



UNIVERSITI PUTRA MALAYSIA

**A NOVEL PATH PREDICTION STRATEGY FOR TRACKING
INTELLIGENT TRAVELERS**

OMID REZA ESMAEILI MOTLAGH

FK 2009 103



**A NOVEL PATH PREDICTION STRATEGY
FOR TRACKING INTELLIGENT TRAVELERS**

By

OMID REZA ESMAEILI MOTLAGH

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

October 2009



To my Parents

For their Love and Support



Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirement for the degree of Doctor of Philosophy

**A NOVEL PATH PREDICTION STRATEGY
FOR TRACKING INTELLIGENT TRAVELERS**

By

OMID REZA ESMAEILI MOTLAGH

October 2009

Chairman: Tang Sai Hong, PhD

Faculty: Engineering

There are various technologies for positioning and tracking of intelligent travelers such as wireless local area networks (WLAN). However, the loss of actual positioning data is a common problem due to unexpected disconnection between tracking references and the traveler. Disconnection of the mobile terminal (MT) from the access points (AP) in WLAN-based systems is the example case of the problem. While enhancement of the physical system itself can reduce the risk of disconnections, complementary algorithms provide even more robustness in localization and tracking of the traveler.

This research aims to develop a novel path prediction system which could keep track of the traveler during temporary shortage of actual positioning data. The system takes the advantage of the past trajectory information to compensate for the missing information during disconnections. A novel decision support system (DSS) is devised with the ability of learning decisional as well as kinematical behaviors of intelligent travelers.



The system is then used in path prediction mode for reconstructing the missing parts of the trajectory when actual positioning data is unavailable.

An ActivMedia Pioneer robot navigating under fuzzy artificial potential fields (APF) and blind-folded human subjects are the two types of intelligent travelers. The reactive motion of robots and path planning strategies of the blinds are similar in that both of them locally acquire knowledge and explore the space based on route-like spatial cognition. It is proposed and shown that route-like intelligent motion is based on a combination of decisional and kinematical factors. The system is designed in such a way to integrate these two types of motion factors using causal inference mechanism of the fuzzy cognitive map (FCM). The FCM nodes are a novel selection of kinematical factors. Genetic algorithm (GA) is then used to train the FCM to be able to replicate the decisional behaviors of the intelligent traveler.

Experimental works show the capabilities of the developed DSS in human path prediction using both simulated and actual WLAN-based positioning dataset. Locational error is set to be limited to 1 m which is suitable for wireless tracking of human subjects with up to 10% improvement compared to the most related works. Both simulation and actual experiments were also carried out on the Pioneer platform. The accuracy in prediction of robot trajectory was obtained about 83% with considerable improvement compared to the recent methods. Apart from the positioning algorithm of this dissertation, there are several applications of this DSS to other areas including assistive technology for the blind and human-robot interaction.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**SATU STRATEGI INOVATIF UNTUK
MERAMALKAN PERJALANAN SUBJEK YANG PINTAR**

Oleh

OMID REZA ESMAEILI MOTLAGH

Oktober 2009

Pengerusi: Tang Sai Hong, PhD

Fakulti: Kejuruteraan

Rangkaian kawasan setempat tanpa wayar atau *wireless local area networks* digunakan untuk mengenal pasti peletakan dan kedudukan terminal bergerak (MT) dengan menggunakan parameter gelombang elektromagnetik yang pelbagai. Namun, terdapat masalah yang timbul dalam sistem ini iaitu kekerapan MT terputus daripada sudut akses atau *access points* (AP). Penambahbaikan sistem fizikal tersebut dapat merendahkan risiko MT terputus, manakala algoritma dan perisian dalam sistem membolehkan kedudukan dan pergerakan MT dikenal pasti dengan lebih utuh.

Kajian ini bertujuan membina satu sistem ramalan pergerakan yang baru yang mampu mengenal pasti kedudukan MT apabila jaringan tanpa wayar terputus. Sistem yang baru ini memperoleh maklumat trajektori MT yang lepas untuk menggantikan maklumat yang hilang semasa jaringan MT-AP terputus. Sistem sokongan keputusan yang baru (DSS) telah diperbaharui dengan kebolehan membuat keputusan secara bijak serta

perilaku kinematikal subjek pintar yang berperanan sebagai MT. Sistem ini kemudiannya digunakan untuk meramal perjalanan bagi membina semula bahagian trajektori MT yang hilang semasa jaringan terputus.

