioning Computer
Positions
Input 1 Sensor Sample X|Y|Z
Output 1 Positon N|E|D
Kalman Filter
State
RotMat
velNED
posNED
Bias a
Bias ω
State Prediction
∫∫dt
Align IMU Data X|Y|Z to N|E|D
State Update
Zero Velocity
Orientation
Position
Sensor Data Preparation
Zero Velocity (ZUPT) Detector
ZUPT Detected
On No-Motion Processing
Heuristic Position Evaluation
±ε
Information Fusion
Algorithm Data Store
Pedestrian Positioning Algorithm


Inertial Positioning Computer – What is Sensor Alignment?
DETAILS
IMU
Data Transmission
Inertial Positioning Computer
Positions
Sample Stream
Align X|Y|Z to N|E|D
∫∫dt
±ε
„Sensor Alignment“
= Rotation Matrix RotMat from Body to Local Level
Rotate Δt
ω
@Time t
@Time t+Δt
• Take „Sensor Alignment“ @Time t
=> RotMat(t)
• And rotate further according to
Angluar Velocities ω happening in Δt (= ω @Time t+Δt)
=> leads to Sensor Alignment @Time t+Δt RotMat(t+Δt)

Inertial Positioning Computer – Align Measurements to common Frame

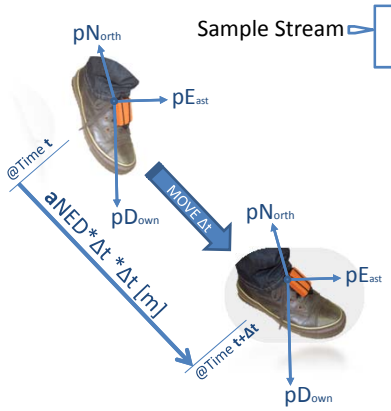


- **for every Sample**
- **use „Sensor Alignment"@that time**
  to align IMU Measurements to a common Coordinate Frame for next computations



IMU Body x|y|z **Local Level N_{orth}|E_{ast}|D_{own}**

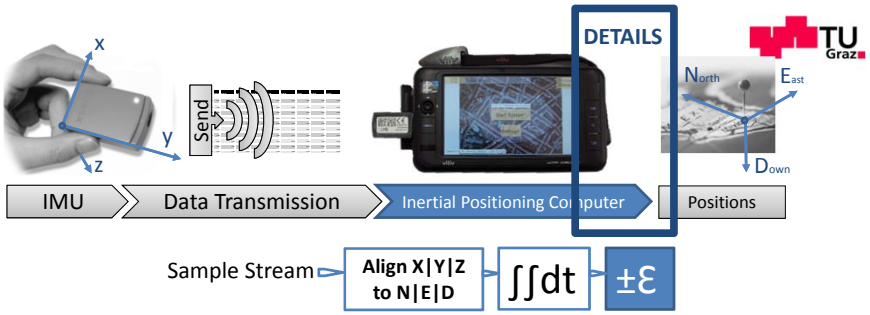
Inertial Positioning Computer – Calculate Movement from Accelerations



@Time **t+Δt: Calculate new Position** [m]
by **adding** the „old" Position @time t to
double **integrated, aligned, gravity cleaned accelerations** @time t+Δt

pNED(t+Δt) = **p**NED(t)
+ **a**NED(t+Δt) *Δt*Δt
– „gravity impact"

Inertial Positioning Computer – Correct calculated Positions with Heuristics



- **Problem: IMU measurement errors** propagage as **Position Drift** exponentially
- **Counteract** with different Means e.g.:
  - **Detect real Motion State** and **correct Algorithm accordingly**
    e.g. *Zero Velocity (ZUPT)*
  - **Use different Sensors** (with different Errors) **or** different **Algorithms**
    „Information Fusion“
  - Use **Plausibility Checks** according to
    Context of Application (e.g. Walking) or *Map-Constraints (e.g. Walls)*

Inertial Measurement Units

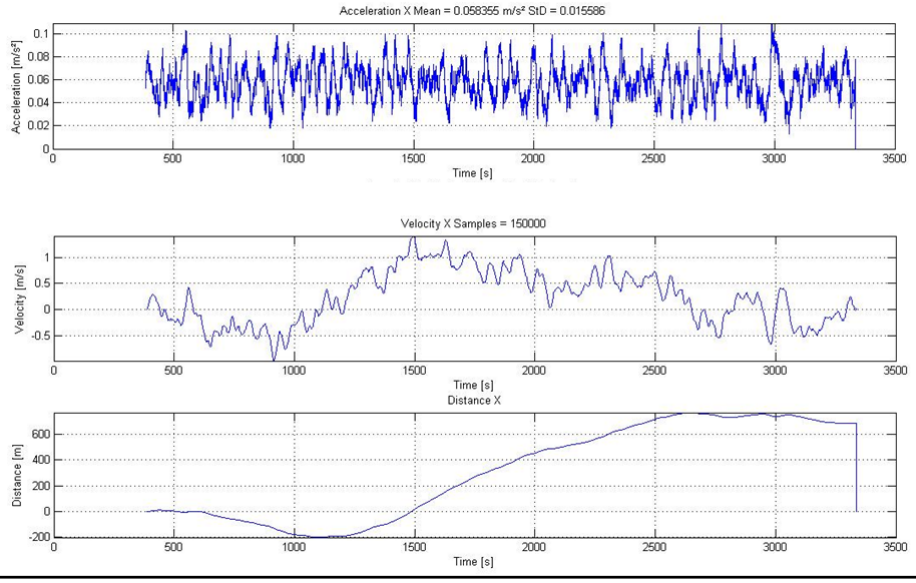
Inertial System Challenges

- Start from a known position into the right direction
- Positioning by double integration of the global accelerations
- Many problems have to be solved:
  - Noise
  - Drift
  - Temperature
  - Calibration
  - Accuracy

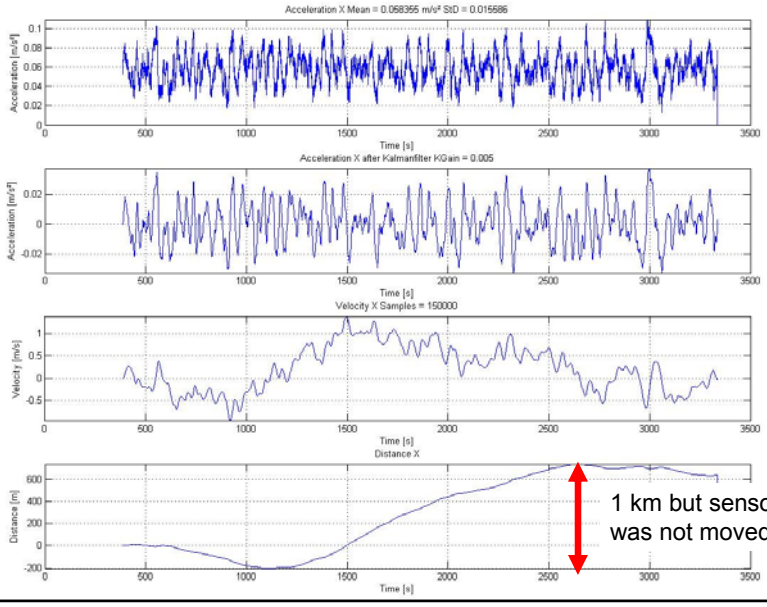
  } stable bias point
- Longer stops
- Moving stairs or floors
- Transmission interrupts of wireless sensors

31

Raw Data with Double Integration



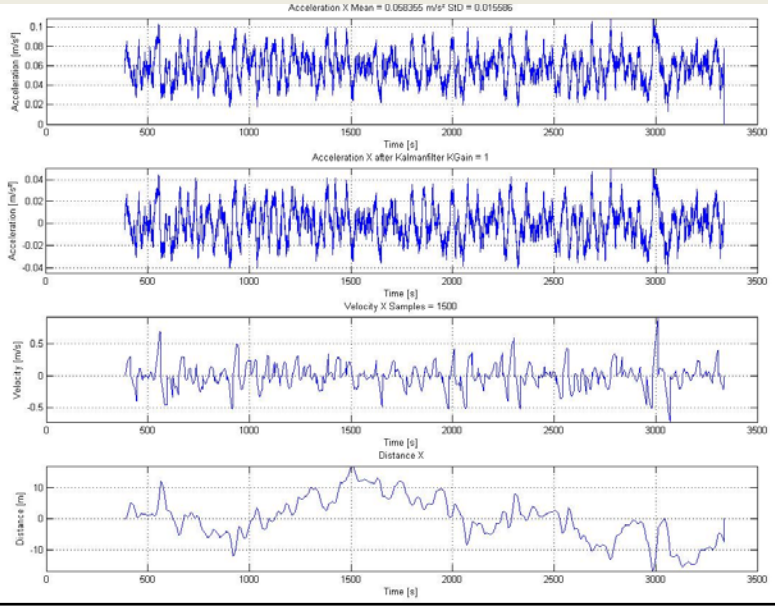
Raw Data with Kalman Filter



1 km but sensor was not moved !!!

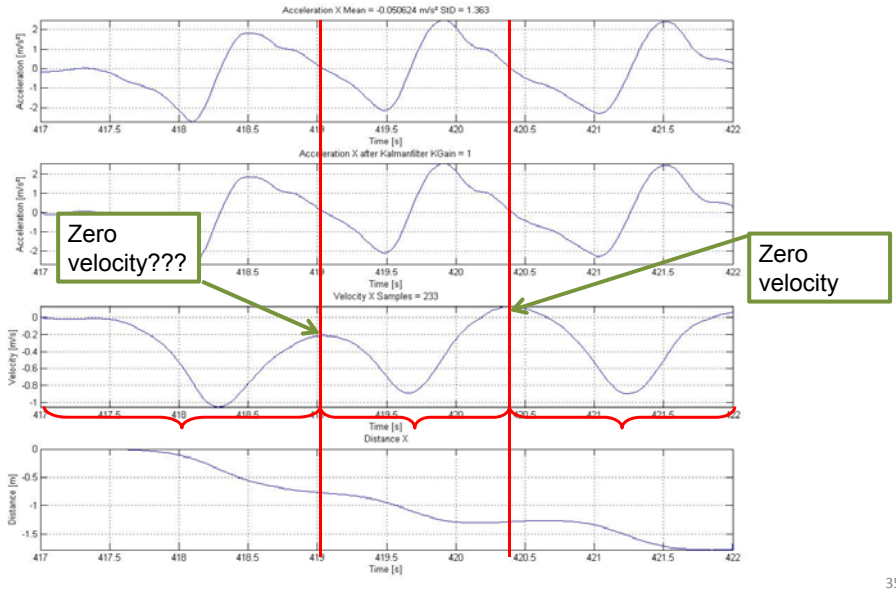
33

Set to Zero Velocity every 30 sec



34

Walking Three Steps



35

Different Sensors Used

- Microstrain 3DM-GX1
- Xsens
  - MTx
  - MTi
  - MTi-G
  - MTw
- MEMSense wireless
- LP Research Bluetooth
- YEI 3-Space Sensor Bluetooth
- Honeywell DRM4000
- Smartphone sensors






IMU Main Characteristics

Output

- Accelerations (x,y,z), angular velocities (x,y,z), magnetic field (x,y,z) (except DRM4000)
- Quaternions or rotation matrix
- Time stamp
- Barometer data
- Coordinates and yaw angle per step (DRM4000)

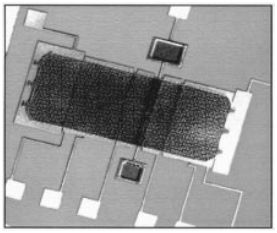
Measurement range

- ± 5 - 50g for accelerations
- 300 - 2000 °/sec gyros
- 30 – 200 Hz

MEMS Accelerometers

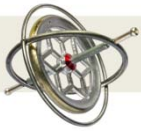
2 types of micromechanical accelerometers:

- pendulous/displacement mass type that use closed-loop capacitive sensing and electrostatic forcing
- resonator type.



