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On the (In-)Accuracy of GPS Measures of Smartphones: A Study of Running Tracking Applications

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Location Technologies in Smartphones

- **Cell ID**
- **WLAN**
- **GPS**

Differences between Positioning Methods

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Differences between GPS, WLAN, and Cell ID based positioning

- WLAN method has potential for indoor positioning
- outdoors it lags behind compared to GPS based localization (Zangenbergen 2009)

Combining different sensors with GPS positioning to increase accuracy level

- assisted by accelerometer and digital compass, GPS positioning accuracy could be improved (Mok, Retscher and Wen 2012)

GPS Positioning Accuracy with Smartphones

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3 different smartphones:
Samsung Galaxy S, Motorola Droid X, and iPhone 4

- acceptable alternative to other tracking devices in vehicles
- accurate within 10 meters about 95% of the time (Menard, Miller, Nowak, & Norris 2011)

3 different Apple devices:
iPhone, iPod Touch, and iPad

- significant differences in accuracy (von Watzdorf & Michahelles 2010)

5 different devices and operating systems:
Android 2.3.3, Android 2.3.6, iOS 4.2.1, iOS 4.3.5, and Windows Phone 7

- measurement accuracy heavily depends on the respective device (Hess, Farahani, Tschirschnitz & von Reischach 2012)

GPS Positioning Accuracy with Smartphones

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Samsung Galaxy S, Motoro

- acceptable alternative to other
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limitations:
different GPS chipsets,
different operating systems

3 different Apple devices:
iPhone, iPod Touch, and iPa

- significant differences in accurac
  (von Watzdorf & Michahelles 2010,

limitation:
different methods
(WLAN vs combination of
WLAN, GPS, and Cell ID)

5 different devices and operating syste
Android 2.3.3, Android 2.3.6, iOS 4.2.1, iOS 4.3.5,
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- measurement accuracy heavi
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Research Design

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Objective

- Compare similar applications with respect to the accuracy of localization measurements
  - on a single device ('HTC Desire Bravo')
  - same OS (Android)
  - same location
  - same method (GPS based localization)

Running with Smartphone Applications

Sample

- 9 currently popular running applications that use GPS based localization in real time while moving (running)

Application	Downloads in millions	User rating	Last actualization
Endomondo	5-10	4.5 (109081)	21-May-2013
Runtastic	5-10	4.6 (76234)	26-Apr-2013
Noom Cardio Trainer	5-10	4.4 (53699)	11-Jan-2012
MyTracks	5-10	4.4 (75482)	17-Apr-2013
Runkeeper	1-5	4.5 (57992)	23-May-2013
Sports Tracker	1-5	4.6 (48275)	16-May-2013
MapMyRun GPS Running	1-5	4.5 (33468)	10-May-2013
Adidas miCoach	1-5	4.4 (16583)	10-May-2013
Orux Maps	1-5	4.6 (9808)	21-Apr-2013

Procedure

- Distance of exactly 500 meters was measured in a highly populated (city) location
  - running back and forth along this track in a straight line:
    - total distance of exactly 1 kilometer
  - starting and ending points were the same:
    - altitude gain = 0
- Test person ran the measured track back and forth in a straight line, with each of the applications in the sample.
- Before the start of every run, the GPS signal was ensured to be good enough for adequate measurement (which is a feature of most running applications).
- Application and/or Web interface that extended the application were checked for data on distance and altitude differences.

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Results

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Visualized Data

example

Running Track (left) - Altitude Differences (right)