Robot *ActivMedia Pioneer* yang mengemudi di bawah bidang berpotensi buatan kabur (APF) dan subjek manusia yang ditutup mata merupakan dua jenis subjek pintar yang berperanan sebagai MT. Sementara proses pembuatan keputusan manusia berlaku dalam otak, bagi robot mobil proses ini berlaku pada algoritma berasaskan pergerakan. Pergerakan reaktif robot mobil dan strategi perancangan perjalanan manusia buta adalah serupa dari segi perolehan pengetahuan secara tempatan dan menjelajahi ruang berdasarkan kognisi ruang yang seperti jalan. Jenis pergerakan ini telah ditunjukkan bahawa ia berdasarkan gabungan pemikiran rasional dan faktor kinematikal.

DSS ini telah direka sebegitu rupa untuk mengintegrasikan faktor kinematikal dan pemikiran rasional dengan menggunakan mekanisma inferens penyebab bagi peta kognitif kabur (FCM). Nod-nod FCM merupakan pilihan konsep-konsep pergerakan baru. Algoritma genetik (GA) digunakan untuk melatih FCM agar boleh mereplikakan perilaku pembuatan keputusan MT. Dengan itu, FCM yang terlatih mampu meramal trajektori MT apabila jaringan terputus.

Penyelidikan membuktikan keutuhan DSS dalam meramalkan perjalanan manusia menggunakan set data WLAN secara simulasi dan sebenar. Kesilapan lokasi telah dihadkan kepada 1 m, yang sesuai untuk mengenal pasti kedudukan subjek manusia



dengan perbaikan sehingga 10% berbanding dengan kebanyakan strategi yang sedia ada. Hasil penyelidikan telah dijadikan sebagai projek perintis. Ketepatan sistem dalam meramal perjalanan robot adalah dalam lingkungan 83% dengan kadar perbaikan yang lebih baik berbanding dengan pendekatan yang lain. Selain peletakan algoritma dalam kajian ini, terdapat beberapa aplikasi DSS dalam bidang-bidang yang lain termasuk teknologi bantuan untuk orang buta dan interaksi antara manusia dengan robot.



ACKNOWLEDGEMENTS

This research would not have been possible without the support of many people. The author wishes to express his gratitude to his supervisor, Assoc. Prof. Dr. Tang Sai Hong, who was abundantly helpful and offered invaluable guidance and support. Deepest gratitude is also due to the committee members, Assoc. Prof. Datin Dr. Napsiah Ismail, and Assoc. Prof. Dr. Abdul Rahman Ramli whose advice, knowledge, and experience provided a path of success for this research.

Special thanks go to the director, Prof. Ir. Dr. Barkawi Sahari, and deputy director, Assoc. Prof. Dr. Ishak Aris, of the Institute of Advanced Technology (ITMA), and to the director, Assoc. Prof. Dr. Abdul Rahman Ramli, and research members of the Intelligent Systems and Robotics Lab. (ISRL), Juraina Yusof, Rosiah Osman, Mohd Wafi, for providing technical facilities, and to all undergraduates who patiently cooperated during the experimental works.

This research was supported by the Research University Grant Scheme (RUGS). The author therefore wishes to convey thanks to the Ministry, and to the head of the research and post graduate studies of Engineering faculty, Prof. Ir. Dr. Norman Mariun, for providing such financial support, and to the head, Prof. Dr. Hasanah Mohd Ghazali, and esteemed staff of the School of Graduate Studies (SGS) for their great guidance.

And finally, this research is a tribute to Dr. Millar, Dr. Ungar, and Dr. Stylios whose researches provided a great fundamental for the current study. This is also a means of appreciation to the author's beloved parents, and to Farid for their love and care, and to all friends especially Phoebe, Nafise, Alireza, Sam, Abdi, Pegah, and Aileen.