Picture Draper Laboratry

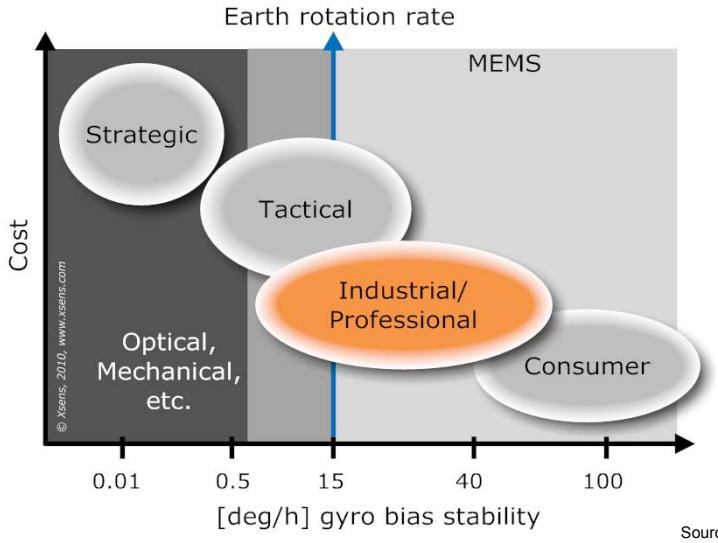
MEMS Gyroscopes



- An IMU consists of three independent vibratory MEMS rate gyroscopes, which detect rotation about the X, Y, and Z axes.
- When the gyros are rotated about any of the sense axes, the Coriolis Effect causes a vibration that is detected by a capacitive pickoff.
- The resulting signal is amplified, demodulated, and filtered to produce a voltage that is proportional to the angular rate.

Source InvenSense

MEMS Gyroscopes

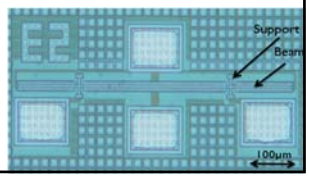


Source: Xsens

MEMS Magnetometers

- Three-axis magnetic compasses contain magnetic sensors in all three orthogonal vectors of an electronic compass assembly to capture the horizontal and vertical components of the earth's magnetic field.
- To electronically gimbal the compass, the three magnetic sensors are often complemented by a tilt-sensing element to measure the gravitational direction.
- The tilt sensor provides two-axis measurement of compass assembly tilt and then computed into a tilt-compensated heading.

Source Honeywell



Main Differencies in Sensor Qualities

Precision

- Linearity
- Bias stability
- Noise
- Alignment error
- Temperature range
- Calibration
- Weight and size
- Battery life time (wireless)

Price

- 300 - 2000 US$

Data transmission

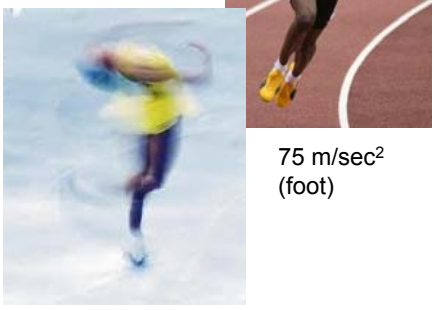
- Sample rate (30 – 200 Hz)
- Cable or wireless (Bluetooth, Bluetooth LE, ZigBee)

Typical Data Sheet

Xsens MTw	Angular velocity	Acceleration	Magnetic field	Pressure
Dimensions	3 axes	3 axes	3 axes	-
Full Scale (FS)	± 1200 deg/s	± 160 m/s^2	± 1.5 Gauss	300 -1100 hPa (-500 ... 9000 m above sea level)
Linearity	0.1 % of FS	0.2 % of FS	0.2 % of FS	0.05 % of FS
Bias stability[1]	20 deg/hr	-	-	100 Pa/year
Noise	0.05 deg/s/√Hz	0.003 m/s^2/√Hz	0.15 mGauss/√Hz	0.85 Pa/√Hz
Alignment Error	0.1 deg	0.1 deg	0.1 deg	-
Bandwidth[2]	100 Hz (max.)	100 Hz (max.)	20 Hz (max.)	-

[1]As measured from the Allan variance diagram.
[2] Half of the chosen sampling rate.

Minimum Requirements for Human Motion Tracking

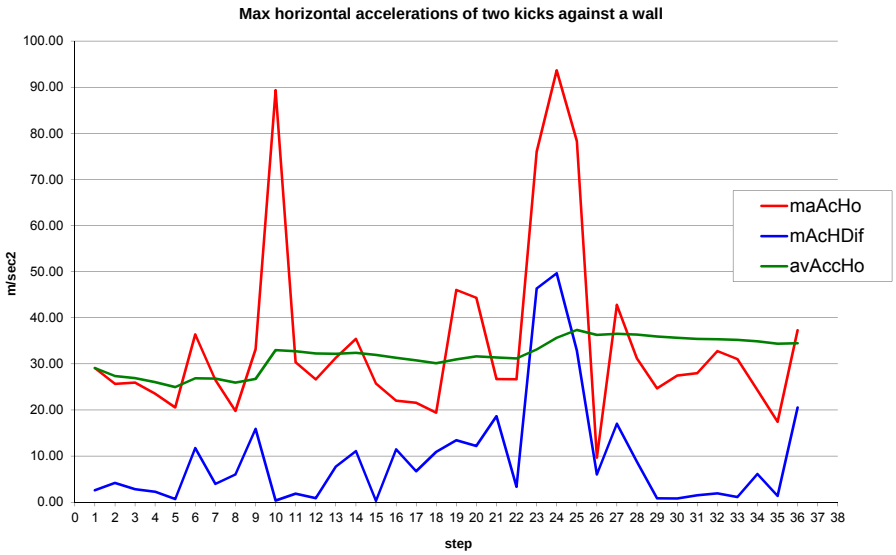


1440 deg/s

75 m/sec^2 (foot)

> 120 m/sec^2 (kick)

Shock waves



Minimum Requirements for Pedestrian Motion Tracking

	Angular velocity	Acceleration	Magnetic field	Pressure
Dimensions	3 axes	3 axes	3 axes	-
Full Scale	± 1200 deg/s	± 160 m/s^2	± 1.5 Gauss	300 -1100 hPa (-500 ... 9000 m above sea level)
Linearity	0.1 % of FS	0.2 % of FS	0.2 % of FS	0.05 % of FS
Bias stability	20 deg/hr	-	-	100 Pa/year
Noise	0.05 deg/s/√Hz	0.003 $m/s^2/\sqrt{Hz}$	0.15 mGauss/√Hz	0.85 Pa/√Hz
Alignment Error	0.1 deg	0.1 deg	0.1 deg	-
Bandwidth	100 Hz	100 Hz	20 Hz	-

Foot Mounted IMU - SWOT Analysis*

* For 3D Soldier Positiong System

Foot Mounted IMU

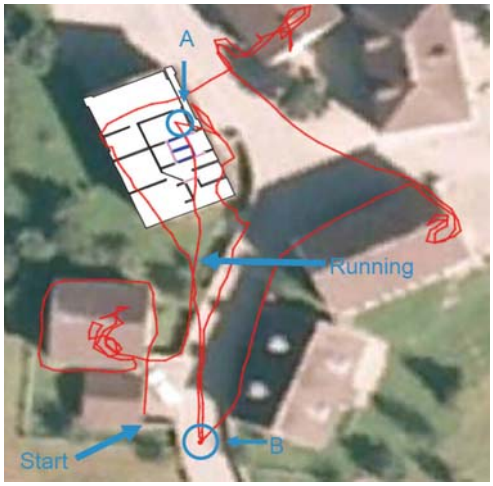
Type of movement	Differences in ZUPT during e.g. walking, running, duck-walking, sneaking, crawling, …
Shoe type, weight being carried, surface	Affects foot-impact and sensed accelerations and thus possibilities for reliable ZUPT
Placement on foot	Affects max sensed accelerations and angular rates, and also ZUPT
Movement trajectory	Some trajectories reduces effects of heading error on position error (e.g. closed-loops etc.)
Gyro noise and bias errors	Random, causes main error typically associated with foot mounted INS (i.e. heading error)

Source: FOI

Foot Mounted IMU

Accelerometer dynamic range	Dynamic ranges well over 10 g should be expected
Gyro dynamic range	Angular velocities well over 700 deg/sec should be expected
Initialization of bias errors	Some systems assume possibility to have short moments of stand-still in beginning of measurement
Initialization of orientation, velocity and position	Not solved completely (automatic initialization) for GPS-denied environments

Minimum Requirements not Fulfilled



Example (using MTi-G IMU)

St. Luzisteig – realistic search

- 1st part - large heading errors during running due to *low dynamic range* in acc and gyros
- 2nd part – small accumulation errors (low-dynamic movement)

A – person outside entrance
B – person at starting point

Magnetometer

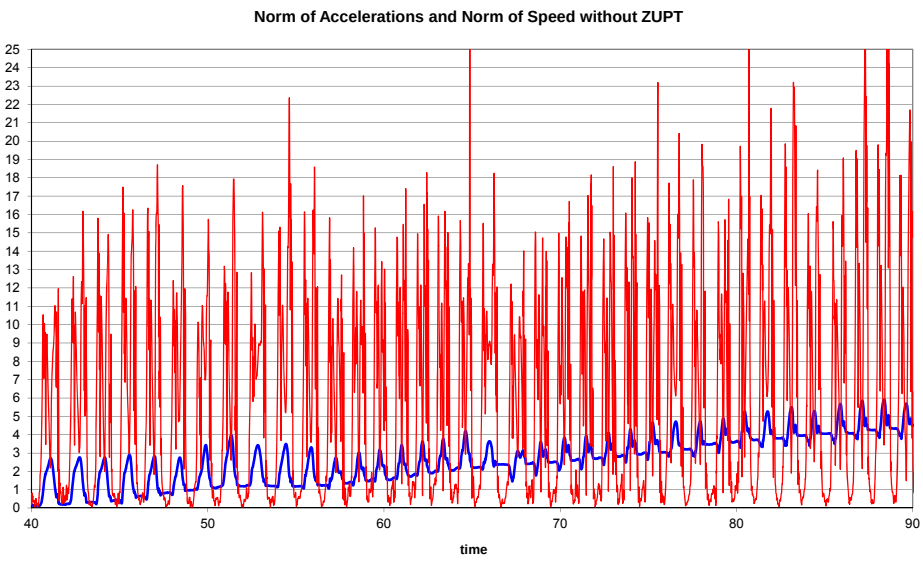
Strong magnetic disturbances in local environment	Metal objects, electrical wires, constructions, and other objects may strongly disturb earth magnetic field
Trajectory	Heading errors reduced by e.g. passing strong magnetic disturbances back-forth (i.e. walking corridor in both directions)
Soldier equipment	May cause large local magnetic disturbances, not possible to calibrate

Barometer

Wind and weather influence	Barometer senses weather changes, use of reference barometer at known height in similar conditions reduces these problems
Noise	Gun fire and exploding munitions could affect barometric pressure locally during shorter time intervals
Dynamic range (w/o brake-down)	Could very high pressure changes destroy sensor?
Opening doors or windows	Buildings may have somewhat different pressure e.g. in staircases or in basements
Fires	Heat from fires may cause turbulence in the air, and increasing temperatures causes higher air pressures

IMU Behaviour in Practice

Walking without Zero Velocity Updates

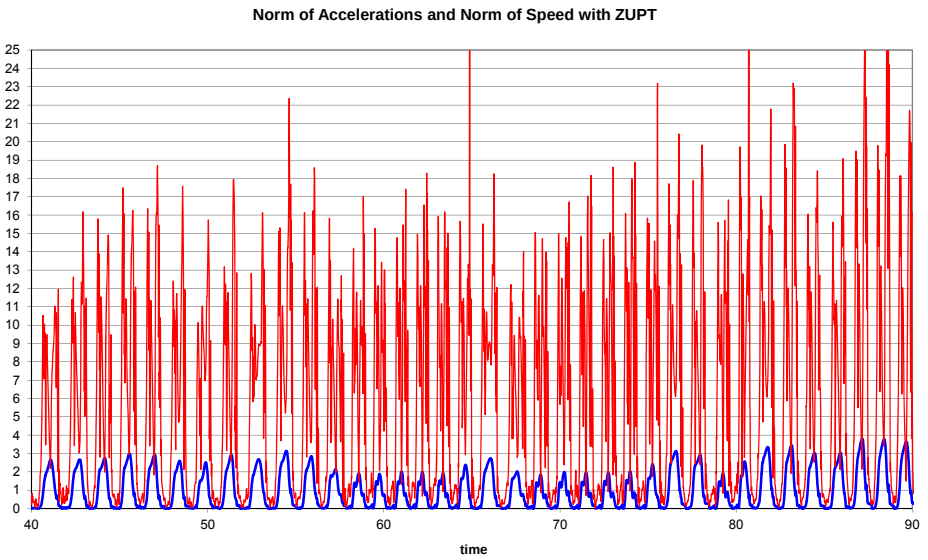


Result without Zero Velocity Update (ZUPT)

Track length 1148.83 m
Error start – end point
895.44 m!

