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the urban big data lab

Indoor-outdoor navigation without beacons:
Compensating smartphone AR positioning errors with 3D pedestrian network

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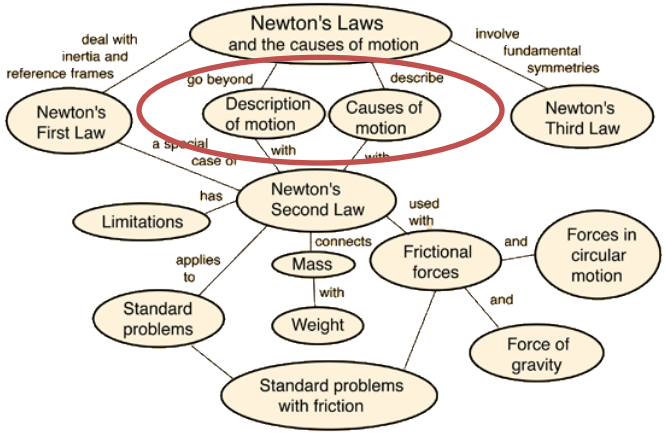
Outline

1. Motion, position, and indoor positioning

- Motion & position
  - Core concepts in Newton's laws
  - With respect to a reference frame
    - E.g., a passenger on a flying maglev train
- Indoor positioning
  - "Where am I?" in a building / underground space
  - Important for the AECO industry
    - ✖ but no satellite signals here ...
  - Possible reference frames
    - Building structure
    - Space
    - Beacons



Newton's Laws (Source: phy-astr.gsu.edu)

Maglev motion

1. Related works

- Beacon-based methods are more expensive ($$$)
  - **Vision** & **Radio Frequency** (RFID, Ultra-wideband (UWB), Bluetooth (BLE), & WiFi)
- Beacon-free methods are more prone to errors
  - Sonic & magnetic field: Natural "beacons"
  - **PDR** stepper & Augmented reality (**AR**): Integration of motion data over time
- **Question**: How to position indoor accurately and inexpensively?

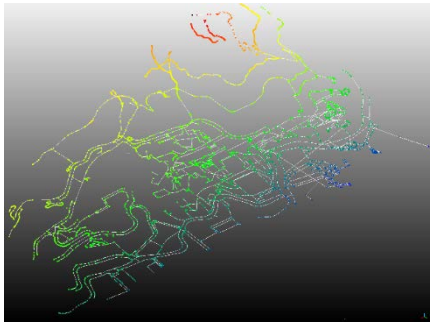
Technique classes	Performance	Price	Examples
Sonic	★★★	★	
Magnetic	★★★	★★	
Vision	★★	★★★★★	Marker, floor pattern, image-to-location reasoning
Radio Frequency (RF)	★★★★	★★★	Infrared, light, WiFi, BLE, GSM, UWB, etc.
Pedestrian Dead Reckoning (PDR)	★	★★★★★	Step counter + motion sensors
Augmented reality (AR)	★★	★★★★★	iPhone 11, Google Tango / Pixel, Huawei Mate 30P
Our WaNAR	★★★★★	★★★★	Ditto

1. Opportunity

- Indoor-outdoor motions are constrained
  - For walking, driving, etc.
    - E.g., No walking through walls
    - Restricted in some areas (e.g., locked)
- 3D walkablility network
  - A digital **reference** for PDR stepper and **AR**
  - **Cheap**: From BIM + GIS
- This paper
  - A Walkable Network-based AR (WaNAR) positioning
    - Beacon-free
    - Accurate, by compensating AR's errors

Indoor motion example

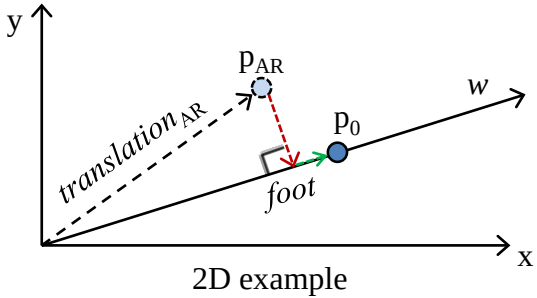
HKU Main Campus
(Source: Google Maps)



HKU Main Campus 3D walkablility
Network (partial indoor + outdoor)
(Sun et al. 2019)

2. The WaNAR method

- Given a true position p_0 sensed as p_{AR}
  - The "drifting" can be compensated as:
  - Green: on the path; Red: in perpendicular
- WaNAR is a loop of three steps
  - 1. To "snap" the p_{AR} to a walkable path *w*
  - 2. To compensate the red if *w* not changed
  - 3. To compensate the green if *w* changed