I certify that an Examination Committee met on 29 October 2009 to conduct the final examination of Omid Reza Esmaeili Motlagh on his Doctor of Philosophy thesis titled “A Novel Path Prediction Strategy for Tracking Intelligent Travelers” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the student be awarded the degree of Doctor of Philosophy. Members of the Examination Committee are as follows:

Rosnah Mohd Yusuff, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairwoman)

Aidy Bin Ali, PhD

Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohd Hamiruce Marhaban, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Musa Mailah, PhD

Associate Professor
Faculty of Engineering
Universiti Teknologi Malaysia
(External Examiner)

BUJANG KIM HUAT, PHD

Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:



This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Tang Sai Hong, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Napsiah Ismail, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Abdul Rahman Ramli, PhD
Associate Professor
Faculty of Engineering
University Putra Malaysia
(Member)

HASANAH MOHD GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 14 January 2010



DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and in not concurrently, submitted for any other degree at University Putra Malaysia or at any other institution.

OMID REZA ESMAEILI MOTLAGH

Date:



TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	viii
APPROVAL	ix
DECLARATION	xi
LIST OF TABLES	xv
LIST OF FIGURES	xvi
LIST OF ABBREVIATIONS	xxi
CHAPTERS	
1 INTRODUCTION	1
1.1 Background	1
1.2 Research problem	3
1.3 Hypothesis	3
1.4 Objectives of the research	4
1.5 Significance of the study	6
1.6 Scope of the study	9
1.7 Research design and organization of the chapters	11
1.8 Summary of the chapter	12
2 LITERATURE REVIEW	13
2.1 Wireless positioning	13
2.1.1 Trilateration technique	16
2.1.2 Positioning technologies	18
2.1.3 Motion tracking using trilateral radiolocation	20
2.2 Motion modeling and estimation	22
2.3 Spatial cognition and wayfinding of the blinds	33
2.3.1 Path prediction based on decision models	34
2.3.2 Theories on the blinds' spatial cognition	35
2.3.3 Role of visual experience in spatial cognition	37
2.3.4 Basic theories	38
2.3.5 Knowledge structures without vision	39
2.4 Spatial coding and behavioral strategies	40
2.4.1 Concepts involved in the blinds' wayfinding	42
2.4.2 Key motion concepts	44
2.4.3 Motor skills and locomotion	46



2.5	Mobile robot path planning	48
2.5.1	Reactive versus deliberative motion	49
2.5.2	Robot kinematical motion concepts	51
2.6	Decision modeling using decision support systems	54
2.6.1	Reasoning techniques	55
2.6.2	Causal inference mechanism	57
2.7	Fuzzy cognitive map	57
2.8	Decision productions and action selection	59
2.9	Supervised learning using genetic algorithm	61
2.10	Summary of review	63
3	METHODOLOGY	65
3.1	Introduction	65
3.2	Research flow	66
3.3	Development of the DSS module	68
3.3.1	Factor concepts and decision concepts	70
3.3.2	Dead-reckoning for weighting the concepts	72
3.3.3	Expert-defined versus AI-defined event weights	79
3.3.4	Expert definition of the decision matrix	81
3.4	Development of a novel AI-DSS for motion prediction	84
3.4.1	Path segments and data-base	88
3.4.2	GA-based optimization of the decision matrix	89
3.4.3	Learning and performing stages	93
3.5	Statistical case-based reasoning	98
3.6	Extraction of path patterns	101
3.7	Assisted wireless positioning	104
3.7.1	Defining contour regions	107
3.7.2	Selection of location estimations	109
3.8	Blind-folded experiments	113
3.9	Positioning and tracking	116
3.10	Experiments with the reactive mobile robot	118
3.11	Summary of methodology	121
4	RESULTS AND DISCUSSION	122
4.1	Introduction	122
4.2	Motion patterns	124
4.3	Behavioral consistency on obstacle-free areas	126
4.4	Experiments with the expert-DSS	127
4.5	Experimental work with the AI-DSS	133
4.5.1	Replication of the predominant behaviors	134
4.5.2	Complex trajectory on plain floor	141
4.5.3	Motion concepts in vicinity of landmarks	144
4.5.4	Replication of the applied APF algorithm	145



