Human Activity Recognition

Weely Report 4 - Reviews

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Localization Overview

Categories

Properties	Details
Accuracy Demand	Absolute position, relative position, proximity position
Positioning Method	Triangulation(AOA, TOA, TDOA, RSS), fingerprinting, proximity, vision analysis
Media	Infrared(IR), Ultra-sound, Radio Frequency (RFID, WLAN, Bluetooth, Sensor Network, UWB), Magnetic Position System, Vision-based, Audible Sound, Pseudosites, Zigbee

Positioning Method

Triangulation

Category	Method	LOS Limitation	Synchronization	Description
Lateration	TOA	Yes	Both receivers and transmitters	RX in fixed known locations,TX sends timestamp 1) Least square algorithm, $argmin_X \sum_i \|\|c\Delta t_i - x_i\|\|$ 2) Closest Neighbor(CN) 3) Residual weighting(RWGH): Weighted MSE
	TDOA	Yes	Between receivers	Measure distance difference signal sent from mobile transmitter to fixed RX $x_i(t) = s(t - d_i) + n_i(t)$, $\tau = argmax_\tau R_{x_i,x_j}(\tau) = \frac{1}{T}\int_0^T x_i(t)x_j(t-\tau)dt$
	RTOF (Roundtrip time of flight)	Yes	No	Time measured at same side Transponder processing time matters Optimize: Modulated reflection for short distance case
	Received Signal Phase	Yes	No	$sin(2\pi ft + \phi)$, $\phi = 2\pi fD_i/c$ $\phi < 2\pi$, carrier ambiguity
Angulation	AOA/DOA	Yes	No	Minimum 2 RPs for 2D, 3 RPs for 3D; Hardware demand Directional antenna or antenna array

Fingerprint

Method	Description
Probabilistic Method(Bayes)	$(x, y) = \sum_{i=1}^{n} P(L_i \| s)(x_{L_i}, y_{L_i})$
kNN	Weighted by RSS strength or not
Neural Network(MLP)	Output 2D or 3D vectors
SVM	Multi-class SVC/SVR
SMP	M-polygen

Media

Media Precision

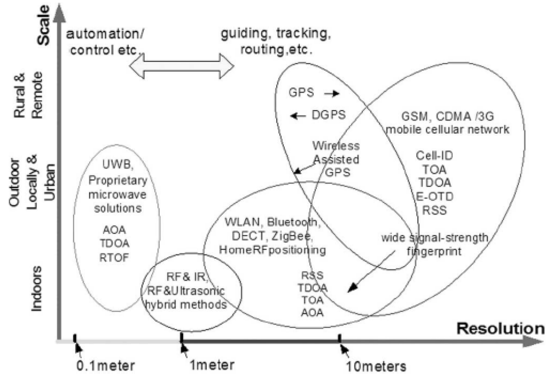

Fig. 6. Outline of current wireless-based positioning systems.

Media Features

Media	Accuracy	Usage	Pros	Cons	Applications
Infrared(IR)	mm level	Tag-Receiver, Triangulation	Very high accuracy; Cheap IR emitter	LOS only; Influenced by florescent and sunlight; wired	Active Badge(1990) ,OPTOTRAK Pro(2008)
Ultra-sound	cm level	Tag-Receiver, Triangulation	High accuracy, non-LOS	Non-through wall; RF assistant; Metal sensitive	Active Bat(2008) Sonitor(2008)
RFID	23̃m	Tag-Receiver	Through-the-wall;	Limited coverage area; (P:12̃m;A:10m)	WhereNet(2008)
WLAN	13̃m	AP-Client; Triangulation , Fingerprint	Through-the-wall; Infrastructure free Converage(50 100m)	Multi-path effect; Multiple objects inextricable	RADAR(2000) Ekahau(2008)
Bluetooth	2̃m	Tag-Receiver Triangulation	Non-LOS Multiple objects	Long delay; Environment sensitive	Topaz(2004)
UWB	cm level	Tag-Receiver Triangulation	Non-LOS; Multi-path exclusive;	Expensive Affected by liquid and metal	Ubisense(2008)
Magnetic Position System	cm level	Tag-Receiver	High Accuracy; Non-LOS	Expensive tracker Affected by metal	MonitorStar Wireless(1979)
Vision-based	cm level	Device-free	High Accuracy; Light-affected	Background motions	Easy Living(2000)
GPS	5 50m	Device-free		Low accuracy	Snap Track A-GPS

Calibration-free Indoor Positioning Systems

TIX[1]

- Method
  - m APs, location server gets inter-AP RSSs and client-to-AP RSSs
  - Each AP forms distance mapping curve(DMC) to other m-1 APs with assumption on RSS(log-scale) decays linearly with distance
  - Client use strongest AP DMC to estimate distance to other m - 1 APs
  - Client use secondary strongest AP DMC to estimate distance to strongest AP
  - Estimating client's location with triangular Interpolation and eXtrapolation(TIX) algorithm
- Constraints
  - Need AP's location information
- Accuracy: 5.4m inside an office of $1020m^2$

[1] **Y.Gwon**, **R.Jain**, **Error characteristics and calibration-free techniques for wireless lan-based location estimatio** **in:Proc.of the Second ACM MobiWac**, **NewYork**, **NY**, **USA**, **2004**, **pp.29**.