2D example

procedure WaNAR_error_compensation:

input $translation_{AR}$, $network_{3D}$, *drifting_vec*

way := nearest_path ($network_{3D}$, $translation_{AR}$)

if distance ($translation_{AR}$, tails_of (*way*)) > *TURNING_BUFFER* **then**

foot := perpendicular_foot ($translation_{AR}$, *way*)

drifting_vec := *drifting_vec* + ($translation_{AR}$ – *foot*)

if || *drifting_vec* || ≤ *OFF_TRACK* **then**

$translation_{AR}$:= $translation_{AR}$ – *drifting_vec*

end if

end if

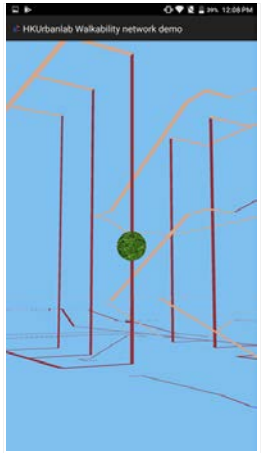
return $translation_{AR}$

end procedure

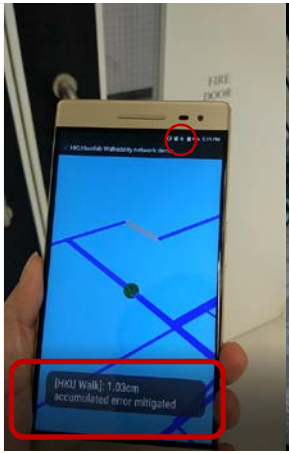
Figure 2. Pseudo codes of the WaNAR error compensation algorithm

2. Pilot test

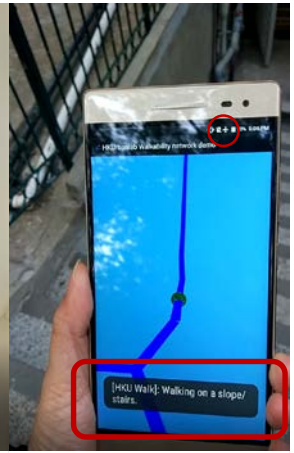
- 10 minutes walk at HKU Main Campus
  - **Outdoor**: Knowles Bld. → outdoor → CYM Amenities Center
  - **Indoor**: … → Knowles Bld. G/F
    → Lobby → 1/F → 2/F
- Android app
  - On Android Studio (version 3.1)
  - 3D walkablility network (Sun et al. 2019)
  - Standard AR API (Google Tango, 2017)
  - Flight mode: (as circled)
  - Active messages: (in boxes)
    - Errors compensated
    - On slopes/steps



