AutoGait: A Mobile Platform that Accurately Estimates the Distance Walked

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Problem Domain

- **Accurately determine distance walked**
- **Critical for indoor navigation systems, pedometers...**
- **Dynamic changes in stride length and step frequency**

“Traditional” Estimation

- Indoor
  - RF-based fingerprinting (WiFi/GSM/Bluetooth)
  - Dead Reckoning (accelerometer or pressure sensing pedometer)
- Outdoor
  - GPS tracking
- Distance = # steps * average stride length

Alternative Approach

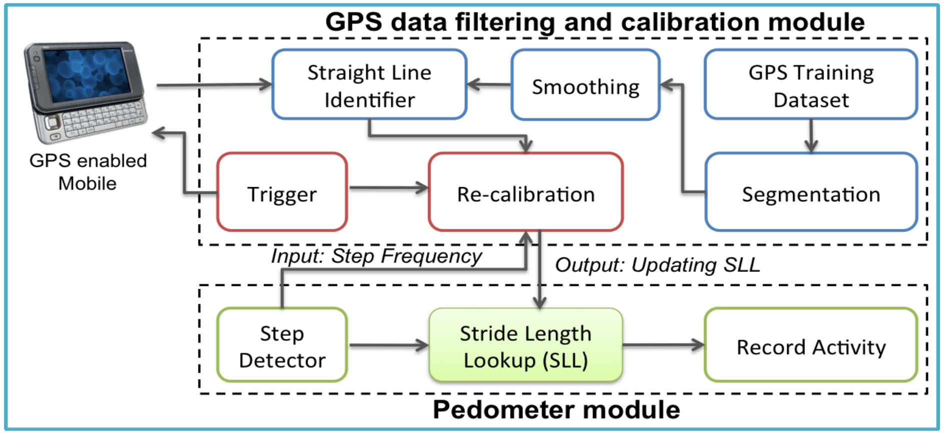
- **Traditional methods do not account for changes in stride length of frequency of steps taken**
- **Traditional approaches may require manual calibration per user**
- **Linear relationship between stride length and step frequency**
  - **Applies indoors, outdoors, and regardless of age/gender**

Location Tracking Technique

- GPS Location Tracking
  - Noisy (error ~ 5m-10m)
- Break path into line segments
  - Change in heading used
  - Compute stride length / step frequency for each segment using walking profile
- Auto calibration for walking profile

Architecture

- GPS data filter/calibration
  - COTS
  - Smoothing
- Pedometer
  - Step history
  - Distance walked



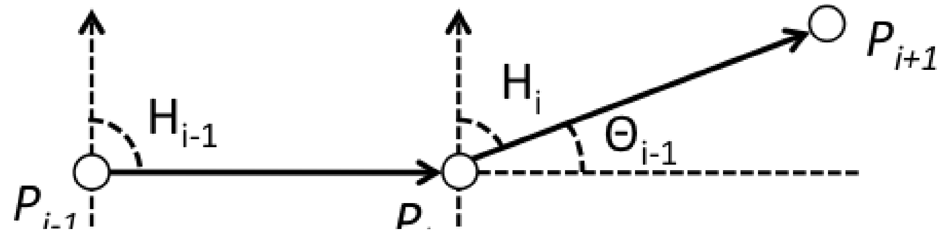
Measurement Approach

- **Stride Length Lookup (SSL)**
  - S = a freq + B
- **Segmentation**
  - Immobility Detection (> sum of mean and three times std deviation)
  - Unrealistic Movement Detection (speed between two points > sum of average and two time std deviation)
- **Smoothing**
  - Convolution with uniform distribution
- **Straight Line Identification**
  - Consider near straight-line walking patterns over noisy GPS

Questions / Comments

- End of over view
- More details coming up...wake up

Straight Line Detection



$$H_i = \frac{180}{\pi}[\mathrm{mod}(\mathrm{atan2}(y,x), 2\pi)], \quad 1 \le i < h$$

Heading change vectors:

$$\theta_i = H_{i+1} - H_i \quad 1 \le i < h-1, -180^\circ \le \theta < 180^\circ$$

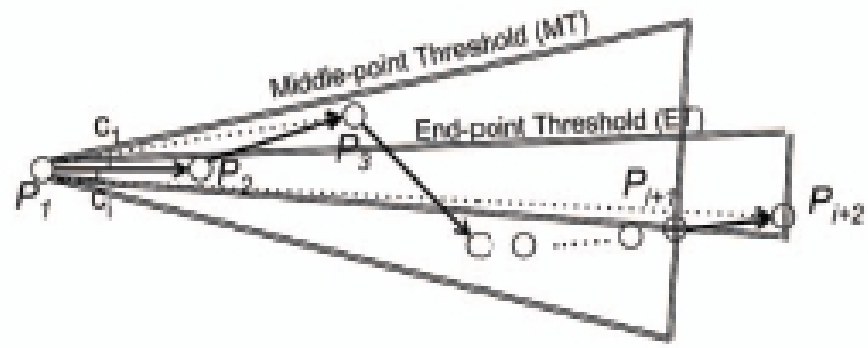
Cumulative heading changes:

$$\vec{c} = [\sum_{t=1}^{1} \theta_t, \sum_{t=1}^{2} \theta_t, \ldots, \sum_{t=1}^{k} \theta_t]$$