4.6	Comparison of results, accomplishments, and limitations	151
4.7	Experiments with an actual Pioneer platform	165
4.7.1	Input and control alternatives	165
4.7.2	Modified APF for the Actual Robot	169
4.7.3	Compensation of the self-localization errors	170
4.7.4	Obtained results	171
4.8	Experimental work with actual wireless RSSI dataset	175
4.9	Summary of the Chapter	179
5	CONCLUSION	180
5.1	Accomplishments	180
5.2	Applications of the developed AI-DSS	181
5.3	Limitations	183
5.4	Future directions of research	184
5.5	Modeling of biological gross motion	185
	REFERENCES	187
	APPENDICES	197
I	The AI-DSS source code	197
II	The fuzzy-APF source code	206
III	Metric layout of the test environment	209
IV	Motion production data-set	211
	BIODATA OF STUDENT	212
	LIST OF PUBLICATIONS	213



LIST OF TABLES

Table		Page
2.1	Wayfinding strategies of the blinds (Hill et al., 1993; Thinus-Blanc and Gaunet, 1997), adopted from (Ungar, 2000)	41
3.1	(a) Blind motion FCM structure (kinematical concepts), (b) Mobile robot's FCM structure in local navigation	71
3.2	The effects of the back-forth and left-right concepts on other concepts	84
3.3	The path segments, the available data, and the data to be extracted	88
3.4	Completion of path data-base with replications of decision productions	89
3.5	Attenuation effect on received signal strength in two WiFi frequency bands due to different types of barriers (Fuhr and Hedroug, 2008)	106
3.6	The path loss exponent in different environments (Shih et al., 2008)	107
4.1	Predominant behaviors observed at points of switch in referencing	125
4.2	Tracking and recording of the robot motion information	148
4.3	The problems of the existing APF and the related solutions	167



LIST OF FIGURES

Figure	Page
1.1 (a) Trilateration with 3 references (APs), (b) Detection of 2 unique points using 2 APs: AP1, AP2, (c) Locational ambiguity due to lack of actual positioning data, (d) Failure in tracking the MT due to disconnection of all APs	8
2.1 The concept of triangulation on x-y plane	15
2.2 Trilateration technique on x-y plane	18
2.3 A positioning-navigation system for the blinds	21
2.4 Definition of variables (Warren and Fajen, 2004)	24
2.5 (a) The AI model at learning stage, (b) AI model starts to predict future motion productions during disconnection period	30
2.6 Robot's space (S) divided into sub-spaces to define fuzzy inputs of the fuzzy-APF. ul, uf, ur describe target orientation (attractors), L,LF, F, RF, R describe obstacles (repellers)	51
2.7 (a) Decision productions, (b) Concepts weights at locations L_{i-1}, L_i	54
2.8 (a) Inductive logic versus, (b) Deductive logic	56
2.9 A cognitive map with eight interrelated concepts	58
3.1 Research flow and activities	67
3.2 Dead-reckoning strategy for modeling kinematical behaviors	73
3.3 (a) Initializing the weights of the FCM inputs and outputs for robot motion modeling, (b) Motion concepts namely: target at left, front, right (TL, TF, TR), obstacle at left, front, right (OL, OF, OR), length of displacement (DL), and heading to left or to right (Θ_L, Θ_R)	78
3.4 The fuzzified sub-spaces as traveler is making a decision for motion	82



3.5	Expert-defined causal influences of the decision concepts on one another	83
3.6	Expert-defined influences of the circular motion on other behaviors	84
3.7	Partially known trajectory of the MT	85
3.8	GA-based learning of the traveler's decision production P_{i-1}	86
3.9	Estimations of a future motion production P_i	87
3.10	The AI-DSS algorithm during learning stage	95
3.11	The AI-DSS algorithm at performing stage	96
3.12	The complementary case-based-reasoning	101
3.13	(a) Immeasurable locational errors due to unequal contour regions, (b) Circular (ring-like) contour regions defined with equal distances	109
3.14	Assisted wireless positioning (a) with 2 APs, and (b) With only 1 AP	112
3.15	(a) Soft-padded walls and soft floor for safety, (b) Applied eye masks	115
3.16	(a) Placement of stickers for tracking the subjects, (b) Measurement of the length and changes in heading direction	117
3.17	(a) Applied Pioneer platform, (b) The array of 8 sonar rangefinders	119
3.18	Local navigation based on fuzzy-APF and local minima avoidance	121
4.1	(a) The test environment with an elliptical table placed at its centre representing environment of Kametani (2006), (b) Blind-folded straight walk	127
4.2	(a) DR concept weighting at L_i based on kinematics of production $\bar{D}_{i-1} = (50 \text{ cm}, 60^\circ)$, (b) Expert definitions of the event matrix for updating the map at time t_i	129
4.3	Motion decision P_i is obtained from FCM convergence. Accordingly the MT is expected to move from location L_i to L_{i+1}	132