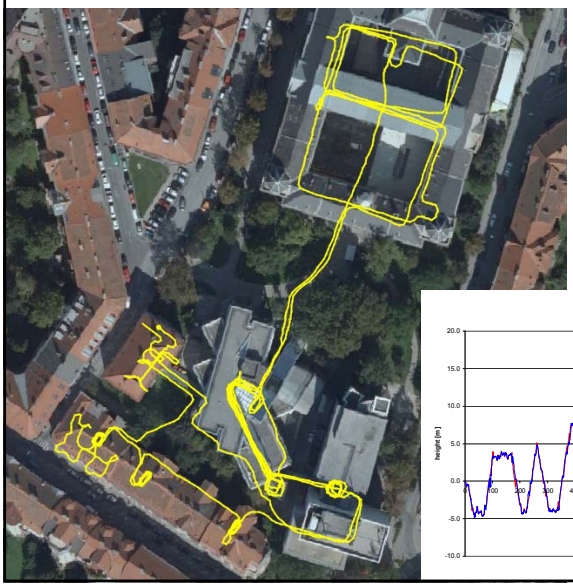
55

Walking with ZUPT

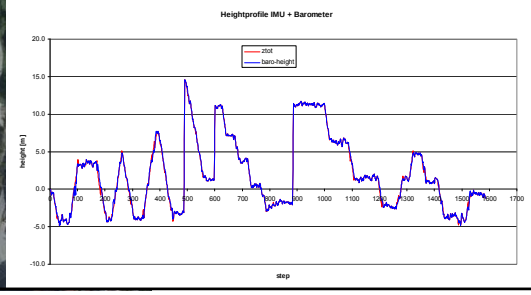


56

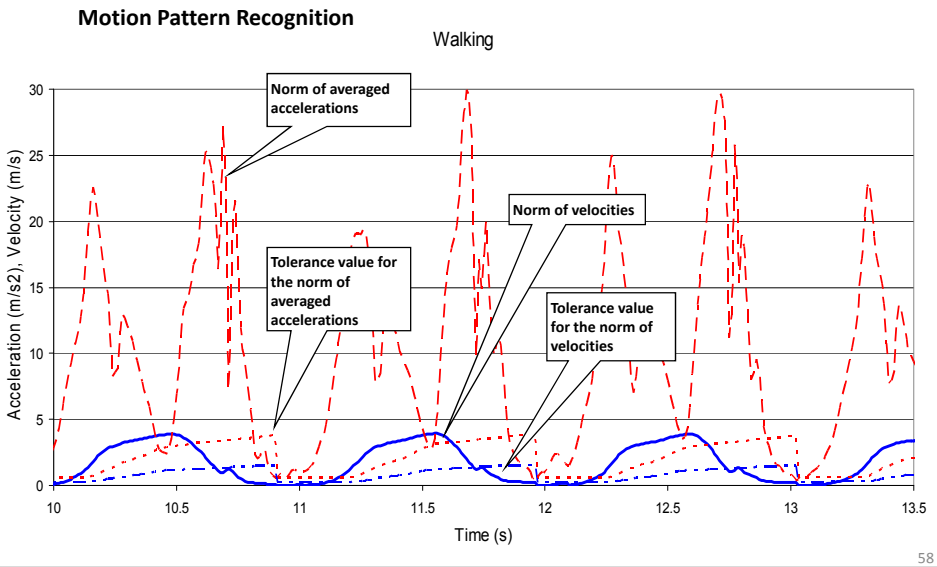
Result with ZUPT



10 buildings
3 elevators
37 floors
Track length 2078.44 m
Track time 41.14 min
Error start – end point 5.42 m
Max error on track < 7m
Accuracy end point = 0.26 %



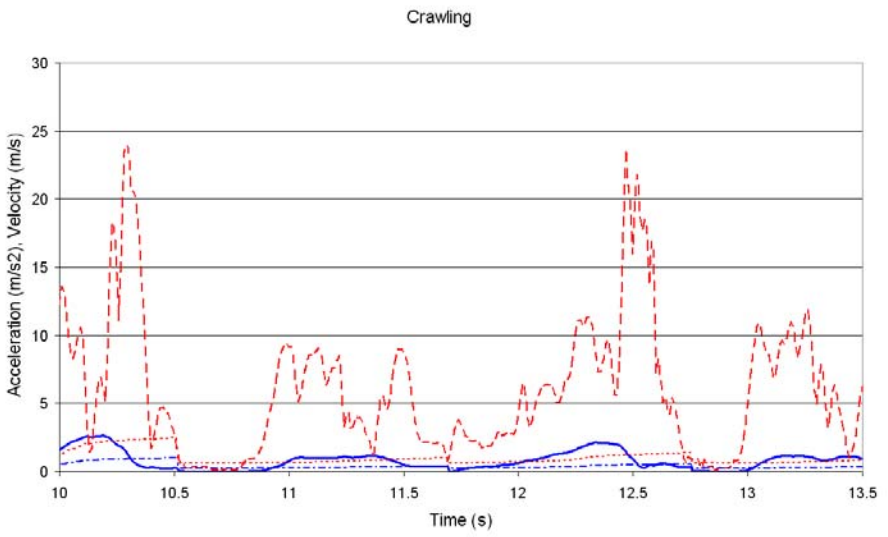
Zero Velocity Updates



58

Zero Velocity Updates

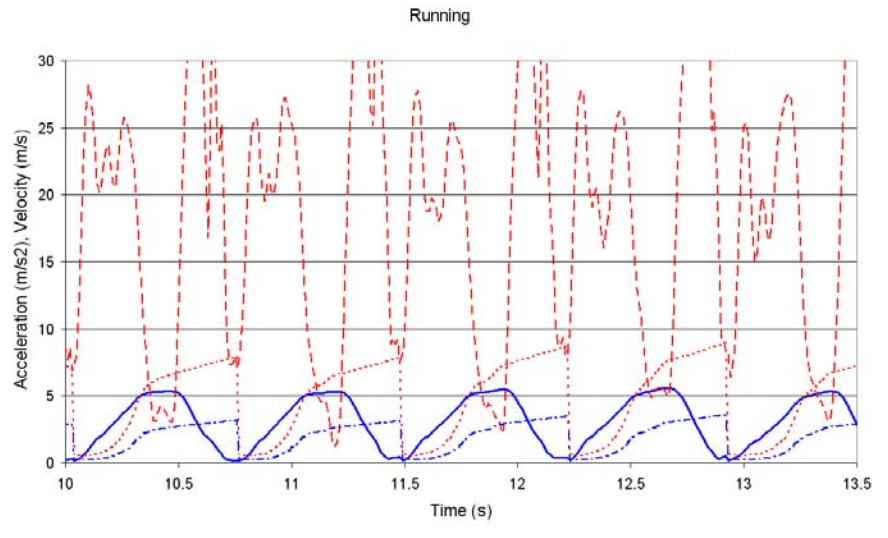
Motion Pattern Recognition



59

Zero Velocity Updates

Motion Pattern Recognition



60

Zero Velocity Updates

ZUPT Algorithm

$$(a_{s(t)} = a_{s(\min)} \wedge v_{s(t)} < v_f \wedge \left|v_{s(t)} - v_{s(\min)}\right| < \Delta v * f_v \wedge a_{s(t-1)} > a_{s(t)})$$

$$\vee (v_{s(t)} = v_{s(\min)} \wedge a_{s(t)} < a_f)$$

(patent pending)

v_f and a_f tolerance values for the maximum norm of velocity / average acceleration in the zero velocity region

$$v_f = \Delta v * f_v * (1 + \Delta t)$$

$$a_f = \Delta a * f_v * (1 + \Delta t)$$

Δv and Δa thresholds for the absolute minimum velocity / average acceleration in the zero velocity region

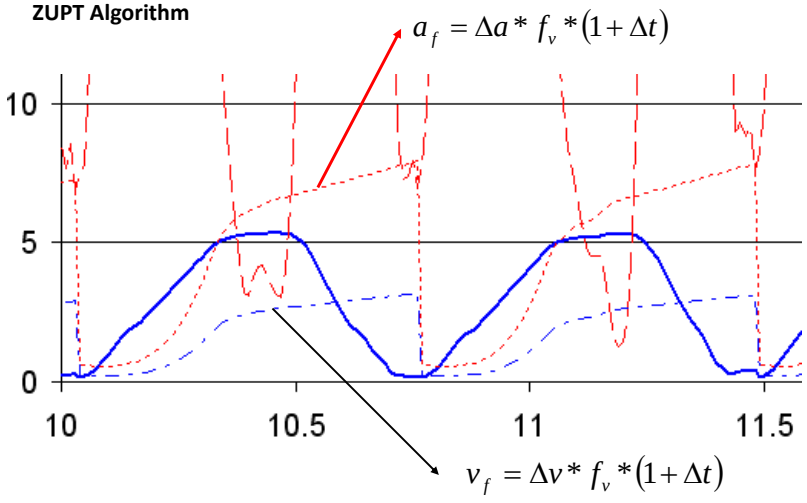
$$f_v = A * v_{\max}^3 + B * v_{\max} + C$$

v_{max} Maximum velocity since the last zero velocity update.

61

Zero Velocity Updates

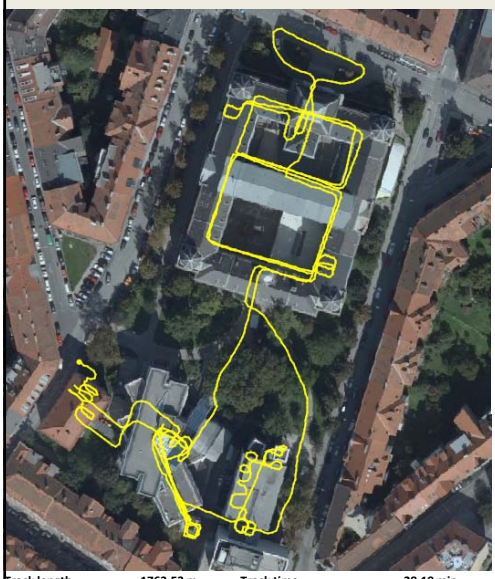
ZUPT Algorithm

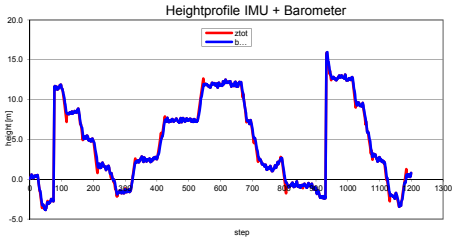


62

IMU with ZUPT – all problems solved?