Signal-Distance Map(SDM)[2]

- Method
  - Inter-AP RSS measurement
  - Object function: $\min e_i = \sum_{k=1}^{m}(log(d_{ik} - b_i s_{ik}))$, where d_{ik} is inter-AP distance; s_{ik} is inter-AP RSS.
  - Coefficient vector $b_i = log(d_i^T)S^T(SS^T)^{-1}$, SDM: $B = log(D)S^T(SS^T)^{-1}$
  - Client-to-jth AP: $d_j = exp(Bs_j)$.
- Constraints
  - Need AP's location information
- Accuracy: 3m inside an small academic building

[2]**H.Lim**, **L.-C.Kung**, **J.C.Hou**, **H.Luo**, **Zero-configuration indoor localization over ieee 802.11 wireless infrastructure**, **Wireless Network16(2)(2010)405420.**.

Organic Indoor Location(OIL)[3]

- Method
  - User contributes to build radio map
  - Voronoi region to map spatial uncertainty of estimation, threshold-based user engagement
  - agglomerative hierarchical clustering approach to group the user feedback by similarity
  - Inter-cluster distance $D_s(C_i, C_j) = \frac{1}{|C_i||C_j|} \sum_{(s_i,s_j)\in(C_i,C_j)} d_s(s_i, s_j)$, where $d_s(s_i, s_j) = [\frac{1}{M} \sum_{k=1}^{m}(s_{ik} - s_{ik})^2]^{1/2}$, M out of m APs' RSS appears in s_i or s_j.
  - $C_l^* = argmin_{c\in C_l} \sum_{k\in N(l) D_S(C,C_k^*)}$
- Constraints
  - Requires availability of a map, active participation of users
- Accuracy: Not reported

[3]J.-G.Park, B.Charrow, D.Curtis, J.Battat, E.Minkov, J.Hicks, S.Teller, J.Ledlie, Growinganorganicindoorlocationsystem, in:Proc.ofACMMobiSys, MobiSys10, 2010, pp.271284..

- Method
  - Log-distance path loss(LDPL): $s_{ik} = s_{i0} - 10\gamma_i \log d_{ik}$ where $d_{ik} = \sqrt{(x_k - c_i)^T (x_k - c_i)}$, x_k denotes user's location, c_i demotes AP's location.
  - Unknown parameters: $AP(\gamma_i, c_i, s_{i0})$, user x_k.
  - m APs and n locations: mn LDPL equations and $4m + 2n$ unknown parameters $\rightarrow$ unique solution when $mn > 4m + 2n$
  - Genetic Algorithm(GA) & Gradient Descent(GD), stop after convergence.
- Constraints
  - Accuracy tradeoff, user engagement
- Accuracy: Not reported

[4] **K.Chintalapudi**, **A.PadmanabhaIyer**, **V.N.Padmanabhan**, **Indoorlocalizationwithoutthepain**, **in:Proc.ofACMMobiCom10**, **2010**, **pp.173184.**.

WiGEM[5]

- Method
  - Gaussian Mixed Model: $p(s) = \sum_{j=1}^{J} \sum_{k=1}^{K} v_j \tau_k N(s|\mu_{(jk)}\sigma^2_{(jk)})$, GMM parameters: $\theta = (v, \tau, \mu, \sigma)$
    - v_j denotes probability of client being at location j
    - τ_k denotes probability of TX power level being k
    - $\mu_{(jk)}, \sigma^2_{(jk)}$ denotes mean/standard deviation of RSSs given client at j with TX power k
  - Traditional fingerprint-based method: J Grid RSSs, using EM to estimate parameters given s.
  - $j^* = argmax_j \sum_k p(x_j = 1, z_k = 1|s^{obs})$
- Pros
  - Heterogeneity of device power level
- Constraints
  - Sniffer location are known, requires a map.
- Accuracy: Not reported

[5] **A.Goswami**, **L.E.Ortiz**, **S.R.Das**, **WiGEM:a learning based approach for indoor localization**, **in:Proc.ofACMCoNEXT**, **2011**, **pp.112**.