4.4	A C-type trajectory from the home location until the first touch point	135
4.5	Trials of AI-DSS for anticipating last 10 productions (dotted line with white circle face) compared against the actual path (solid line with gray circle face)	137
4.6	(a, b) Error graphs related to the experiment of Figure 4.5a, (c, d) Error graphs related to experiment of Figure 4.5b	138
4.7	Better path prediction due to more sufficient training using 23 samples	139
4.8	Bar-graph of pairwise locational comparison (error), and the resultant error graph (E_t) both related to predictions of Figure 4.7	140
4.9	(a) MT's location samples supplied to the AI-DSS for training, (b) Two trials of path prediction (circle face) compared against the actual trajectory (triangle face)	143
4.10	Motion concepts identified in vicinity of landmarks	145
4.11	(a) Obstacle avoidance and target seeking behaviors, (b), Input membership functions, (c) Variations in the robot heading direction along the path	147
4.12	Sample trajectories (motion productions) used to train the AI-DSS	149
4.13	A trajectory simulated by the AI-DSS in a sample environment (MATLAB), (b) The same trajectory under control of the fuzzy-APF (ActivMedia)	150
4.14	Figure 4.18: (a) Path prediction using mathematical model of Ciurana et al. (2007b) against (b) Path prediction using an extended Kalman filter. The actual path is shown by circle-face. Predicted paths are shown by square-face. $Ls1$, $Ls2$, $Ls3$ show the points of switch along the path	153
4.15	Figure 4.19: (a) Path prediction using AI-DSS alone with no statistical tuning or reference to APs, (b) AI-DSS performance against the actual path and other works	153
4.16	Availability of at least two access points (Ciurana et al., 2007b)	154



4.17	Path estimation using AI-DSS with locational tuning by only one access point $AP1$, (a) $AP1$ placed at location $R1:(0,50)$, (b) $AP1$ placed at location $R2:(50,50)$	155
4.18	Estimated paths $P1$ and $P2$ are compared against the actual path (Pa) and a reference path from the previous work (Pr)	156
4.19	(a) A trajectory made by an unknown traveler carrying a mobile terminal, (b) Motion tracking using RSSI radiolocation (Markoulidakis et al., 2008), (c) Partial replication of the trajectory only using AI-DSS of the blind	158
4.20	Motion prediction of human subjects (Vasquez and Fraichard, 2004)	160
4.21	(a) ActivMedia Mapper used for layout design, and robot localization, (b) The paths used for training the AI-DSS, (c) Predicted versus actual trajectory	162
4.22	Path prediction using a kinematical model (Warren and Fajen, 2004)	163
4.23	A sample actual trajectory from Figure 4.22 that is partly learnt and partly predicted by the AI-DSS	164
4.24	(a) Skid steering by means of left and right wheel velocity controls, (b) The control alternatives and the actual controls	166
4.25	Input membership functions, (a) Target direction: target at left (TL), in front (TF), at right (TR), and (b) Obstacle direction: obstacle at left (L), at left front (LF), in front (F), at right front (RF), at right (R)	167
4.26	(a) Input membership function for fuzzified obstacle range: obstacle near (ON), far (OF), no obstacle (NO), (b) The relationship between the robot's velocity and presence of obstacles	168
4.27	The expert-FCM for reactive control of the actual Pioneer	170
4.28	An example of the robot motion (ActivMedia Simulator)	172
4.29	The developed FCM Simulator software, (a) map initialization at point A, (b) map convergence for motion decision from point A to point B	173