TU Graz – it seems to be





Track length	1763.53 m	Track time	28.19 min
Start-end point	8.88	Accuracy	0.50 %

TU Graz – it seems to be

Track length	1728.80	m	Duration	34.38	min	No. of Floors	21
Start-end point	3.14	m	Accuracy	0.18	%	No. of Elevators	1

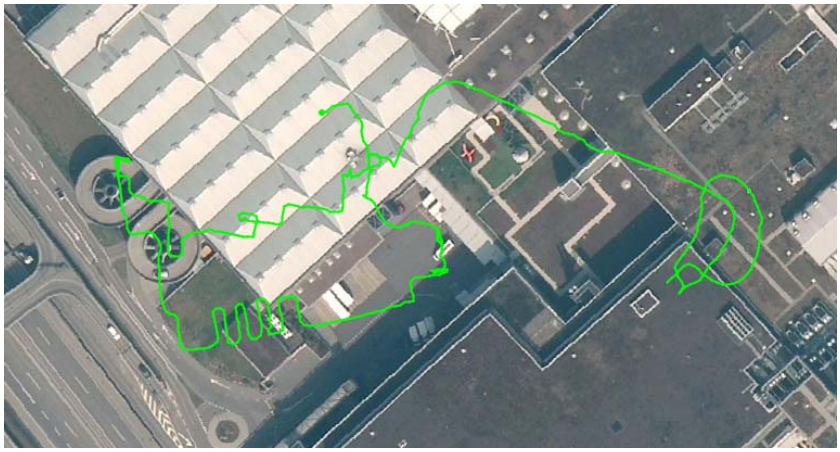
65

Söding – an other Location

Track length	4829.30	m	Track time	63.30	min
Start - End point	7.29	m	Accuracy	0.15	%

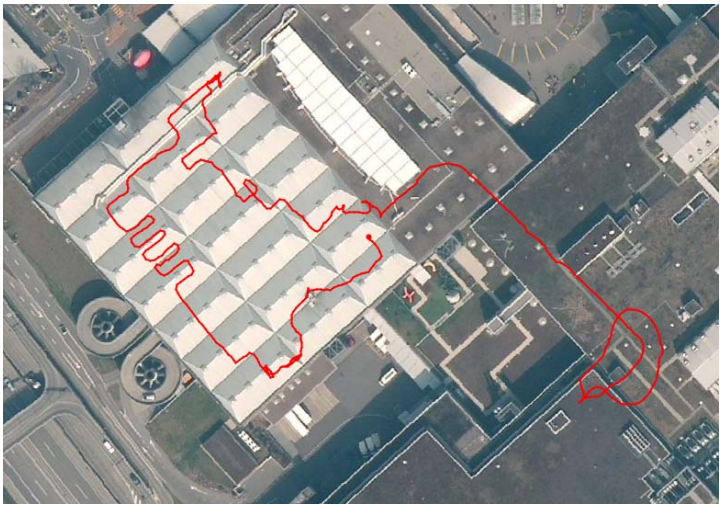
66

Let‘s go Shopping - Shoppyland, Berne



Environment with magnetic field disturbancies: track is completely distorted

Shoppyland, Berne



Track ± 5m accuracy as it should be (with automatic magnetic field supression)


Jing

Industry Park with Metal Skin Buildings

Same problem: track is completely distorted, start direction 50 deg wrong

Industry Park

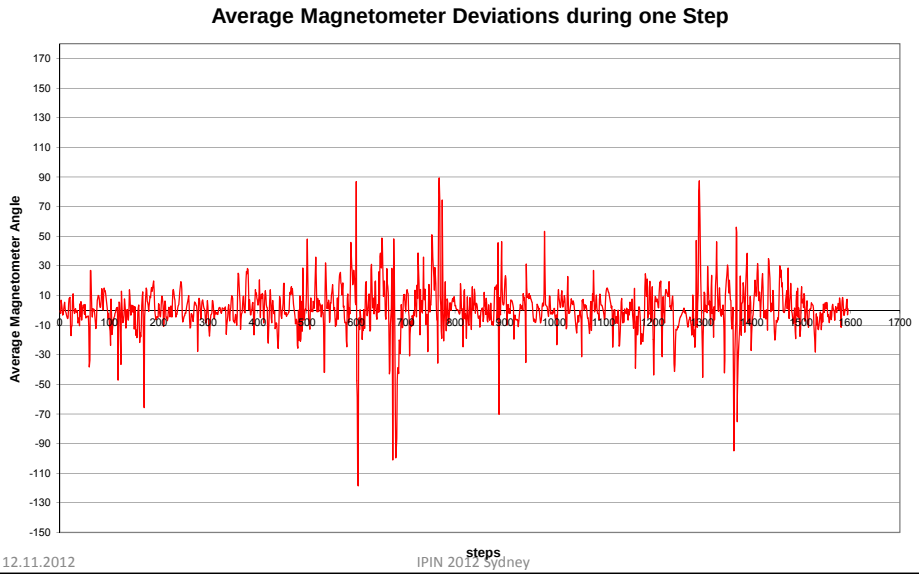
Track ± 5 m accuracy (with slight automatic magnetic field supression)

Industry Park

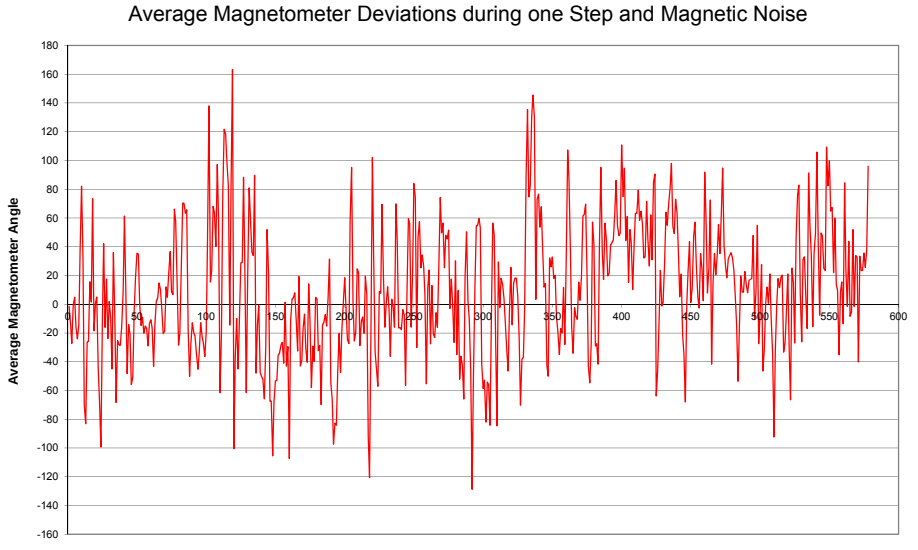
Track ± 2 m accuracy (with total magnetic field supression)