WILL[6]

- Method
  - RSS changes sharply through walls, accelerometers to detect user moving status
  - RSS Grouped to virtual rooms by similarity of WIFI fingerprints, user traces used to determine reachability among virtual rooms
  - Actual physical floor plan converted to connected graph
  - Map logic floor plan to actual physical plan by vertex matching(e.g. skeleton mapping, branch-knot mapping), neighboring info refines mapping.
- Pros
  - No knowledge requirements of AP locations
- Constraints
  - Need actual physical map; Fingerprint collection & preprocess needed.
- Accuracy: 86% room-level accuracy

[6] **C.Wu**, **Z.Yang**, **Y.Liu**, **W.Xi**,
WILL:Wireless indoor localization without site survey, **in:Proc.of IEEE INFOCOM**, **2012**, **pp.6472.**.

UnLoc[7]

- Method
  - Use urban dead-reckoning to track user.
  - Calibrate by user encounters landmark:Seed landmarks(SLM, e.t. elevators, escalators, stairs), organic landmarks(OLM, small confined geographical areas with distinct signal patterns)
  - Use FSM to separate SLM
  - OLM identified by $\lambda = \frac{1}{|m|} \sum_{\forall k \in m} \frac{min(s_{1k}, s2k)}{max(s_{1k}, s_{2k})}$, $4m^2$ area to be considered as a landmark.
  - User starts itinerary when encountering first landmark, resets at next landmark.
- Pros
  - No knowledge requirements of AP locations, No physical map required. Self-adaptive.
- Constraints
  - Need user engagement, low accuracy at beginning.
- Accuracy: 1.6m across 3 different settings including a shopping mall. Heterogeneity not considered.

[7] **H.Wang**, **S.Sen**, **A.Elgohary**, **M.Farid**, **M.Youssef**, **R.R.Choudhury**, **No need to war-drive: Unsupervised indoor localization**,

Zee[8]

- Method
  - A users traveled distance and direction might be obtained
  - Placement Independent Motion Estimator(PIME) estimates step count and heading offset(HO)
  - Augmented Particle Filter(APF) 4-D joint probability distribution(locationx, locationy, stride length, HO)
  - APF runs belief back-propagation with map constraints to correct user's path history(Determine initial location), trace+WIFI fingerprints as database
- Pros
  - No fixed location. A crowdsourced method.
- Constraints
  - Need user engagement; Need physical map
- Accuracy: Horus/EZ use it and achieve error of 3m

[8] **A.Rai**, **K.K.Chintalapudi**, **V.N.Padmanabhan**, **R.Sen**, **Zee: Zero-effort crowd-sourcing for indoor localization**, **in: Proc. of ACM MobiCom12**, **2012**, **pp.293304**.

LiFS[9]

- Method
  - Transforming the map into a stress free floor plan; Creating fingerprint space; Mapping between fingerprint and real location.
  - kNN to estimate client's location.
  - Grid locations, fingerprints are recorded of itinerary with walking distances(steps*stride length)
  - Floyd-Warshall Shortest path build a fingerprint graph, mapping to stress-free floor plan.
  - Spatial similarity(Betweenness centrality, k-Means) to identify corridors/rooms.
- Pros
  - No fixed location.
- Constraints
  - Need initial sensor and user trace info; Need physical map
- Accuracy: 89% room-level accuracy(Average error distance 5.8m) inside medium sized academic building.

[9] **Z.Yang**, **C.Wu**, **Y.Liu**, **Locating in fingerprint space:wireless indoor localization with little human intervention**, **in:Proc. of ACM MobiCom12**, **2012**, **pp.269280**...

Walkie-Markie[10]

- Method
  - RSS tread instead of absolute value considering of heterogeneity;
  - RSS trend tripping point(RTTP, et. maximum) as Wi-Fi marks(AP's MAC,(D1,D2),N), where D1, D2 are steady walking directions approaching and leaving the RTTP, N is neighbor info of AP.
  - Spatial similarity(Betweenness centrality, k-Means) to identify corridors/rooms.
  - Utilize location of users when passing WiFi mark, dead-reckoning locate intermediate locations.
  - Use "Arturia" positioning algorithm mapping trajectories to place WiFi marks with real location.
- Pros
  - Neither need knowledge of floor plan nor locations of APs.
- Accuracy: 1.65m in office floor of $3600m^2$.

[10] **G.Shen**, **Z.Chen**, **P.Zhang**, **T.Moscibroda**, **Y.Zhang**, **Walkie-Markie: Indoor pathway mapping made easy**, **in:Proceedings of the 10th USENIX Conference on Networked Systems Design and Impleme**
Berkeley, **CA**, **USA**, **2013**, **pp.8598.**.

UWB Survey[a]

[a] Alarifi, Abdulrahman,
et al. "Ultra Wideband Indoor Positioning Technologies: Analysis and Recent Advances." S

UWB Algorithms

Table 8. Comparison of UWB Algorithms.