(a) Android APP

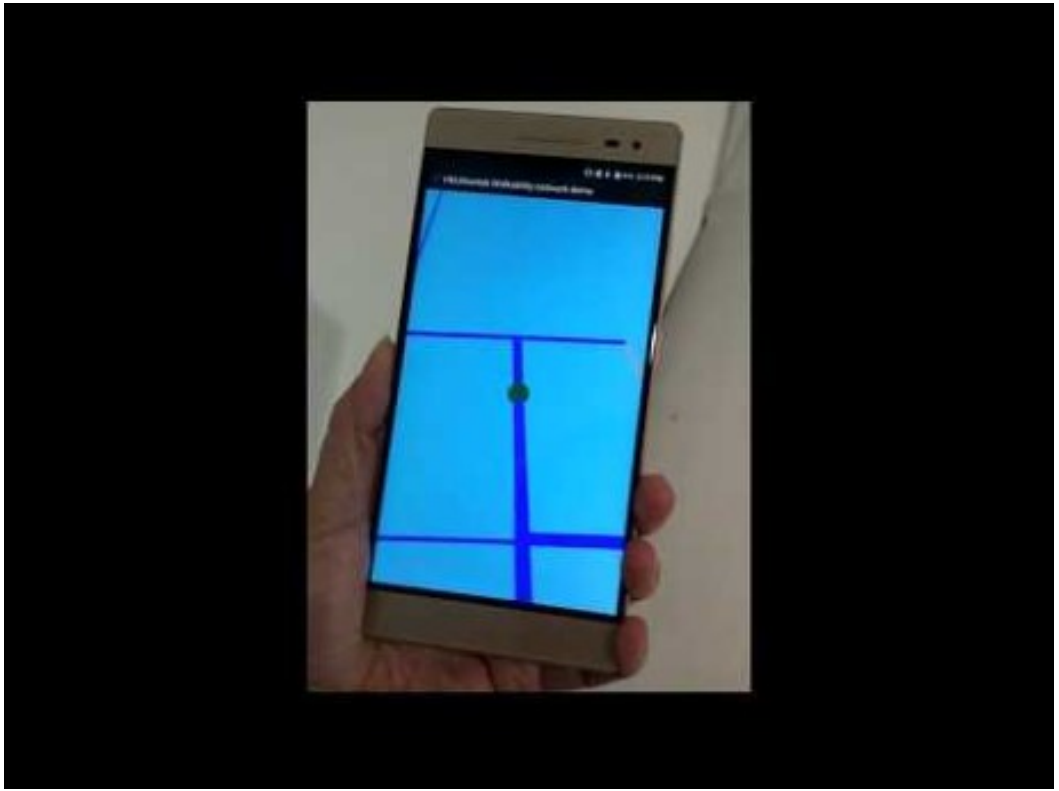


(b) Error compensation



(c) On slopes

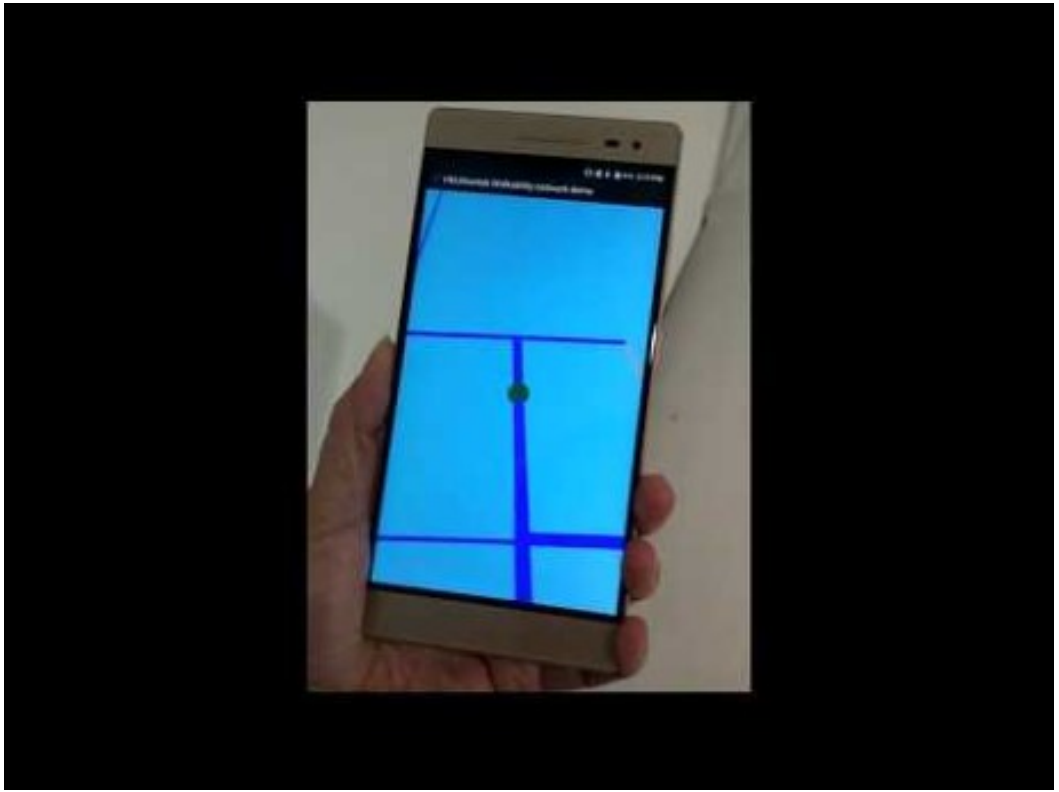
2. Demo video 1/2 (outdoor)



- Knowles Bld. → outdoor → CYM Amenities Center
- Flight mode: On
  - No RF signals
- AR drafting was compensated
  - Continuously
  - Small
- Accurate, real-time
  - E.g., from cross to cross

Xu et al Video available on YouTube (link in CRC Proceedings)

2. Demo video 2/2 (indoor)



- Knowles Bld.
  - G/F→ Lobby → 1/F → 2/F
- Flight mode: On
- Worked well on steps, corridors, and doors
- Failed in lifts
  - Too high acceleration on *z*
- Limited in an open area
  - Must follow a line

Video available on YouTube (link in CRC Proceedings)

3. Discussion

- Pros
  - WaNAR is accurate, **cheap** (a few modeler-hours), AR-ready
  - Taking advantage of the walkability in BIM/GIS models
- Cons
  - A location synchronization before use
  - Limited to linear network in this paper
  - Cannot handle lifts' acceleration yet
- Future work
  - Automatic location synchronization (e.g., a few BLE, RFID)
  - More types of walkability spaces
  - Integration of rear camera and POIs (e.g., voice navigation for visually impaired)

Let BIM/GIS contribute to smart cities!

For questions, pls Email Frank: xuef@hku.hk