Visualized Data

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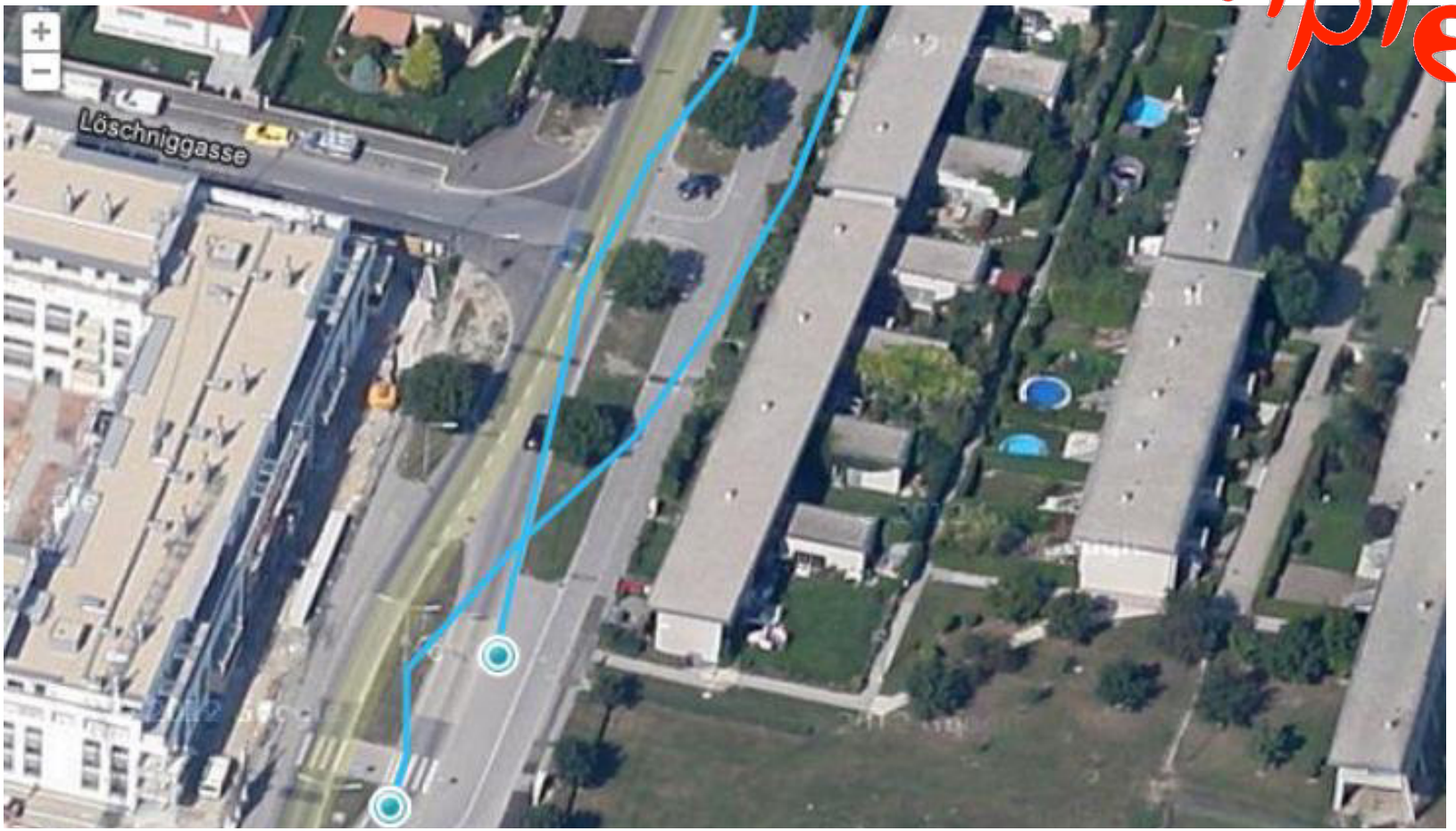
example