Magnetic Field Disturbancies

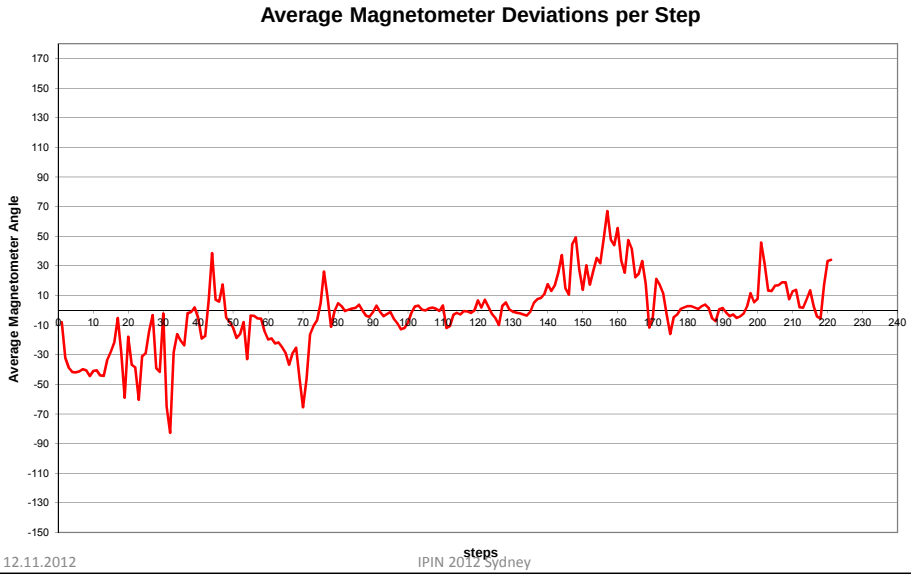
TU Graz - Magnetic Field



Shoppyland - Magnetic Field



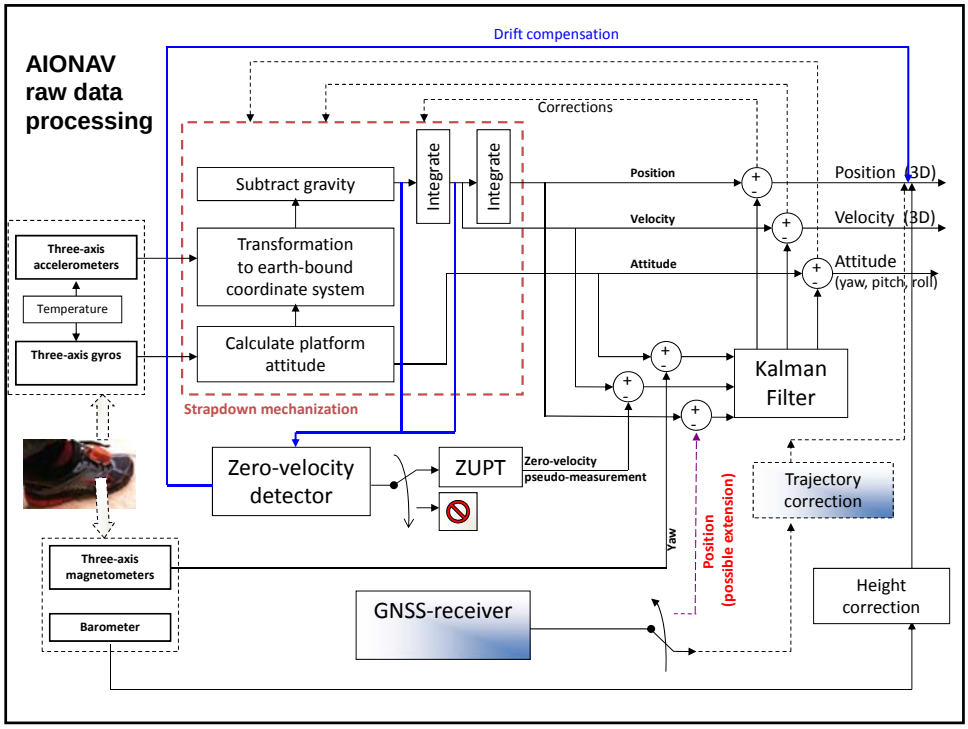
Industry Park - Magnetic Field

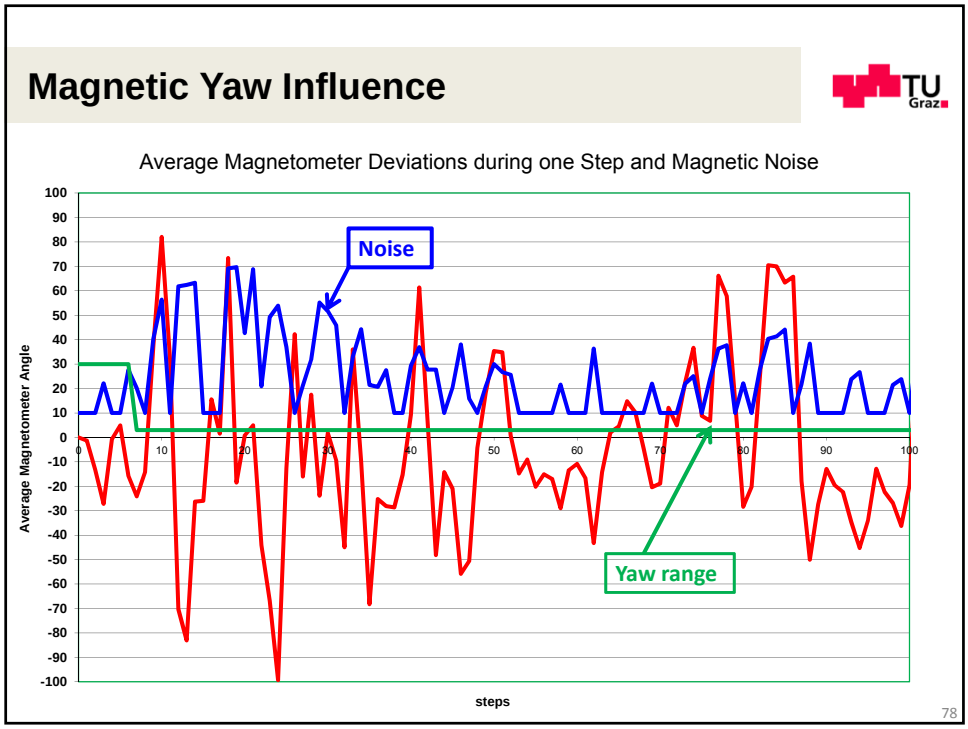


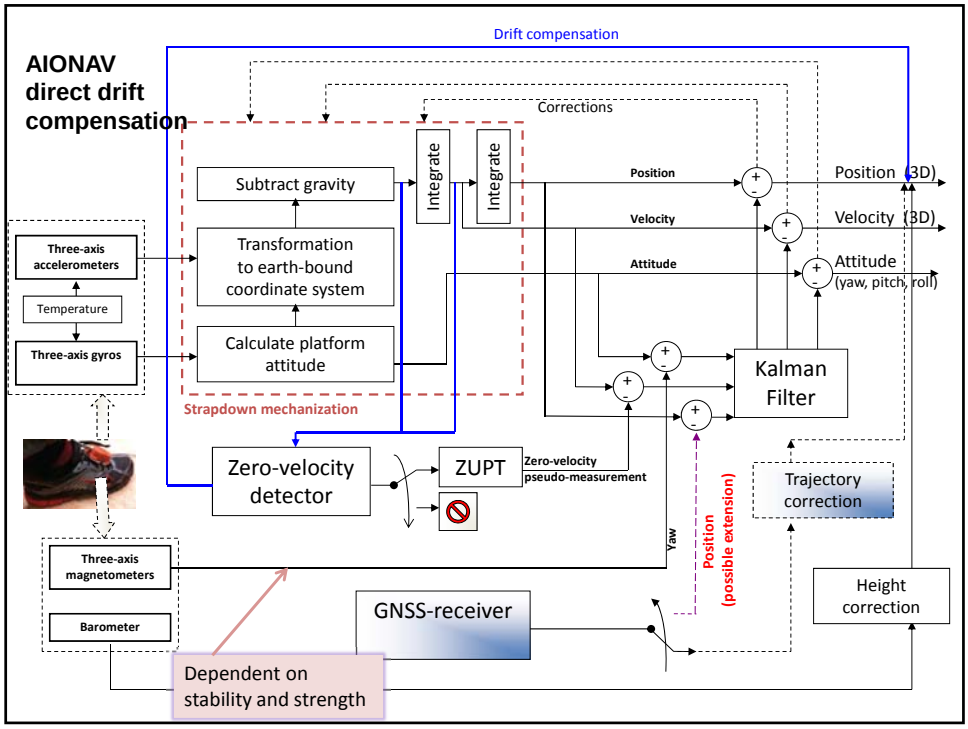
AIONAV Raw Data Processing

- State of the art IMUs, such as from Xsens, contain a significant portion of on-board processing for signal conditioning and filtering
- Magnetometer data are used to determine the initial alignment and to enhance the gyro stability
- Different parameter settings of the firmware can be chosen
- No possibility to influence the filter parameters directly

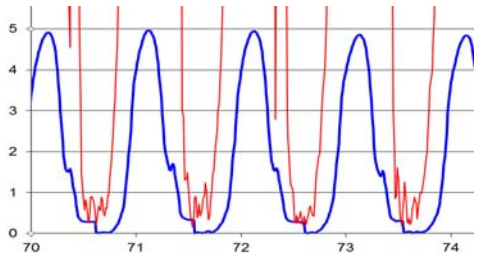
- An additional extended Kalman filter for the raw data has been established in AIONAV

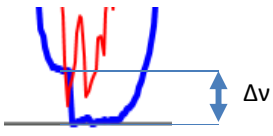

AIONAV raw data processing
Drift compensation
Corrections
Subtract gravity
Integrate
Integrate
Position
Velocity
Attitude
Position (3D)
Velocity (3D)
Attitude (yaw, pitch, roll)
Three-axis accelerometers
Temperature
Three-axis gyros
Transformation to earth-bound coordinate system
Calculate platform attitude
Strapdown mechanization
Kalman Filter
Zero-velocity detector
ZUPT
Zero-velocity pseudo-measurement
Trajectory correction
Three-axis magnetometers
Barometer
GNSS-receiver
Yaw
Position (possible extension)
Height correction


Magnetic Yaw Influence
TU Graz
Average Magnetometer Deviations during one Step and Magnetic Noise
Noise
Yaw range
Average Magnetometer Angle
steps
78



Direct Drift Compensation



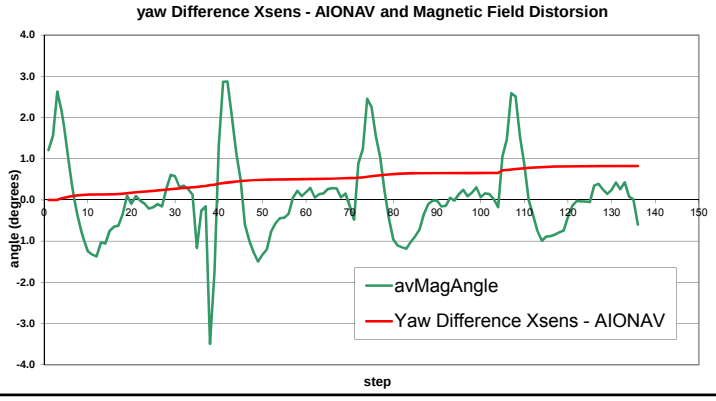


$X = X + \Delta v_x * dt_{step}/2.$
$Y = Y + \Delta v_y * dt_{step}/2.$
$Z = Z + \Delta v_z * dt_{step}/2.$

80

Xsens and AIONAV Position Merge

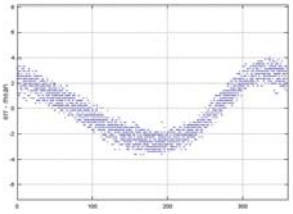
- If (Yaw_{Xsens} – Yaw_{Aionav}) < angle threshold (e.g. < 0.5 deg)
  - Xsens alignment is used in AIONAV Kalman filter
  - $(X,Y) = ((X,Y)_{Xsens} + (X,Y)_{AIONAV}) / 2.$



81

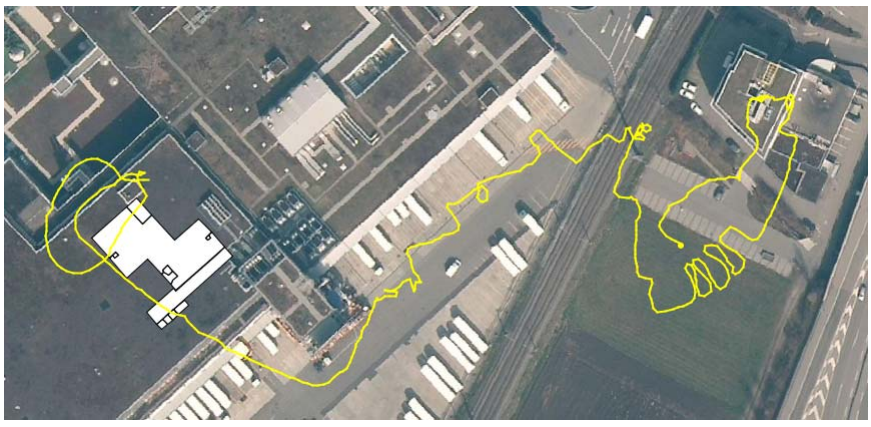
System Initialisation

- Calibration and Gyro Warm-up
- Initial Alignment



Calibration Errors

Shoppyland – Start without SW-Calibration



Completely wrong track

Industry Park – Start without SW-Calibration

Calibration and Gyro Warm-up

- State of the art IMUs are factory calibrated
- but depend on local conditions, like
  - Strong magnetic fields
  - Temperature
  - Vibrations or shocks
  - Age or slight damage of the sensor
  - etc.

- Factory calibration in general not satisfactory
- Gyro “warm-up” for stabilization of minimum 1 min is necessary
- Recalibration at least at the start is necessary
- Permanent recalibration of gyros and barometer is possible

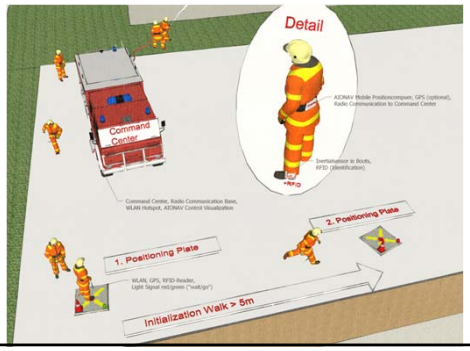
Start Procedure

Start Procedure – Initial Alignment

1. Connection between sensor and mobile computer
2. Warm-up of the gyros
   - Select start position
   - Select start alignment
     - 1 point plus direction
     - 2 points
     - Known direction (street, border of a room, etc.)
3. Calibration of the sensor (2 – 5 sec)
4. Start walking

Start Procedure

1. Connection between sensor and mobile computer
2. Warm-up of the gyros and calibration of the sensor before deployment
3. Start walking and pass at least 2 fix points



Position Corrections and Updates

What Users Want – STTC Request

6A-3. Position, Location and Tracking for Live Training

*STTC is interested in technologies that improve live training of simulated tactical engagements, particularly in urban terrain, where GPS signals may become degraded or obscured due to multi-path phenomena. ….. **The technology applied to solve these challenges must be able to determine the position/location accuracy to less than 60 cm (95%) and have a battery life of up to 72 hours without changing or charging batteries.***

The need for infrastructure to support the technology must be minimal, or ideally, none at all.

United States Army Simulation and Training Technology Center

91

First Conclusions Concerning Accuracy

- Accuracy depends mainly on
  - Sensor quality and mathematical modeling (extended Kalman filter)
  - Duration of deployment
  - Environmental disturbances
- For deployments >~ 30 min and a constant accuracy of 3 -5 m it needs (today 2012):
  - Sensors with better accuracy, or
    - Additional filters (e.g. Partical Filter)
    - Periodic repositioning

92

Different Repositioning Methods

- User interaction to verify automatic repositioning or to define new start point and alignment
- Realignment of tracks from the command and control station
- Sensor fusion with other positioning technologies (GPS, Barometer, RFID, WiFi, etc.)
- Automatic re-positioning relative to known tracks, boundaries or objects (context sensitive navigation)
- Video context analysis

93

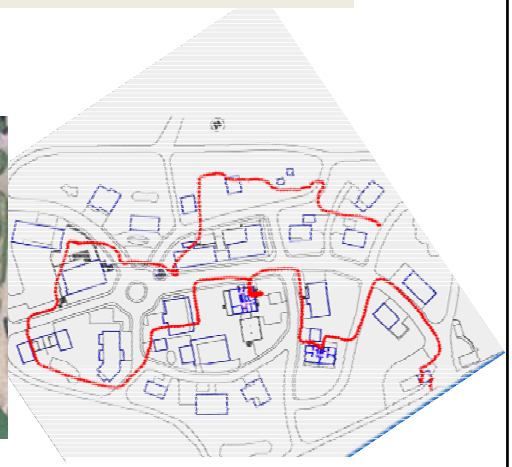
Repositioning with GPS and Barometer

Test site: Walenstadt, Switzerland

94

Repositioning with GPS and Barometer

Official test track
(~16 min, length 756 m)



AIONAV IMU only
(MTx Xsens)

