An Integrated Simulation Model of Pedestrian Movements

The outline of the model and measurement systems

Kay Kitazawa

Contents

2

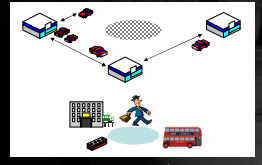
Background

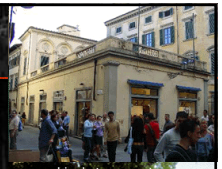
- Urban planning
- Spatial marketing
- Location-based services

3

Background

- Urban planning





Lively town centres

Pedestrian-oriented planning

4

Background

- Pedestrian-oriented urban planning
  - ✓Safety — less crime, fewer traffic accidents
  - ✓Convenience — accessibility to transport, shops, services
  - ✓Amenity — comfortable walking environment

Actual movements
Necessary information
Influential factors

Needs for Pedestrian behavior model

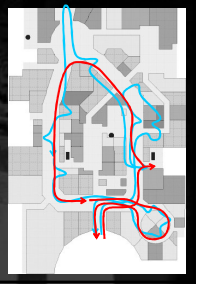
5

Background

- Spatial marketing
  - ✓Tenant strategy (leasing, fee)
  - ✓Improvement of -floor plans
    -signage system

Actual movements
Influential factors

Needs for Pedestrian behaviour model



6

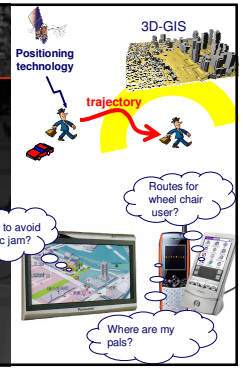
Background

- Location-based services

Provide appropriate information according to user's location / needs

Patterns of users' routes/activities
Necessary Information - contexts

Needs for Pedestrian behavior model



7

Requirements of pedestrian behavior models

- There are several needs to develop pedestrian behaviour models
- Key issues
  - ✓Understand and explain real pedestrian's movement
  - ✓Represent dynamic interaction process between pedestrians and their environment

(esp. Information which people obtain)

8

Requirements of pedestrian behavior models

Current pedestrian behavior models

✓Crowd dynamics

Micro scale behaviour (e.g. obstacle avoidance)

✓Transport model

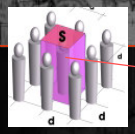
Network analysis and OD/route estimation

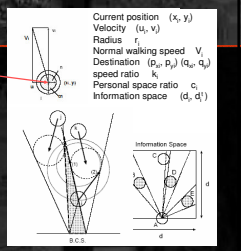
✓Stochastic model

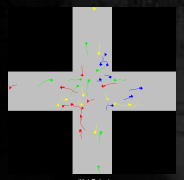
Probability of state-to-state transition

9

Crowd dynamics







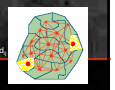
(Kai Bolay)

⬆ Estimation of the next steps of other pedestrians

⬅ Collision avoidance bahaviour

10

Transport model



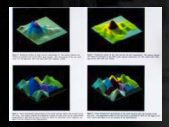
Shortest path between OD

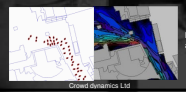
(weights associated with each link can be distance, costs, condition of the road, etc)

- Influence of other areas?
- Which area generates more trips than others?
- Why?

Gravity model $y_{ij} = \alpha_i^x \beta_j^y e^{\mu_{ij}}$

α_i potential as origin
β_j potential as destination





Most evacuation models adopt this concept

Crowd dynamics Ltd

11

Logit model --- calculate probability of discrete choice

$$p_{ij} = \frac{\exp\left(-\alpha d_{ij} + \sum_k \beta_k A_{jk}\right)}{\sum_{j=1}^{n} \exp\left(-\alpha d_{ij} + \sum_k \beta_k A_{jk}\right)}$$

Consumer: $C_1, C_2, \ldots C_n$

Shop: $S_1, S_2, \ldots S_n$

Attribute k of shop S_j: A_{jk}

Probability of C_i choosing S_j: p_{ij}

Distance between Ci and Sj: d_{ij}

parameter estimation by maximum-likelihood method

12

Stochastic model

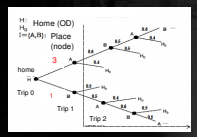
Marcov chain model

From \ To	A	B	H	total
A	0	0.6	0.4	1
B	0.5	0	0.5	1
H	3	1	0	

P_{II} Probability of visiting from one place to another

F_{HI} The observed number of people at their first destination

P_{IH} Probability of being the last destination



・Number of people who visit each place via another (Trip n : n>1)

$$RE = F_{HI}P_{II} + F_{HI}P_{II}^{2} + \cdots = F_{HI}P_{II}(I - P_{II})^{-1}$$

13

Requirements of pedestrian behavior models

	advantage	disadvantage
✓Crowd dynamics	• Well represent micro-scale physical response • Dynamic	Not take it into account: • where they are going to and why • pre-fixed route = static model • geographical attributes
✓Transport model	•Suitable for description of selection behavior	Several things can't be represented: • interaction between others/environment •cognitive process of pedestrian
✓Stochastic model	•Useful for being briefed on how people move around •Capable of representing changeability of movements	•Inadequate to small scale movement •Not explain why they choose certain place

