Real-time Applications of Particle Filters in the Engineering Field

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Approach : State space modeling

Formulate the dynamic scene into a state space model and grasp the situation by state estimation

State vector $\boldsymbol{x}_k = (x_1^k, \cdots, x_n^k)$

Car driver’s status (posture, etc.)

System model $f(\boldsymbol{x}_k \mid \boldsymbol{x}_{k-1})$

Car driver’s behavior

Formulate the motion of car driver

Observation model $h(\boldsymbol{y}_k \mid \boldsymbol{x}_k)$

$\boldsymbol{y}_k$ Obs.

Formulate a process of sensing

Likelihood computation : likeliness of hypothesis

Face : :position and direction

Hands :
positions : angular positions
directions of arms

Time smoothness

Motion by free will :
random variation
special property in driving

Face :
pupils, face detection

Hands :
palm, wrist

Formal solution to state estimation

Alternative application of prediction and filtering for time update

One-step-ahead Prediction

Convolution

$$p(\boldsymbol{x}_k \mid \boldsymbol{y}_{1:k-1}) = \int p(\boldsymbol{x}_{k-1} \mid \boldsymbol{y}_{1:k-1}) f(\boldsymbol{x}_k \mid \boldsymbol{x}_{k-1}) d\boldsymbol{x}_{k-1}$$

Filter of previous — System model

Filtering

Bayes rule

Observation model — Prior

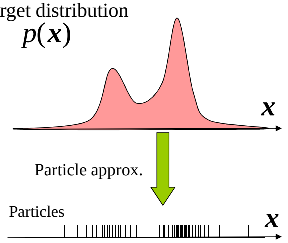
$$p(\boldsymbol{x}_k \mid \boldsymbol{y}_{1:k}) = \frac{h(\boldsymbol{y}_k \mid \boldsymbol{x}_k) p(\boldsymbol{x}_k \mid \boldsymbol{y}_{1:k-1})}{p(\boldsymbol{y}_k \mid \boldsymbol{y}_{1:k-1})}$$

Filter of current (posterior)

Likelihood

Approximation of distribution by many particles

Monte Carlo approximation



$\{\boldsymbol{x}^{(l)}\}_{l=1}^{M} \sim p(\boldsymbol{x})$

Filtering $p(\boldsymbol{x}_k \mid \boldsymbol{y}_{1:k})$

≀

Particles $\{\boldsymbol{x}_k^{(l)}\}_{l=1}^{M}$

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Monte Carlo Filter, Bootstrap Filter (SIR filter)

Simplest particle filter

Approximate computation of prediction and filter by particles

prediction

(1) Sampling — Particles of one-step-ahead prediction

System model

$$\tilde{\boldsymbol{x}}_k^{(l)} \sim f\left(\boldsymbol{x}_k \mid \boldsymbol{x}_{k-1}^{(l)}\right) \quad l = 1,2,\cdots,M$$

(2) Importance — Likelihood by observation model

Obs. model

$$\tilde{w}_k^{(l)} = h\left(\boldsymbol{y}_k \mid \tilde{\boldsymbol{x}}_k^{(l)}\right) \quad l = 1,2,\cdots,M$$

Go to the next time step

filtering

(3) Re-sampling — Particles of filter

Draw with prob. prop. to $\tilde{w}_k^{(l)} \Rightarrow \boldsymbol{x}_k^{(l)} \quad l = 1,2,\cdots,M$

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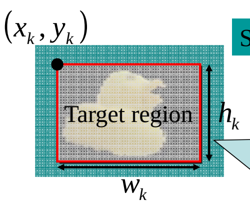
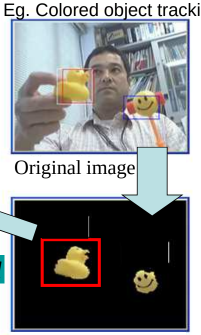
Visual Tracking : Pixel ratio likelihood

Observation model



Eg. Colored object tracking



Original image

Colored pixel extraction

Pixel ratio of colored pixel in target region p

Pixel ratio of colored pixel in surrounding region q

Log-liklihood = log(p) + log(1 - q)

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Visual tracking : simple target