Criteria	AOA	TOA	TDOA	RSS
Position Estimation	The intersection of several pairs of angle direction lines	Time taken by the signal to go from the target node to several reference nodes The distance is directly proportional to the propagation time	The delta in time between the signal's arrival at multiple reference nodes The time differences are mapped to multiple intersected hyperbolas	The received signals strength from several reference nodes at the target node The distance is inversely proportional to the signal strength
2D space	At least two reference nodes	At least three reference nodes	At least three reference nodes	At least three reference nodes
3D space	At least three reference nodes	At least four reference nodes	At least four reference nodes	At least four reference nodes
Synchronization	Lower requirement in terms of clock precision and synchronization	All transmitters and receivers in the system have to be precisely synchronized Difficult and costly	Only the reference nodes need to be synchronized	Not required
LOS vs NLOS	Require a clear line-of-sight (LOS) between sender and receiver Multi-Path effects change phase of a signal and cause large position error			Prefer LOS to reduce multipath effects Great negatively affected by existence of obstacles and walls
Issues	Small errors in angle measurement will negatively impact accuracy Require costly and large dimensions of antenna arrays	Relative clock drift between sender and receiver	Lower accuracy than TOA with the same system geometry	Sensitive to channel inconsistency Require short distances between nodes

Recent UWB Research(1)

Table 7. Comparison of Ultra WideBand (UWB) Systems.

No.	Authors	Year	Accompanied Technology	Algorithm	Environment	More Details
1	Ch'oliz *et al.* [23]	2011		TOA	LOS, NLOS	Compared the performance of impulse radio (IR) UWB indoor tracking systems using different parametric and non-parametric algorithms such as weighted least square with multidimensional scaling (WLS-MDS), trilateration, least square with distance contraction (LS-DC), particle filter (PF), and extended kalman filter (EKF).
2	Guangliang Cheng [46]	2012		TOA	LOS, NLOS	Presented a new UWB-based personnel localization system for coal mines.
3	Fischer *et al.* [61]	2010		TOA	LOS, NLOS	Designed a new monolithic integrated IR-UWB transceiver chipset with a high-precision TOA measurement unit using two-way ranging and 8-PPM modulation.
4	Krishnan *et al.* [50]	2007		TDOA	NLOS	Used multi-cell implementation to cover large spaces, using Chan's method to provide an accurate estimate of the mobile tag's position within each cell. A heuristics-based approach was used to improve the accuracy at the boundaries.
5	Rowe *et al.* [62]	2013		TDOA		Presented a new multi-tag millimeter accuracy localization system that utilize digital sampling to enhance its accuracy.
6	Jiang *et al.* [63]	2010	GPS	AOA, TDOA	LOS, NLOS	Provided indoor/outdoor location tracking in a hospital environment by integrating UWB and GPS technologies in one system. Ubisense solutions are used to provide a UWB infrastructure and a system and to work as location platform with a standard bidirectional time division multiple access control channel.
7	Pittet *et al.* [64]	2008	MEMS	AOA, TDOA		Combined UWB positioning with micro electro mechanical sensors (MEMS) inertial sensors in an extended Kalman filter to improve positioning and navigation performance.
8	Shahi *et al.* [47]	2012		AOA, TDOA	LOS, NLOS	Developed a UWB positioning system for material and activity tracking in indoor construction projects and studied the effect of construction materials on performance.
9	Segura *et al.* [48]	2012		TOA, TDOA	LOS, NLOS	Developed a UWB navigation system for mobile robot (MR) in indoor environments. Synchronization by the receivers is not required since a centralized transmitter with TDMA is used. Also, an adaptive threshold crossing algorithm is used to improve TOA estimator resistance to noise and interference.
10	Cao and Li [65]	2012		AOA, TOA	LOS	Developed a new H_∞ filter based algorithm to estimate the location and velocity of a target object in a real-time.
11	Mucchi *et al.* [66]	2010		AOA, TOA	LOS	Developed an UWB real-time positioning system using Ubisense UWB solutions to provide cinematic data that helps in monitoring the performance of a professional athlete, especially after a surgery.
12	Liu *et al.* [67]	2012	GPS	TDOA	LOS, NLOS	Developed an indoor and outdoor cooperative real-time positioning system for disaster aid missions by considering their requirements.
13	Kuhn *et al.* [58]	2011	TDMA, FPGA	TDOA		Designed a multi-tag access scheme for UWB positioning systems with millimeter range accuracy for surgical navigation which allows simultaneous tracking of up to 30 UWB tags.

Blue: New method/algorithms;
Yellow: New applications;
Red: New circuit design;

Purple: Hybrid of media.

Recent UWB Research(2)

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