Understand and explain real pedestrian's movement

Represent dynamic interaction process between pedestrians and their environment

New pedestrian behaviour models are needed

14

Research Aim and Objectives

To develop a new pedestrian behavior model

✓be capable of explaining real pedestrian's movement

Every factors should be determined based on observed data
It can deal with more complex behavior (e.g. shopping)

✓represents dynamic interaction between pedestrians and their environment

To deal with not only pre-determined route-choice
but also people's cognitive process or other changeable events

✓can be used as a simulation model

To visualize, To make the model easy to understand, more transferable

✓be validated through comparison between actual trajectories

It should be different from playing with beautiful animation

15

Framework of the model

Integrated Simulation Model of Pedestrian Movements

Built environment agents

Geographic attributes
Attraction level

Knowledge
Needs

Pedestrian agents

Multi-agent-based model

Interaction between environment
✓**collision avoidance**
✓**walking speed**
✓**basic walking tendencies (e.g.avoid rapid turn over)**

Stimuli-Response

Calculation of the optimum route
✓**shortest path**
✓**cognitive process**
✓**spatial knowledge**

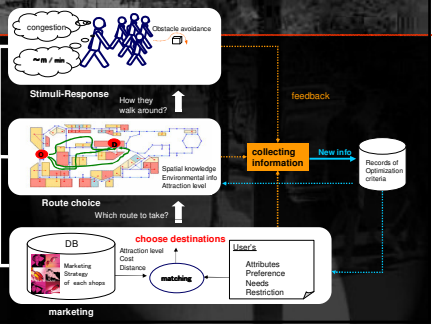
Route choice

Matching between people's preference/needs and attributes of places
✓**Which place to be chosen as a destination?**

Marketing

16

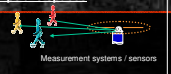
Framework of the model 3 levels of pedestrian's behavior



17

Methodology

Survey of pedestrian movement in public spaces



Measurement systems / sensors

•**Trajectory → walking patterns**
•**Network analysis** → factors in route selection

Stimuli-response
Route choice
Marketing

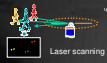
Marketing research

•Develop DB of attributes of the place
•Analysis on relationship between the shop's attributes and those of individuals

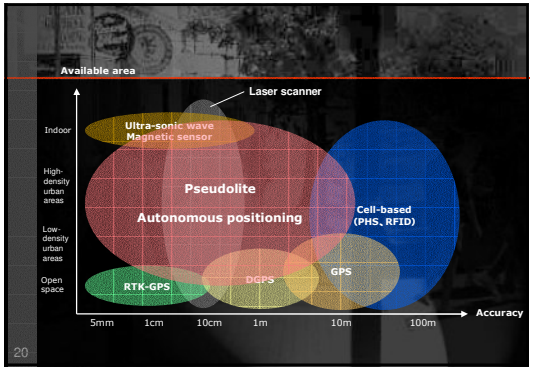
18

Current positioning technologies

- ✓GPS-based technology
- ✓Cell-based technology
- ✓Image processing
- ✓Autonomous-positioning
- ✓Laser scanning
- ✓Ultra-sonic wave
- ✓Traffic counter



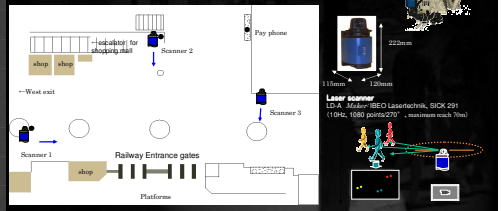
19



20

Survey on pedestrian movement in a railway station

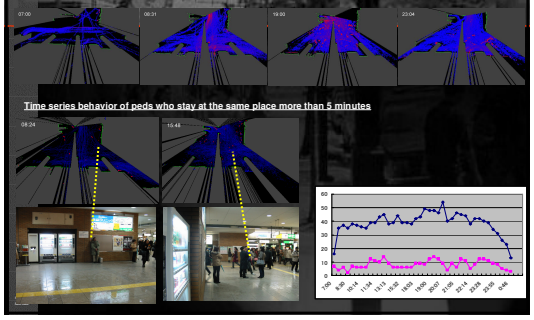
■Time 2003/02/21(fri) 5:00 - 2003/02/22(Sat) 25:00



Routes = consecutive series of coordinates(ID,t,x,y)

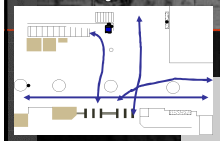
21

Analysis on basic walking patterns



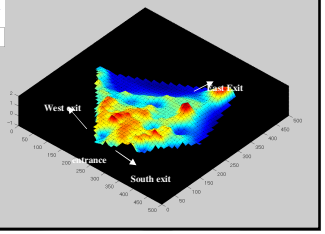
Time series behavior of peds who stay at the same place more than 5 minutes