Colored object tracking

Target shape : rough approximation by rectangle

State vector : target's position / velocity and shape

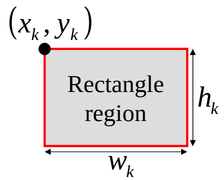
Location of rectangle — Width and height of rectangle

$$\boldsymbol{x}_k = \left(x_k, y_k, x_{k-1}, y_{k-1}, w_k, h_k\right)'$$

System model

$$\boldsymbol{x}_k = \boldsymbol{F}\boldsymbol{x}_{k-1} + \boldsymbol{G}\boldsymbol{v}_k$$

$$\boldsymbol{F} = \begin{bmatrix} 2 & 0 & -1 & 0 & & \\ 0 & 2 & 0 & -1 & & \\ 1 & 0 & & & & \\ 0 & 1 & & & & \\ & & & & 1 & 0 \\ & & & & 0 & 1 \end{bmatrix} \quad \boldsymbol{G} = \begin{bmatrix} 1 & 0 & & \\ 0 & 1 & & \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ & & 1 & 0 \\ & & 0 & 1 \end{bmatrix}$$



$$\boldsymbol{v}_k = \left(v_k^x, v_k^y, v_k^w, v_k^h\right)' \sim N(\boldsymbol{0}, \boldsymbol{Q})'$$

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Likelihood : pixel ratio of target region

Observation mode for likelihood computation

$$h(\boldsymbol{I}_k|\boldsymbol{x}_k) = \mu_R(\boldsymbol{I}_k, \boldsymbol{x}_k) \times \{1 - \mu_S(\boldsymbol{I}_k, \boldsymbol{x}_k)\}$$

$\in [0,1]$ $\in [0,1]$

Pixel ratio likelihood

Count the number of target pixels in the target region.

(x_k, y_k) $R(\boldsymbol{x})$ $S(\boldsymbol{x})$ s_k

ROI (Region Of Interest): $R(\boldsymbol{x}) \subset D$

Surrounding region of the ROI: $S(\boldsymbol{x}) \subset D$

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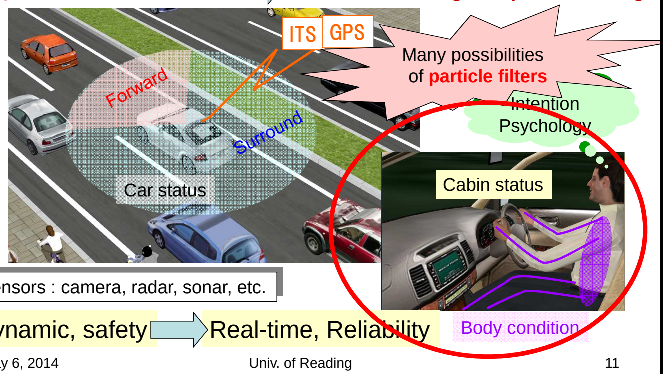
Automotive Applications

Advanced car driving support using highly functional sensors

Signal ≠ Information ⇒ Advanced signal processing



Sensors : camera, radar, sonar, etc.

Dynamic, safety ⇒ Real-time, Reliability Body condition

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Background : car driver's behavior estimation

- Active use of highly functional sensors such as camera
  - Due to recent price down and becoming easy to use
- Expected use for safety driving support of cars
  - Surrounding sensing by on board sensors
  - Car driver sensing in cabin
  - Traffic grasping by infrastructure sensors

•Observation behavior
•Driving operations
•Other motions

Possibilities for various safety driving support

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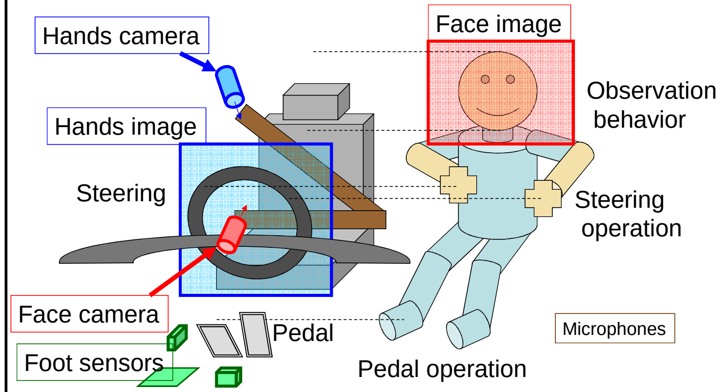
Measurement of car driver : Requirement

- Non-contact
  Not attach sensors to the driver's body.
- No-restriction
  Not disturb driving operations.
- Non-invasive
  Not affect driver's health.
- No-marker, No-regulation on the scene
  Natural (actual) scene measurement.