95

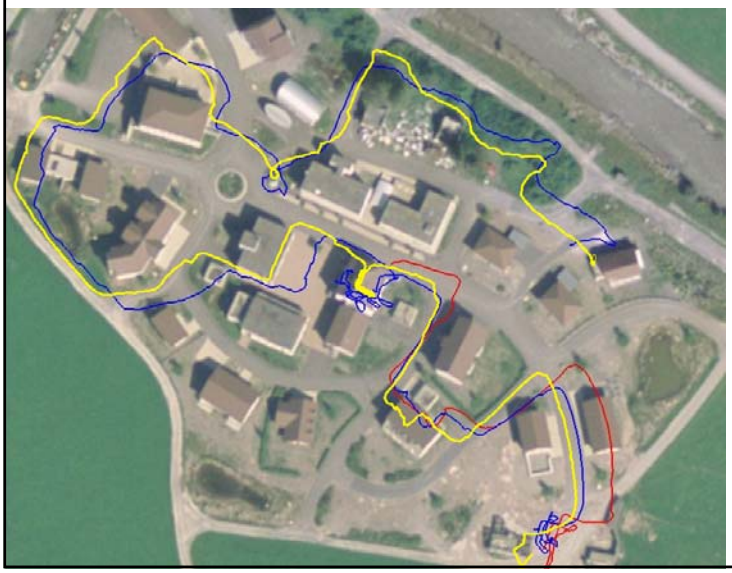
Repositioning with GPS and Barometer

GPS track

GPS + IMU fusion

96

Comparison with Body Mounted System



AIONAV and IMESS track 1 (1418)

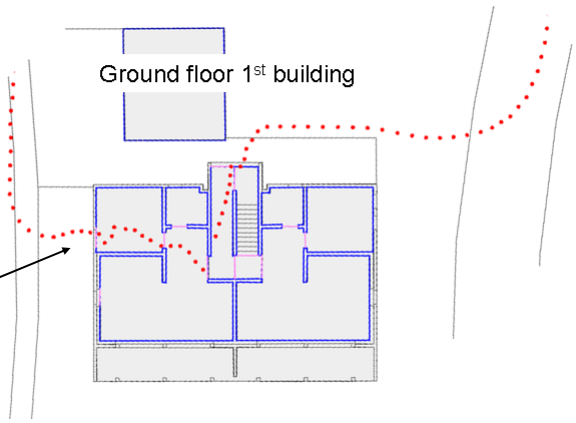
No building interaction !

IMU + GPS + barometer fusion

Red and blue = IMESS

Yellow = AIONAV

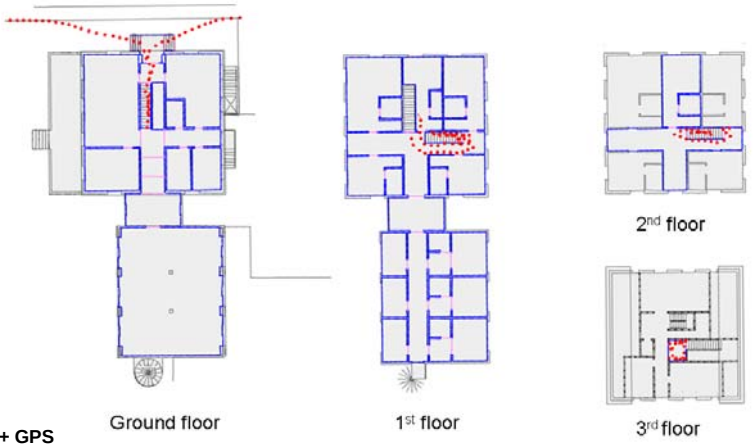
Comparison with Body Mounted System



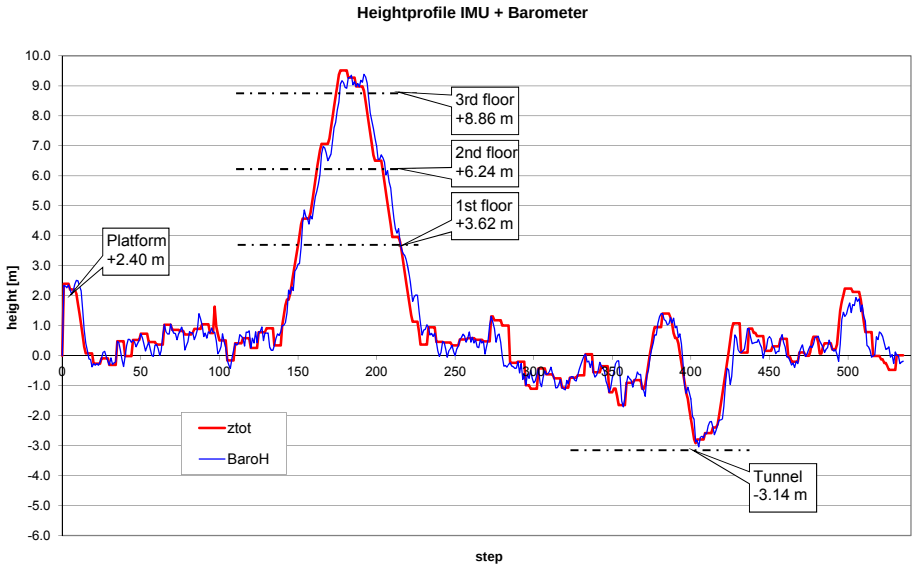
Cassidian System
Inertial (DRM4000) + GPS

Comparison with Body Mounted System

Cassidian System
Inertial (DRM4000) + GPS



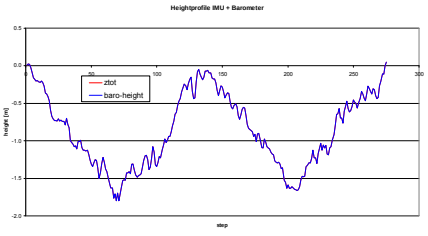
Repositioning with GPS and Barometer



Comparison of GPS and IMU in open space

Yellow = GPS
Magenta = IMU

Comparison of GPS and IMU in urban area

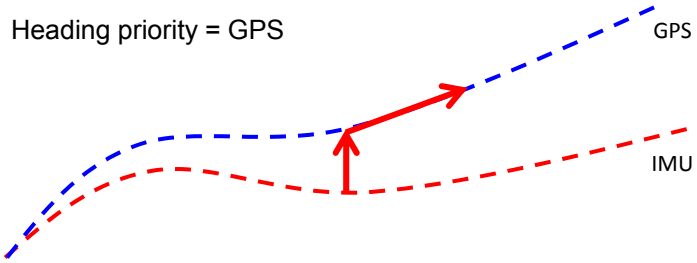


Track length	479.12	m	Track time	5.89	min
Start - End point	1.23	m	Accuracy	0.26	%

Repositioning with GPS

Methods used

- IMU - GPS fusion with Kalman filter on step level
- Track analysis and comparison
  - Affinity of curvatures for several steps
  - Position priority = IMU
  - Heading priority = GPS



Repositioning by Building Model Interaction

Context-sensitive Sensor - BIM interaction

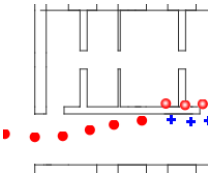
- Graphical data are available for all major buildings (evacuation planning) in standard formats
- Important information in case of disasters have been defined and are integrated in the building model data

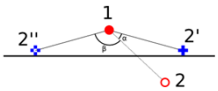
Position Control

- Catching functions
  - Doors and other transitions
  - Stairs
- Reflecting functions
  - Walls, doors
- Correction functions
  - Automatic re-positioning or heading correction relative to known points or directions (walls, given tracks, etc.)
- Reloading functions
  - Floor plans
  - Neighbor floors

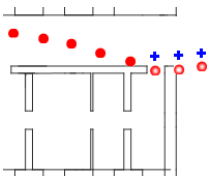
105

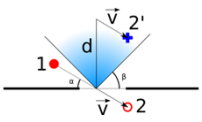
Sensor – BIM Interaction





Correction when hitting a wall

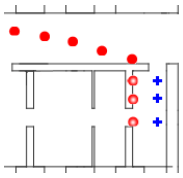


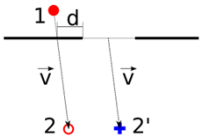


Correction when entering unwillingly a door

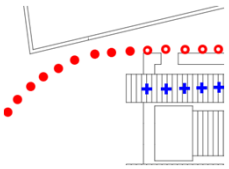
106

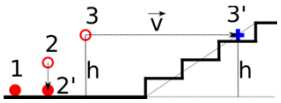
Sensor – BIM Interaction





Correction when a door is missed

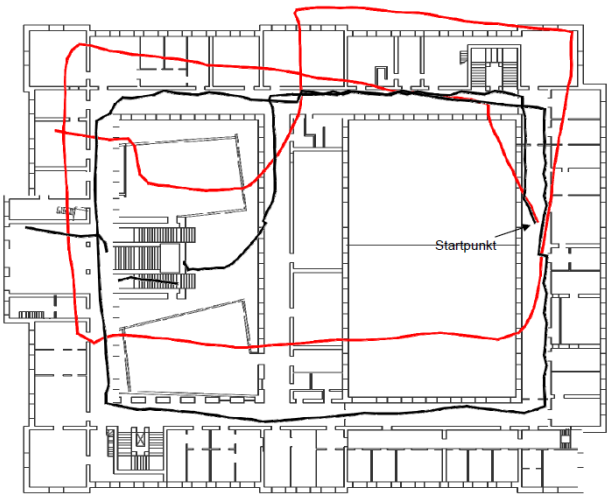




Correction when a staircase is missed

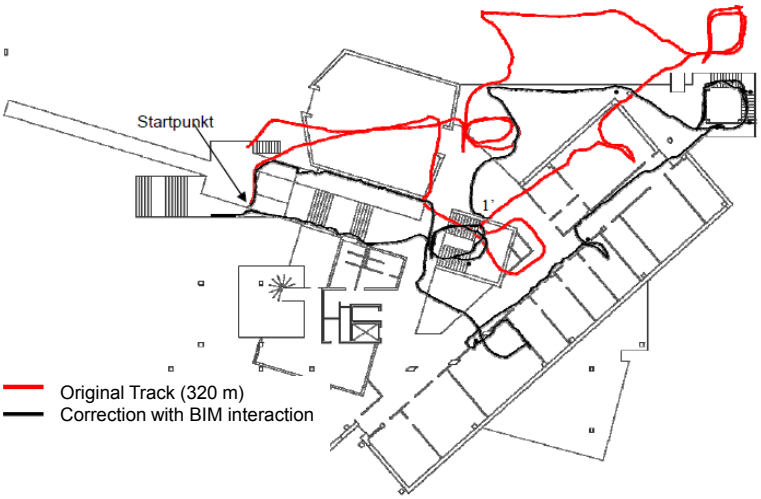
107

Sensor – BIM Interaction



108

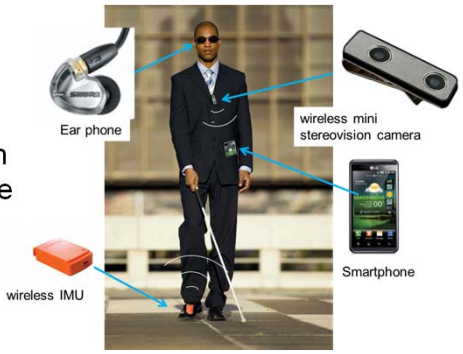
Sensor – BIM Interaction



109

Video Content Analysis

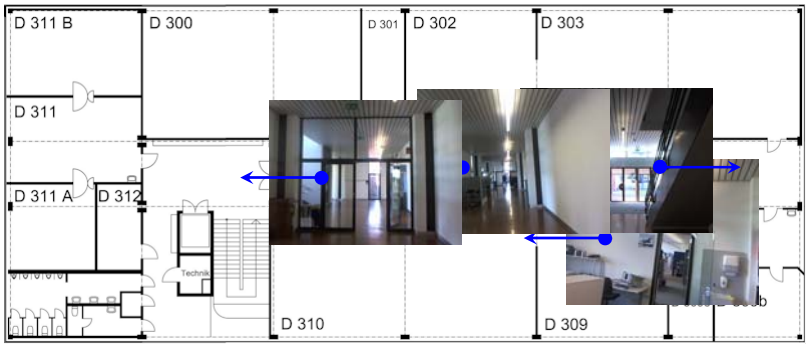
- Video context analysis is an elegant method to improve the accuracy of dead rechogning technologies
- AIONAV®-4VIP (for visually impaired people) is a project on which we work together with the University of Lucerne in Switzerland.
- It is based on real-time image recognition and sensor fusion with an IMU.