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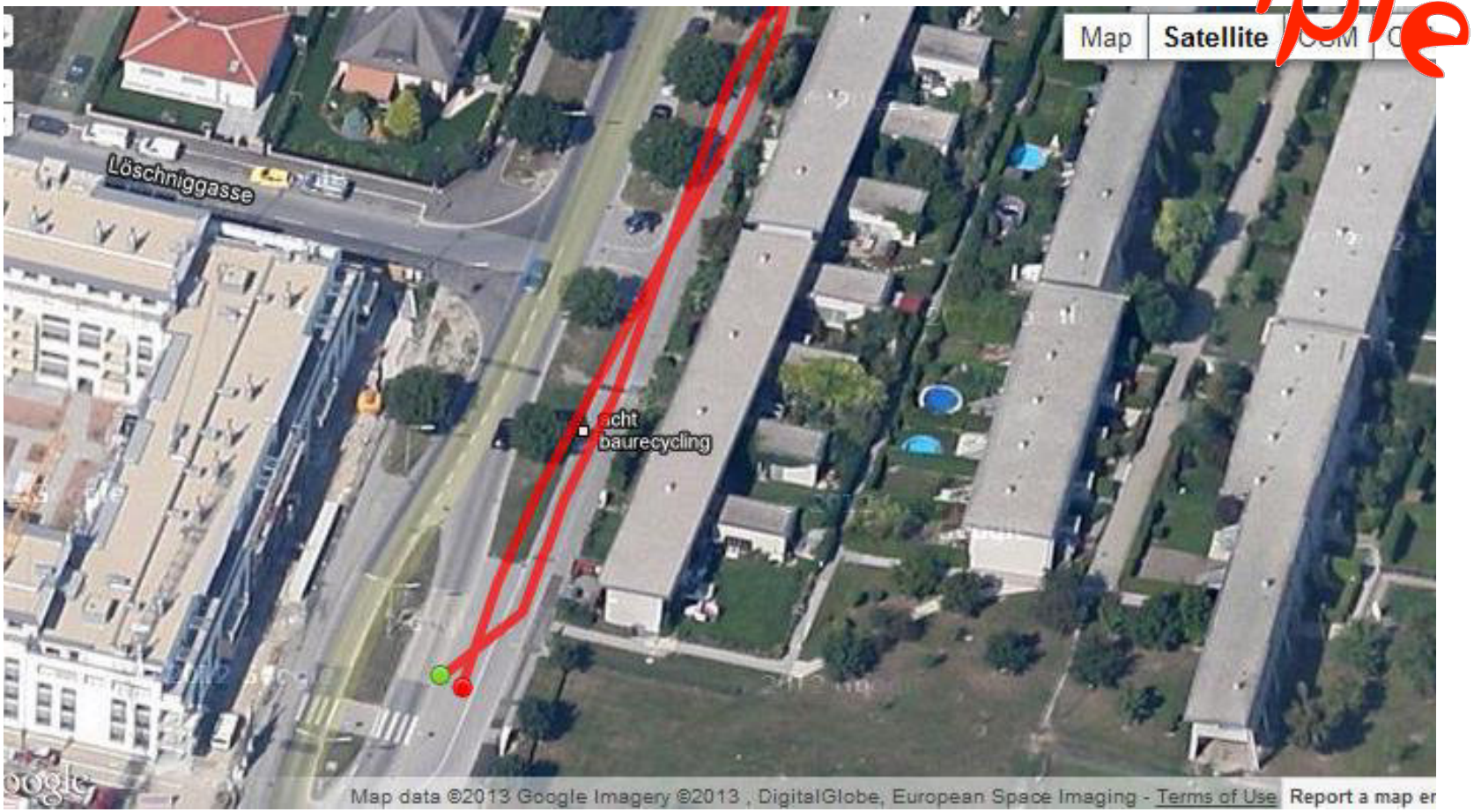