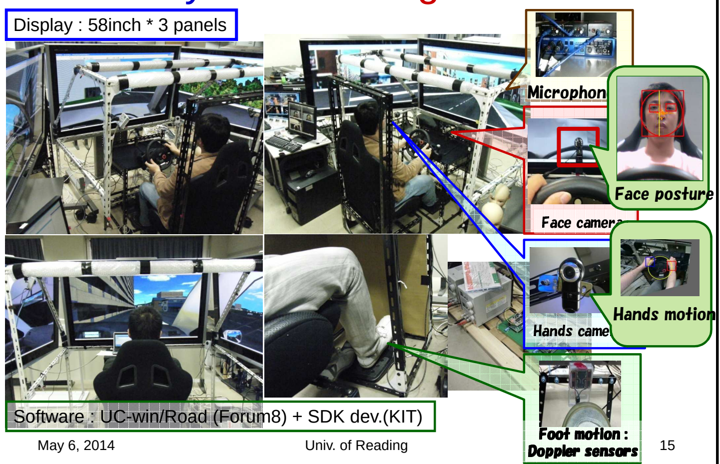
Car driver's behavior : Sensors and Sensing items



N.Ikoma, et.al., "Car Driver's Body Motion Estimation for Safety Driving using Particle Filter", Proc. of 4th International Symposium on Computational Intelligence and Industrial Applications (ISCIIA2010), 2010.

Facility : Car Driving Simulator

Display : 58inch * 3 panels



Software : UC-win/Road (Forum8) + SDK dev.(KIT)

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Estimation of face posture of car driver

- Front view of the face over the steering
- Pupils' positions over the image
- Supplement use of face detector
- Face posture estimation in 3D (real) space
  - 6 DOF $(x, y, z, \theta, \psi, \varphi)$

    => 3DOF (x, y, θ) as first
- Grasping the driver's observation behavior
  - Safety driving support adaptive to the driver's condition, recognition, and intention

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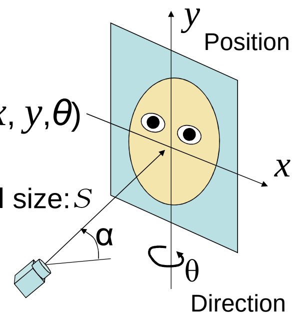
Simplified scene of face posture

- Simplified face model
  - Solid shape => flat face
  - Focus on two pupils
- State variables: 3DOF(x, y, θ)
- Fixed parameters
  - Interval of pupils: D, pupil size: S
  - Elevation of camera: α
  - Other 3DOF (z, ψ, φ)



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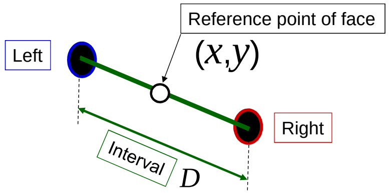
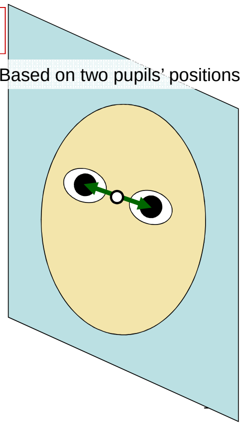
Simplified face posture model

Center of pupil : eye position

Interval D: btw two pupils

Ref. point of face :mid. point





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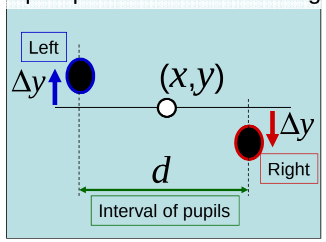
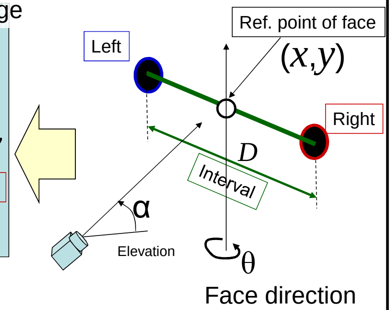
Face direction : image appearance

Pupils' positions over the image





$$d = D \cos \theta$$

$$\Delta y = \frac{D}{2} \sin \alpha \sin \theta$$

Rot. axis: middle of pupils

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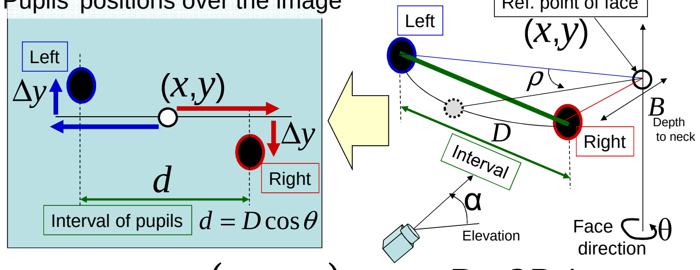
Face direction : more precise model