Analysis on basic walking patterns



Distribution of walking speed in the concourse

→relationship between distance from walls, entrance, other peds



✓Identify the place where two traffic flows cross each other

✓Identify how pedestrians avoid obstacles

23

Research plan

✓**Survey of pedestrian movement in public spaces**

- ●walking patterns
- ●Distance between other pedestrians
- ●Distance between objects (walls, columns)
- ●Walking speed
  - •Avarage speed
  - •distribution
  - •relation between objects
- ●Network analysis → factors in route selection
  - •width of corridor
  - •visibility
  - •connection to other network

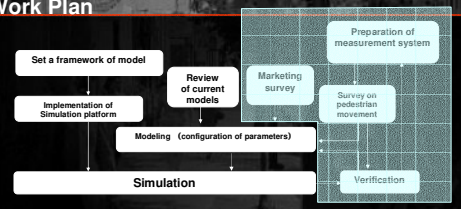
✓**Marketing research**

- ●Develop DB of attributes of the place
- ●Analysis on relationship between the place's attributes and those of pedestrian
  - •What kind of people go to WHICH place (shop/restaurant)
  - •HOW often?
  - •WHY?

Implement simulation

24

Work Plan



✓Best case
- •Resource Funding— need to buy sensors!!!!
- •Permission Survey fields (railway stations, high streets, public square, shopping malls)
- •Marketing data DB of geo-demographic data of their customers

✓Worst case
- •Use old data to implement models
- •Less accurate verification

25

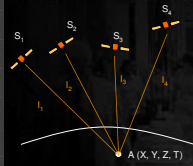
Thank you!

Kay Kitazawa

k.kitazawa@ucl.ac.uk
http://www.casa.ucl.ac.uk/kay

26

GPS-based technology



GPS satellite positions

(x_i, y_i, z_i, t_i) i =1..4

$(X-x_i)^2 + (Y-y_i)^2 + (Z-z_i)^2 = I_i^2$

$= C^2 * (T - t_i)^2$ → (X, Y, Z, T)

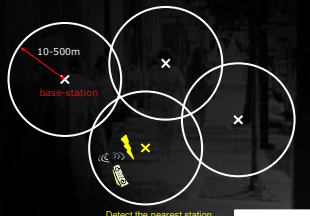
✓Requirement
Signals from at least 4 different satellites

✓Lots of complementary technologies

DGPS	Improve the accuracy by FM radio wave	0.3m-10m
RTK-GPS	Receive the same GPS signal at a reference points & mobile receiver	1-10cm
Pseudolite	Set transmitters which emit signal similar to that of GPS	6-30cm
SnapTrack	Mobile GPS receiver and server	10-100m
Indoor GPS	High-reception receiver	10-100m
GPS one	Combination of GPS and cellular system	10-500m

27

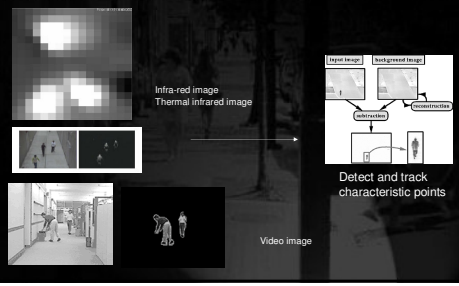
Cell-based positioning



- ✓Cellular phone
- ✓PHS
- ✓RFID Tag
- ✓Beacon (GI Stone)

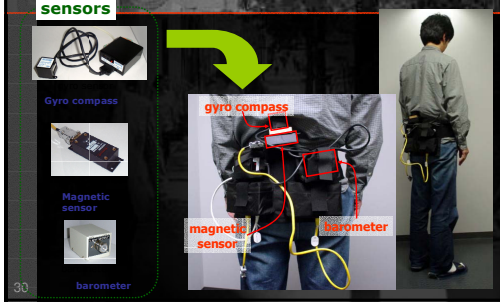
28

Image processing

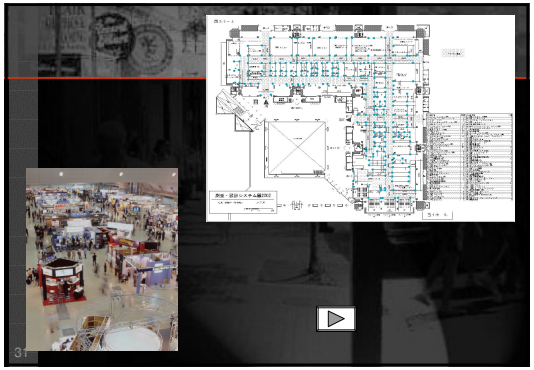


29

sensors

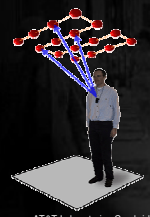


30

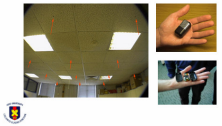


Ultra-sonic wave

trilateration measurement of distances from 3 points



3-D Active Ba



AT&T Laboratories Cambridge