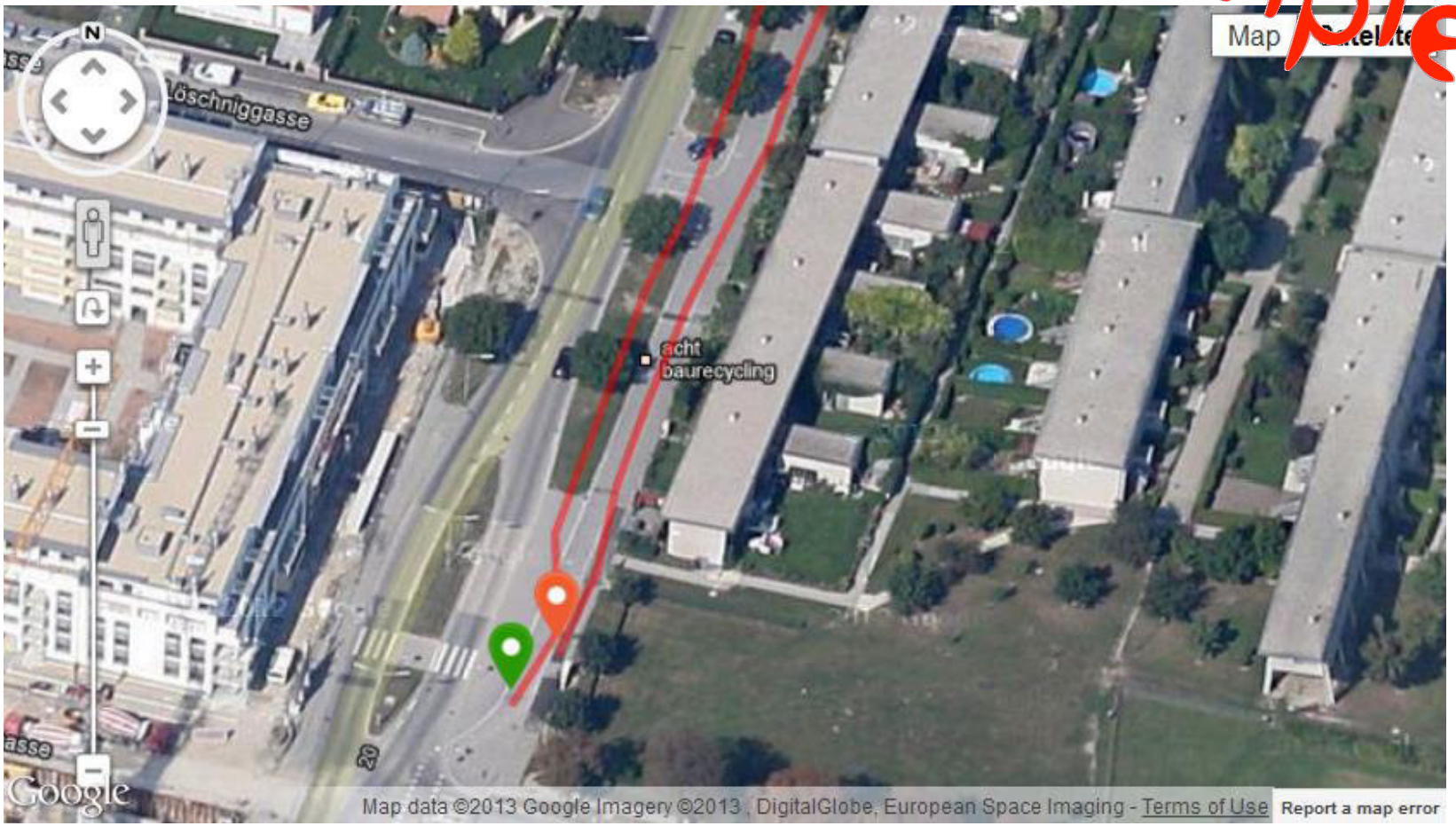
Visualized Data