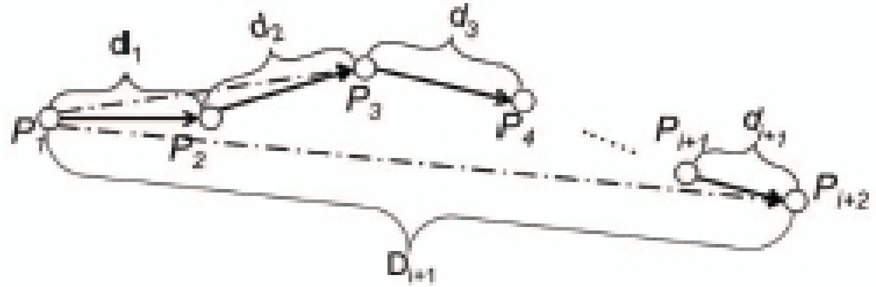
Straight Line Detection Cont.

- Obtain maximum i such that e_i < ET and e_j $(1<=j<i)$
- If GPS coordinates P_1,..P_{i+2} are within boundary, where i is sufficiently large, it is assumed a straight-line segment.
- The process repeats to extract more straight line segments. Heading values are excluded from the

mation (i to h) if needed.



Walking Profile Calibration



- **End-to-End: D_{i+1} Distance between two endpoints of the segment**
- **Sum Up: $\sum_{j=1}^{i+1} d_j$ cumulative distance of two consecutive points in the segment**
- **Average Stride Length = distance / (# edges in segment * # steps in an edge)**
- **Update SLL using linear least squares fitting with existing samples to obtain new alpha and beta coefficients**

Calibration Termination

- **Continuous calibration until least squares method converges**
  - **After sufficient samples obtained**
  - **GPS is turned off to conserve energy**

$$\forall i, \left| \arctan\left(\frac{\alpha_i - \alpha_{i-1}}{1 + \alpha_i \cdot \alpha_{i-1}}\right) * \frac{180}{\pi} \right| < \gamma^\circ, k \leq i < k + m$$

- **Angle of change between slope of new equation (a_i) and previous slope (a_{i-1}) is smaller than gamma for m calibration samples**

AutoGait Prototype

- Nokia N810, Linux, Python
- Custom pedometer using low force sensors
  - SmartShoe platform to avoid low acceleration motion sensing problems
  - Bluetooth connection to N810, sepearte threads for gathering data and counting steps
- GPS reading acquired every 10 steps

Results

Participant	A	B	C
α (SLL)	0.453	0.064	0.539
β (SLL)	0.23	0.612	0.2156
Segments Found	15	18	14
Est Dist (m)	1577.5	1579.4	1616.9
Error Rate	-1.41%	-1.29%	1.06%

Speed		Slow	Moderate	Fast
Distance (m)		400	800	400
Lap Time (min:sec)		9:56	11:52	3:45
# of Steps (Ground truth)		718	1192	488
AutoGait	Est Dist (m)	395.9	795.4	396.3
	Error Rate	1.02%	0.58%	0.93%
Const. Stride Length ($0.7m$)	Est Dist (m)	502.6	834.4	341.6
	Error Rate	-25.7%	-4.3%	14.6%

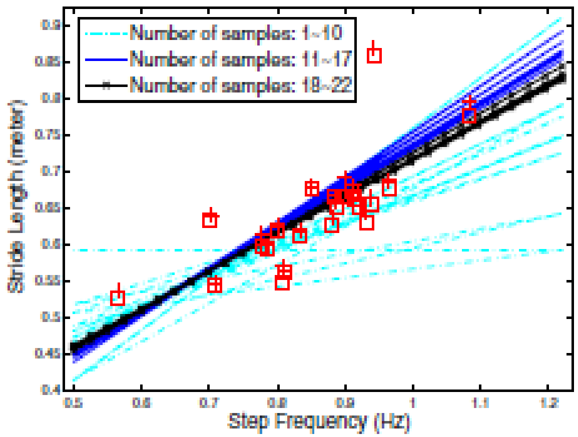


Fig. 9. Least Square: As number of samples increases, the linear line converges to a line

- Calibrated by walking around campus
- Track testing (sum up wins) with Treadmill verification (end-to-end)

Questions / Comments

- Change in altitude?
- Running vs Walking?
- Typical battery life?
- Claimed to be useful for indoors, but how do you read GPS indoors?
  - Mentioned compasses, but how reliable are they in your pocket?