110

Video Content Analysis

Step 1: Recording of Reference Images



111

Conceptual Approach

Step 2: Comparison of live image sequence with database

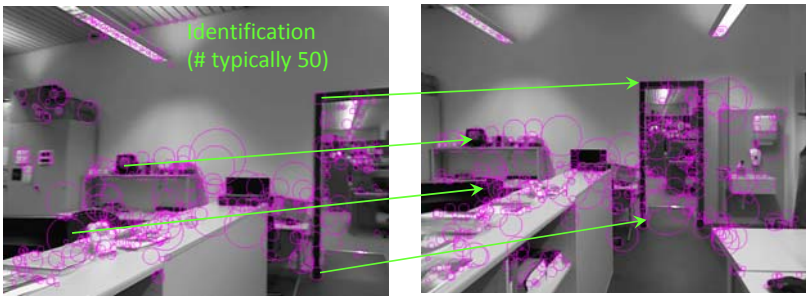
Current Image

Reference Image

112

Conceptual Approach

Pixel level: Identification of corresponding features



Current Image Reference Image

113

Conceptual Approach

Warp reference image to new coordinate system

Current Image Reference Image

114

Conceptual Approach

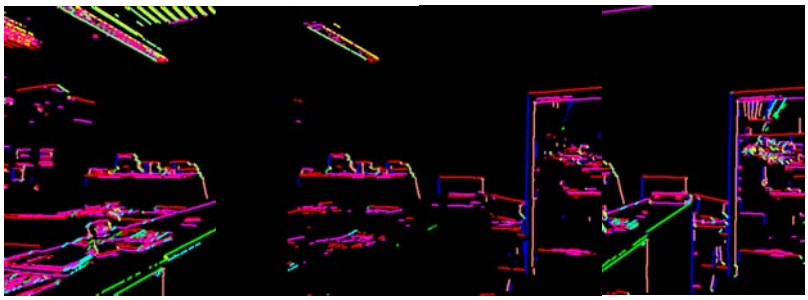
Produce overlay for “visual” match

Current Image Overlay both Reference Image

115

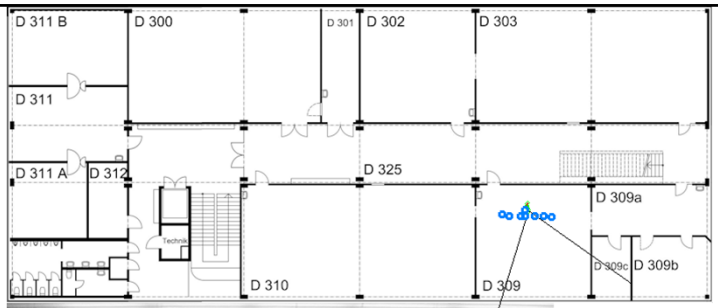
Conceptual Approach

Produce edge orientation based correlation
to rule out false positives



r = 0.37

116



Lucerne University of Applied Sciences and Arts
HOCHSCHULE LUZERN
Technik & Architektur

117

Required Computing Time

VGA Resolution				
#database images checked	4.5	14.6	28.8	43.0
Processing time (ms)	531	1141	1872	2630

QVGA Resolution				
#database images checked	4.0	14.1	25.0	35.9
Processing time (ms)	262	692	925	1325

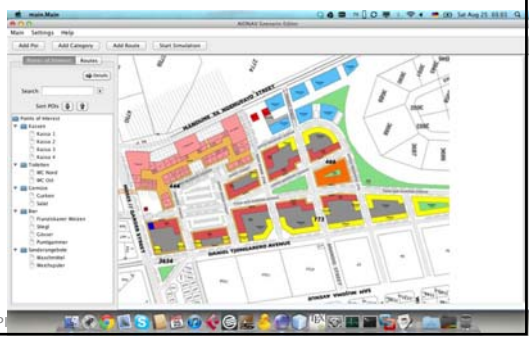
118

The AIONAV Development Framework

- Management of Maps
- Integration of Floor Plans
- Using Building Models
- Management of Location Based Services

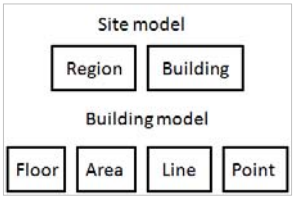
Reference Systems

- Indoor maps are getting available for shopping centers and public buildings
- Initiative of Samsung, Nokia, Sharp, to define standards
- Policy for usage not yet clearly defined (on/off line)
- Own tools necessary for
  - Offline maps
  - Geo-referencing floor plans
  - Add LBS items (POI, etc.)
  - Reference to database
  - Create own GUIs

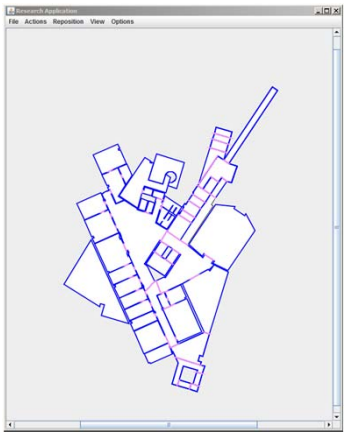


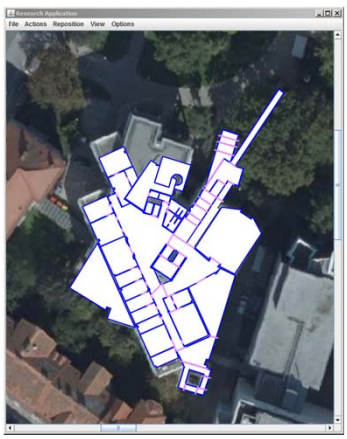
Reference Systems

1. Satellite images (Google Earth, Google Maps, Earth Wind)
2. Maps
   - Google Maps (with indoor maps)
   - Open Street Map
   - Nokia Maps (indoor maps)
3. Combined with own floor plans
   - CAD (2D)
   - Building model data (3D)
   - CAFM (facility management)
   - With / without semantic

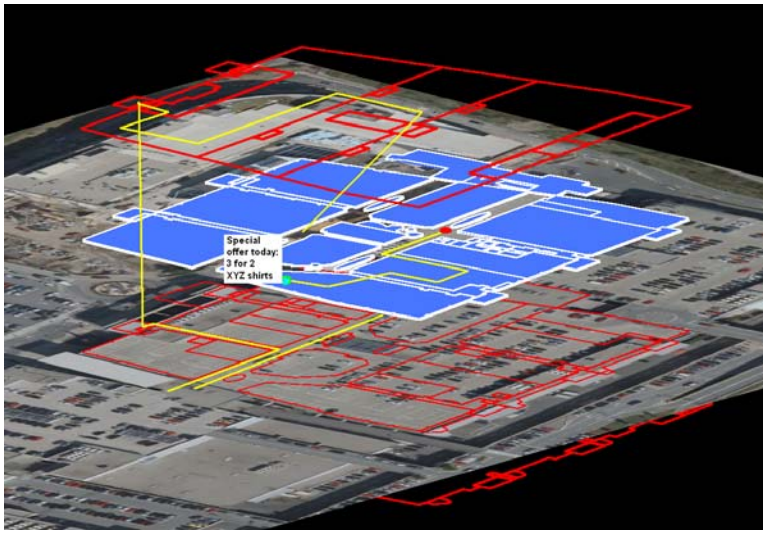


Floor Plan Integration



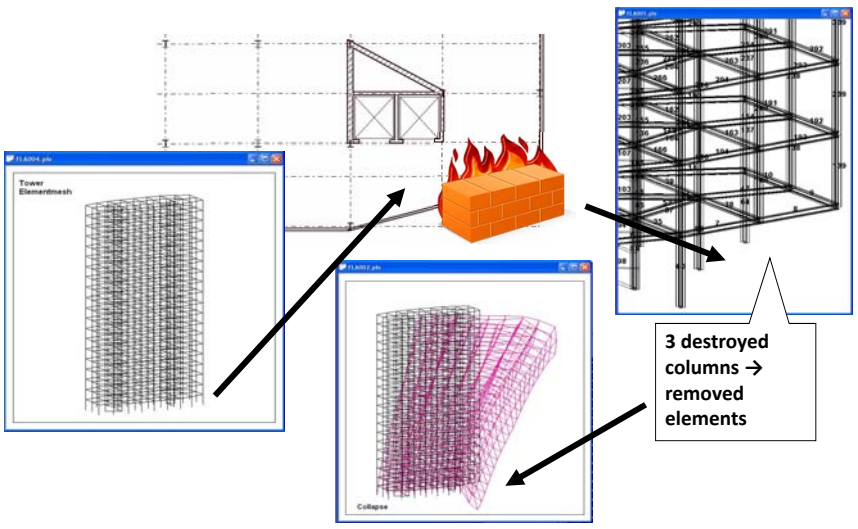


Reference Systems – 3D Building Model



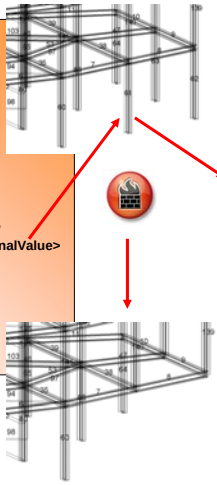
Building models are defined by IAI standards (International Alliance for Interoperability)

Link to other Models – Static Model



Link of the Static Sub-model with the BIM

```
.
<IfcRelDefinesByProperties id="i2">
   <HasProperties>
      <IfcBeam>
         <GlobalId>295H6hv1z5T</GlobalId>
         <Name>Element4931</Name>
      </IfcBeam>
      <IfcPropertySet>
         <HasProperties>
            <IfcPropertySingleValue>
               <Name>ReferenceToFE</Name>
               <NominalValue>BEAM61</NominalValue>
            </IfcPropertySingleValue>
         </HasProperties>
      </IfcPropertySet>
   </HasProperties>
</IfcRelDefinesByProperties>
.
```



```
.
.
BEAM   1996  JOINTS 952   951   0.0
BEAM   1997  JOINTS 953   952   0.0
BEAM   1998  JOINTS 954   953   0.0
BEAM   1999  JOINTS 955   954   0.0
BEAM   2000  JOINTS 956   955   0.0
*
,   COLLAPSED BEAMS
INACTIVE BEAM 61
INACTIVE BEAM 62
INACTIVE BEAM 63
*
,   SUPPORT CONDITIONS
N N N N N N   JOINTS  33 TO 64 72 73 81 82
*
,   ELEMENTMESH DRAWINGS
DRWAWING SCALE 100. VIEWPOINT -1. -2. .5 ELEMENTS
*
.
.
```

BIM - XML (graphic + object sub-model)

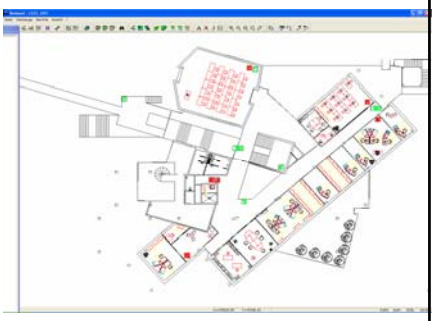
Input file for structural analysis (static sub-model)

Location Based Service Management Tool

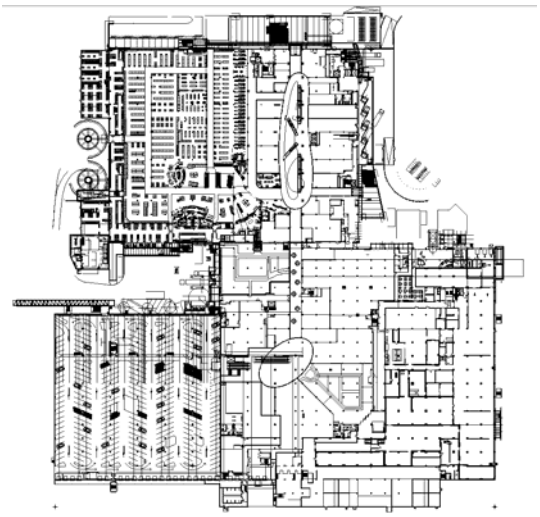
Database with
- Maps
- Pre-defined tracks
- Routing
- Points of interest (POI)