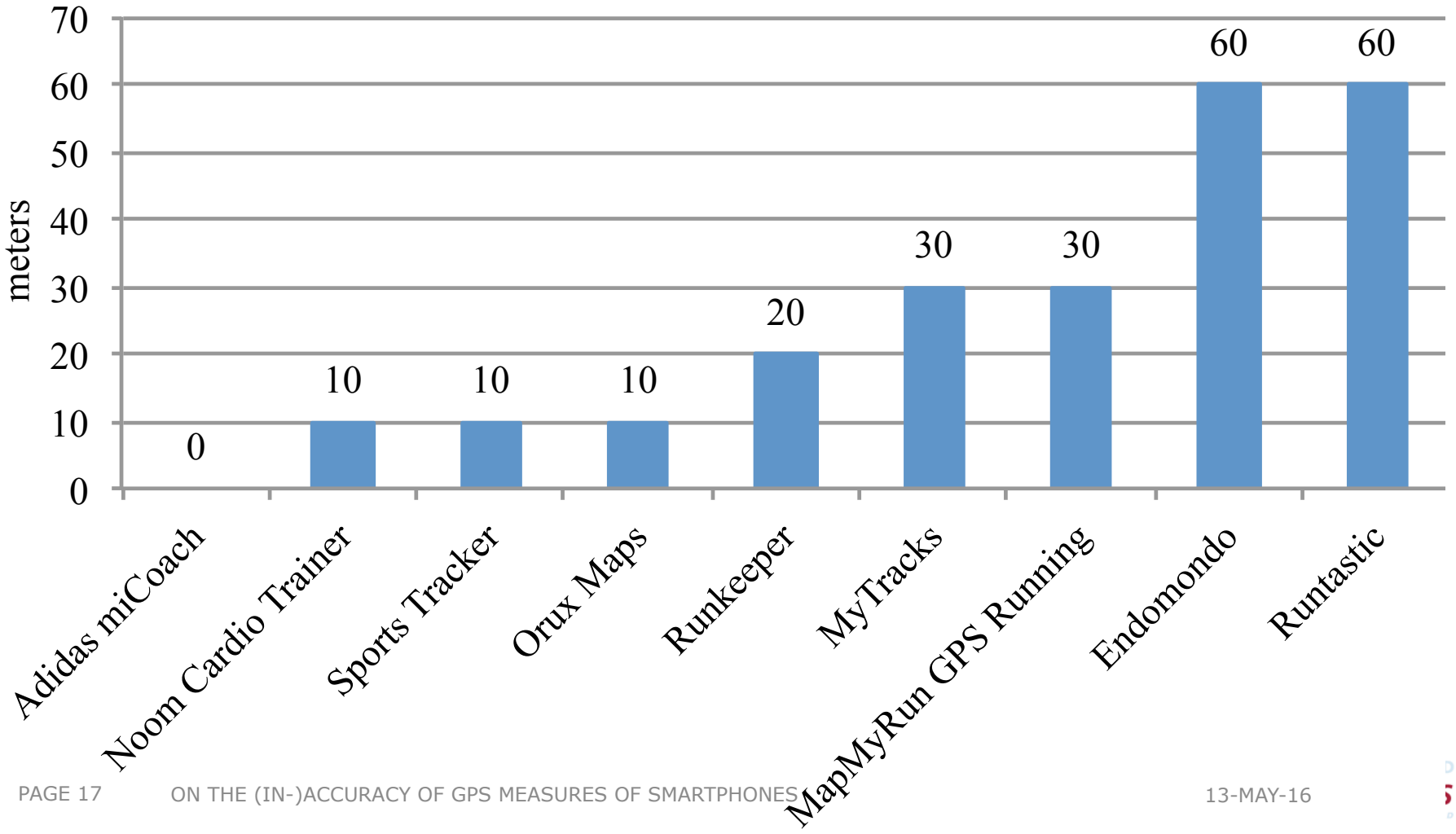
Visualized Data



Accuracy measurements for distance

Application	Distance in meters	Deviation in meters	Rank
Adidas miCoach	1000	0	**1**
Endomondo	940	60	**8**
MapMyRun GPS Running	1030	30	**6**
MyTracks	1030	30	**6**
Noom Cardio Trainer	1010	10	**2**
Orux Maps	1010	10	**2**
Runkeeper	980	20	**5**
Runtastic	940	60	**8**
Sports Tracker	990	10	**2**