4.30	Actual paths (solid) are compared against the simulated path (dotted)	174
4.31	Layout of the test environment showing the actual track (dashed line)	175
4.32	The actual track and the track generated using the Kalman filter (Yim et al., 2010)	176
4.33	AI-DSS (white face) compared against the detected path (gray face)	177
4.34	One to one comparison between the last 10 actual locations ($\text{Location}_{\text{WLAN}}$) and 10 predicted locations ($\text{Location}_{\text{AI-DSS}}$)	178



LIST OF ABBREVIATIONS

AP	Access Point
AHL	Active Hebbian Learning
AOA	Angle of Arrival
AI	Artificial Intelligence
AI-DSS	Artificial Intelligence-Decision Support System
APF	Artificial Potential Fields
AGV	Automated Guided Vehicle
BHL	Blind Human Locomotion
BBD	Brain-based Device
CBR	Case-Based Reasoning
DR	Dead Reckoning
DSS	Decision Support System
EEG	Electro-Encephalography
EKF	Extended Kalman Filter
FHSS	Frequency Hopping Spread Spectrum
FCM	Fuzzy Cognitive Map
FLC	Fuzzy Logic Control
GA	Genetic Algorithm
GPS	Global Positioning System
GUI	Graphical User Interface
HCI	Host Control Interface
IMU	Inertial Measurement Unit
IR	Infrared
KF	Kalman Filter
KBS	Knowledge-based System
LQ	Link Quality
LBS	Location-based Service
MAB	Malaysian Association for the Blinds
MT	Mobile Terminal



NN	Neural Network
NLP	No Light Perception
PDA	Personal Digital Assistant
PSO	Particle Swarm Optimization
RF	Radio Frequency
RFID	Radio Frequency Identification Devices
RSSI	Received Signal Strength Indication
RPY	Roll-Pitch-Yaw
RMS	Root Mean Square
SNR	Signal to Noise Ratio
SW	Straight Walk
SWSR	Straight Walk and then Straight Return
TOA	Time of Arrival
UDP	Undetectable Direct Path
WF	Wall Following
WLAN	Wireless Local Area Network
WHO	World Health Organization



CHAPTER 1

INTRODUCTION

1.1 Background

There are various techniques for tracking intelligent travelers, i.e., subjects whose motion involve deliberative as well as reactive behaviors. Motion tracking has wide range of applications in security, surveillance, etc. However, due to partial or total loss of actual positioning information, motion prediction techniques have to be employed using simulation tools to predict the future motion. There are many algorithms developed for motion prediction of intelligent and non-intelligent travelers (Bennewitz et al., 2002; Bruce and Gordon, 2004; Iglesias and Luengo 2007; Vasquez and Fraichard, 2004; 2005; Ciurana et al., 2007; 2007b).

As the first approach, there are different kinematical models of path prediction for moving objects such as dead reckoning (DR) (Randell et al., 2005; Warren and Fajen, 2004). But when it comes to intelligent subjects e.g., human or any biological mechanism, there is no mathematical solution to take the challenge of motion prediction that is due to inherent uncertainties and variability of such systems. Kalman filter



(Kalman, 1960) and other recursive filters, as well as Markov localization (Fox, 1998) have been widely used to minimize DR errors. However, they require continuous supply of actual data for update stage of the filter or update of the transition matrix.

In these situations, another approach is to resort to statistical models (Vasquez and Fraichard, 2004). However, the main problem of statistical methods is in the stage of clustering and generation of path patterns (Jain et al., 1999) which requires lots of experimental work with subjects of the same type that is not always possible.

The third approach is to use the knowledge of the past trajectory to predict the future motion based on kinematical (Ciurana et al., 2007a; 2007b), statistical (Vasquez et al., 2005), or artificial intelligence models (Luengo and Iglesias, 2004). The future trajectory of an intelligent subject can be estimated by learning its motion behaviors from the past trajectory. However, in the related works, identification of the motion factors involved in generation of the past trajectory has been based on either kinematical characteristics, or decision making behaviors.

Wireless local area network (WLAN) systems are used for indoor tracking of human and other intelligent travelers e.g., mobile robots, automated guided vehicles (AGV), which are equipped with wireless mobile terminals (MT). Traditionally, the wayfinding behaviors of these travelers have been investigated from a single point of view. The traveler has been either treated as a moving object based on kinematical analysis of motion factors, or as a truly intelligent subject based on decisional factors of motion.