Interface to CAFM System

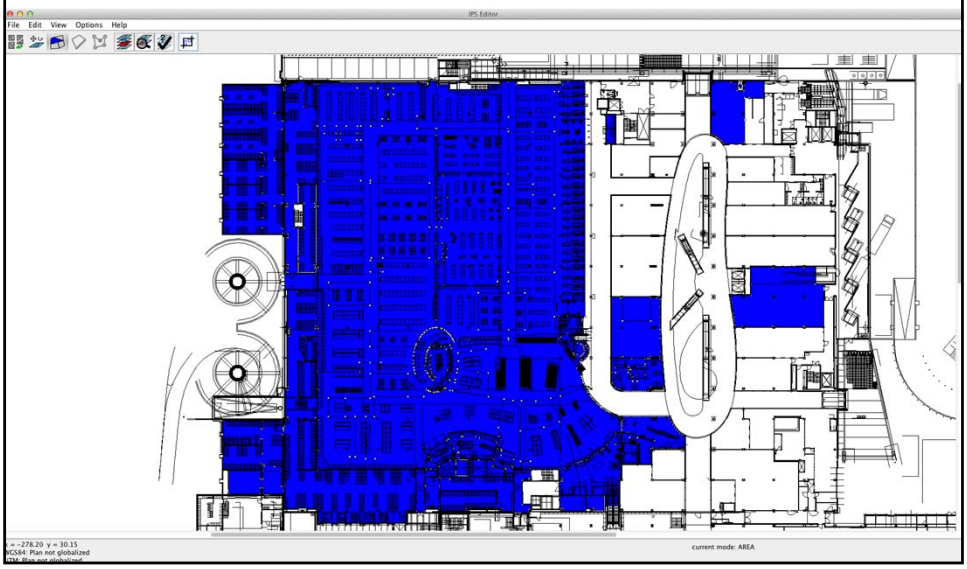
- **Computer Aided Facility Management (CAFM) system provides**
  - Floor plans with semantic (rooms)
  - Surrounding areas
  - Parking lots
- **CAFM database provides**
  - Real estate data
  - Data of floors and rooms
  - Technical equipment
  - Escape routes
  - Location of dangerous goods
  - Documents (technical manuals, schemas, contracts, etc.)



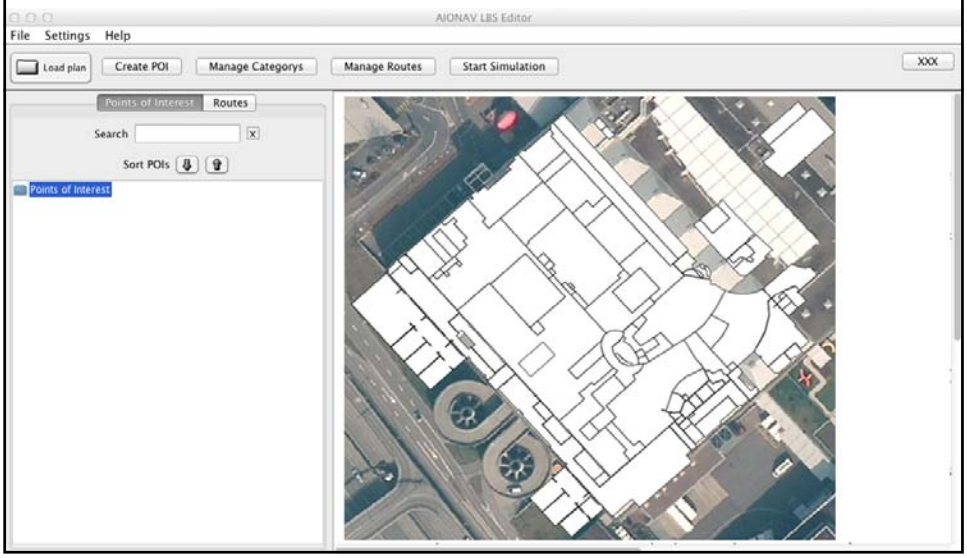
Information Reduction



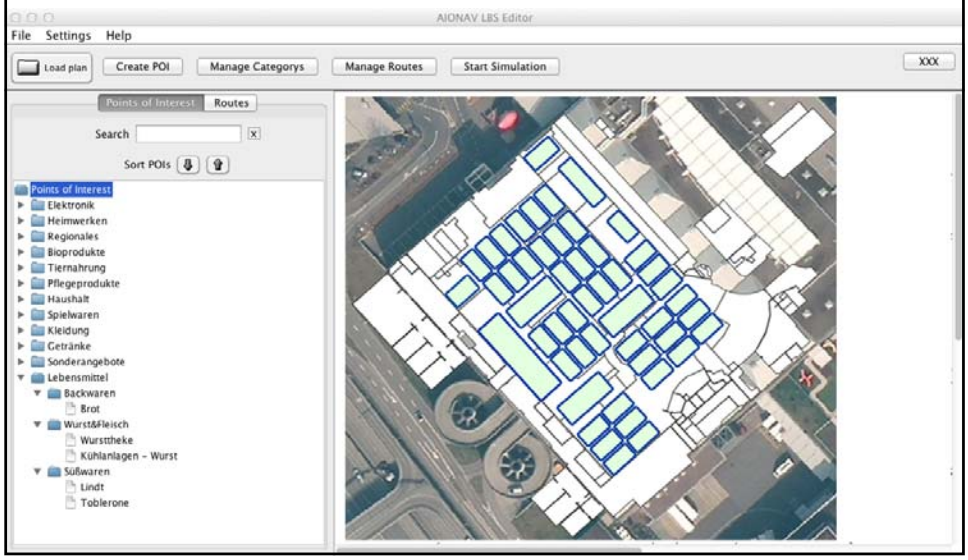
Information Reduction



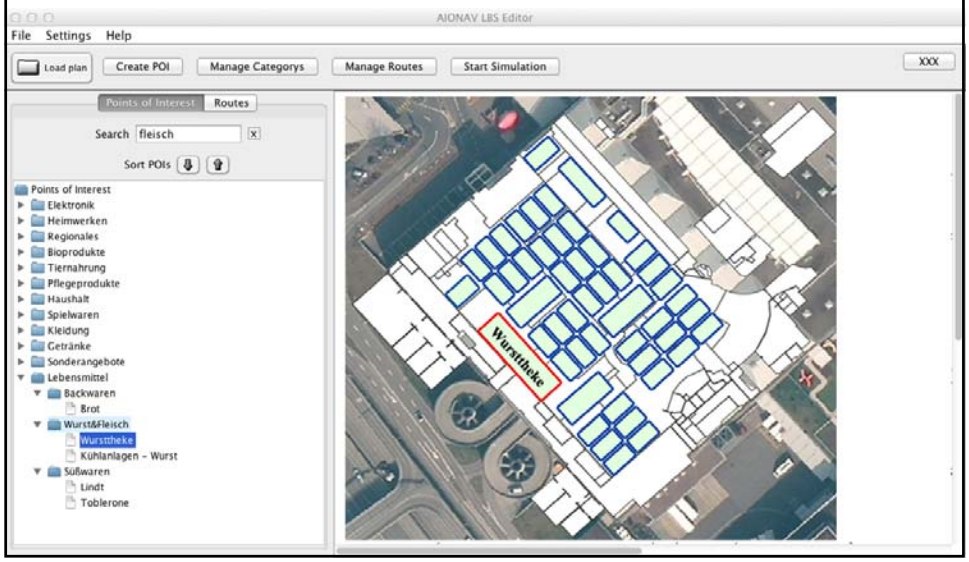
Information Reduction



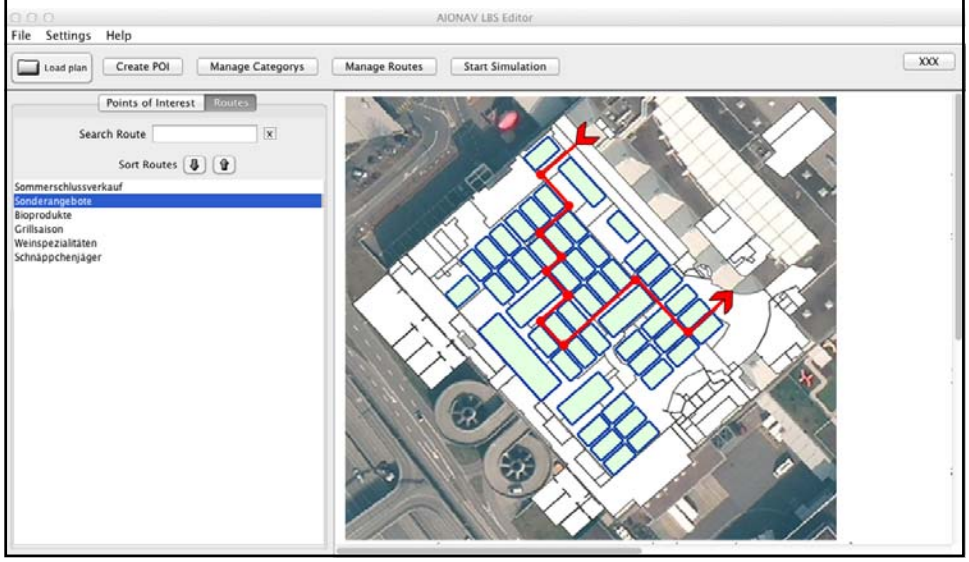
Adding LBS Information



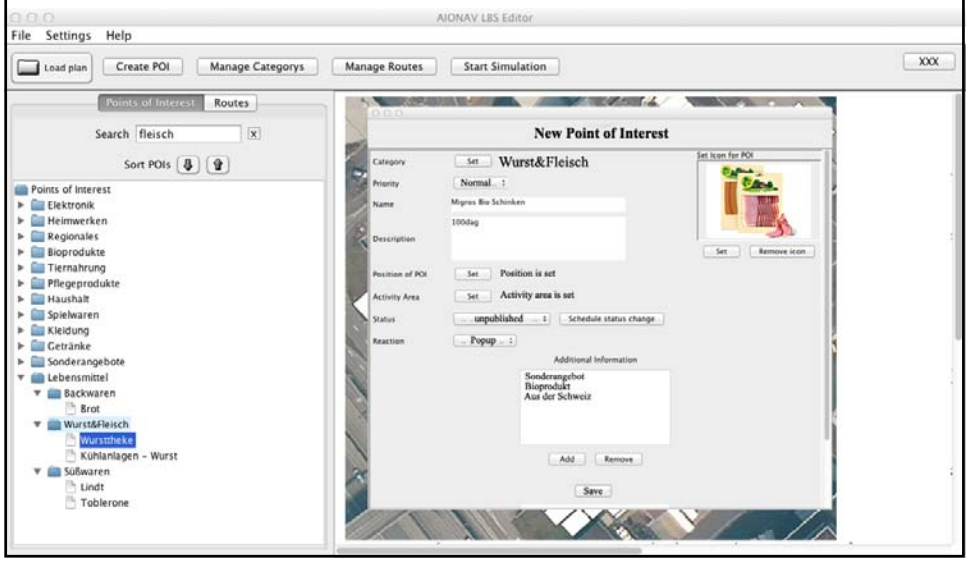
Adding LBS Information



Adding LBS Information - Routing



Adding LBS Information - POI



LBS Services

- **Positioning and navigation**
  - Where do I find a product?
  - Where is the sanitary zone?
  - Where is my car?
- **Notice on events**
- **Special offers**
- **Emergency calls**
- **Technical staff support**
- **Tourist guidance (individually)**
- **Etc.**

Thank you for your attention!

www.aionav.com

Find us on Facebook

136


Jing