Distance inaccuracies in meters

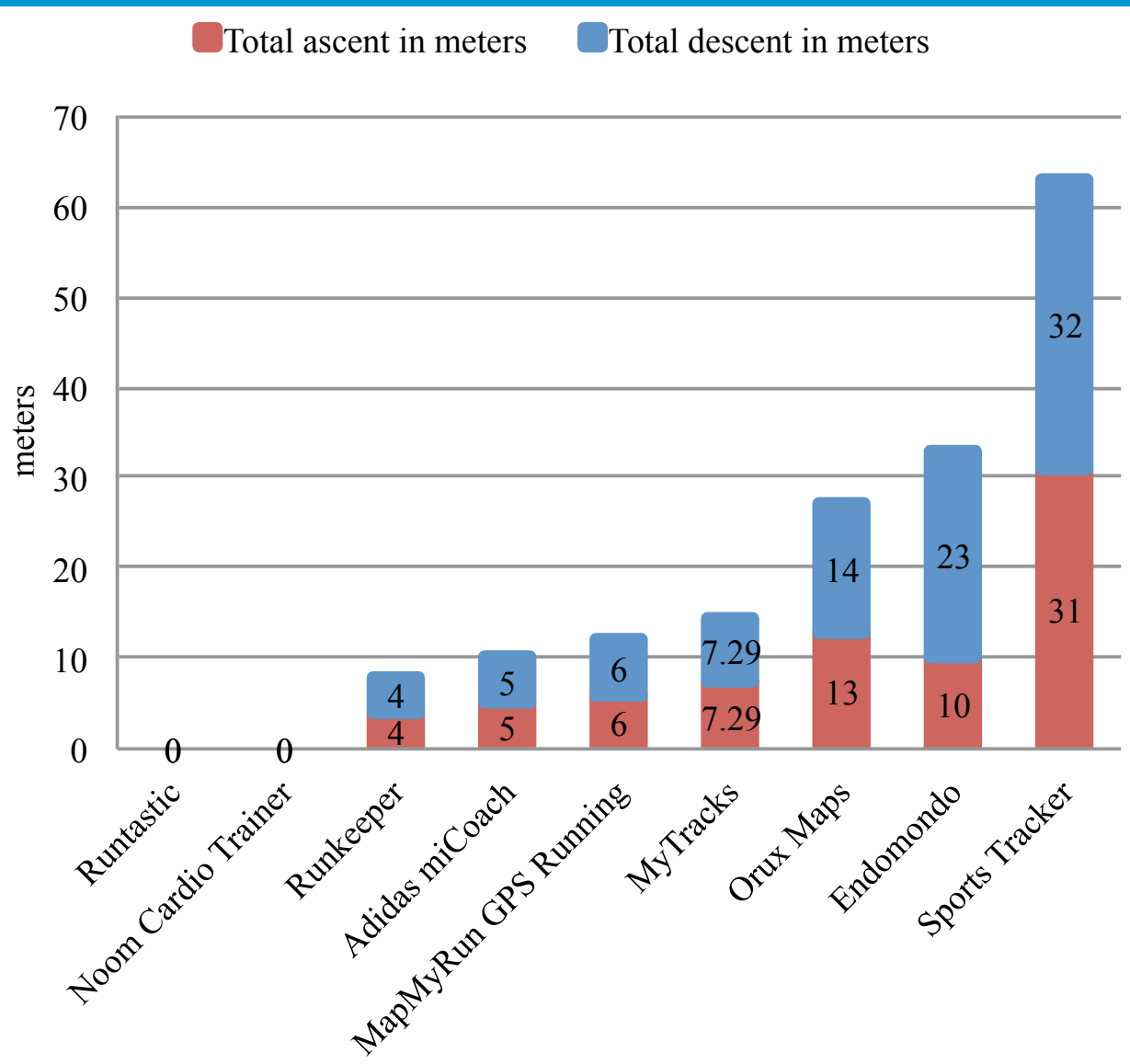


Accuracy measurements for altitude differences

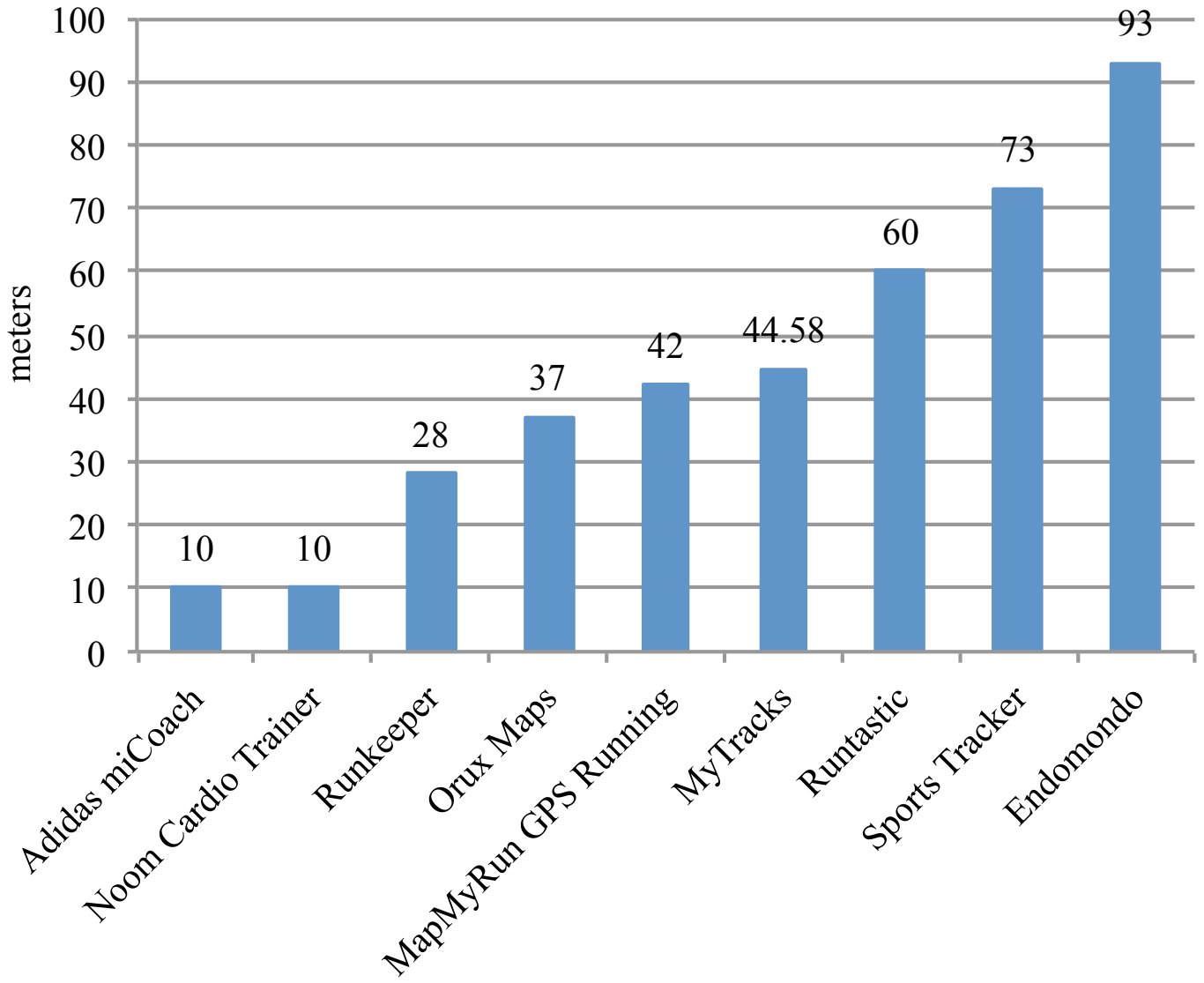
Application	Total ascent in meters	Total descent in meters	Total deviation in meters	Rank
Adidas miCoach	*5*	*5*	10	**4**
Endomondo	10	23	33	**8**
Noom Cardio Trainer	0	0	0	**1**
MapMyRun GPS Running	*6*	*6*	12	**5**
MyTracks	*7.29*	*7.29*	14.58	**6**
Orux Maps	13	14	27	**7**
Runkeeper	*4*	*4*	8	**3**
Runtastic	0	0	0	**1**
Sports Tracker	31	32	63	**9**

Estimates are given in *italics*.

Elevation inaccuracies in meters



Total deviation in meters



Take away messages

Positioning accuracy depends on **various** factors!

For practice:

- Study indicates a quality ranking of the analyzed applications

For scientific knowledge base:

- Study qualifies the findings of previous studies in the field

Limitations & Future Directions

- Control for **crowdedness** and **traffic** when tracking the locations.
- Control for smartphone's **internal activity** (lowering read out frequency) as well as temporary surrounding influences, such as the **reflection of signals** disturbing GPS reception.
  - Future work should control for this:
    - e.g., running the track several times with each application; or
    - runner could wear 9 phones of the same type, each running one of the applications
- Control for **space weather** influence (see also Kos and Brčić)
- 1 kilometer is a rather short distance
  - unclear how measurements develop over **long distances**
  - e.g., if Endomondo would keep its deviations per km, a marathon (42.195 km) would result in a deviation of 2531.7 meters. For a runner that maintains a pace of 5 minutes per kilometer, that would distort the performance by more than 12 minutes.

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