Rot. axis : neck

Pupils' positions over the image



$$D = 2B\sin\rho$$

$$\Delta x = B\sin(\theta \pm \rho)$$

$$\Delta y = B\sin\alpha\{\cos(\theta \pm \rho) - 1\}$$

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System model : face motion

State vector $\boldsymbol{x}_k = (x_k \quad y_k \quad \theta_k)$

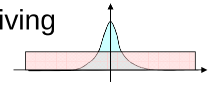
Pos: (x, y) : arbitral motion and swaying in driving

$x_k = x_{k-1} + v_k^x \qquad y_k = y_{k-1} + v_k^y$

Gaussian ($x \perp y$) Similar to previous time step

Direct: (θ) : typical motion in driving

$\theta_k = \theta_{k-1} + v_k^\theta$



Gaze at the target : almost no motion => Gaussian N(0, σ^2)

Some changes in direction : abrupt change => Heavy tailed dist.

Gaussian + uniform (out of $\pm\sigma$) : mixture

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Fixed parameters estimation

"Initial phase" : estimate as state variable

$\boldsymbol{x}_k = (x_k \quad y_k \quad D_k \quad S_k)$

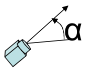
Assumption : face directs straight (θ=0)

"Tracking phase" : use the result as fixed value

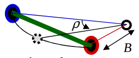
$\boldsymbol{x}_k = (x_k \quad y_k \quad \theta_k) \qquad \{D, \quad S\}$

Interval of pupils — Pupil size

Fixed (given) parameters



$\{\alpha, \quad \rho\}$



Elevation of camera — Spread angle of eyes

$D = 2B\sin\rho$

Other 3DOF (z, ψ, φ) — Angles : 0; z: fixed

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Observation model : likelihood

Likelihood = Pupils likeliness × Face position

Pupils likeliness

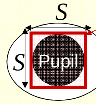
Pupil region : roughly in rectangle

Likeliness : evaluated by color

=> dist. in L*a*b* color space

Dist = | Ref.color - pixel color |

Rough approx. by rect.



(Normalized mean value) p

of dist in the region

Dist=0 => 1
Dist=max => 0

Face position

Face position(s) by detector

"Missing" (not detected)
=> No evaluation of likelihood

"False detection" (wrong detection)
=> Heavy tailed distribution

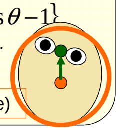
Middle point over the image (offset)

$\Delta x = B\sin\theta$

$\Delta y = B\sin\alpha\{\cos\theta - 1\}$

Height offset to face det.

$\Delta y += H$



Face detection (circle)

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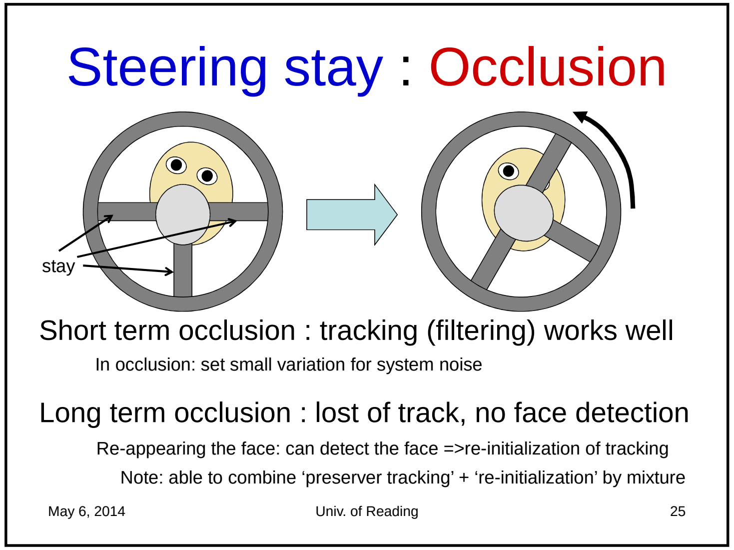
Steering stay : Occlusion
stay
Short term occlusion : tracking (filtering) works well
In occlusion: set small variation for system noise
Long term occlusion : lost of track, no face detection
Re-appearing the face: can detect the face =>re-initialization of tracking
Note: able to combine ‘preserver tracking’ + ‘re-initialization’ by mixture
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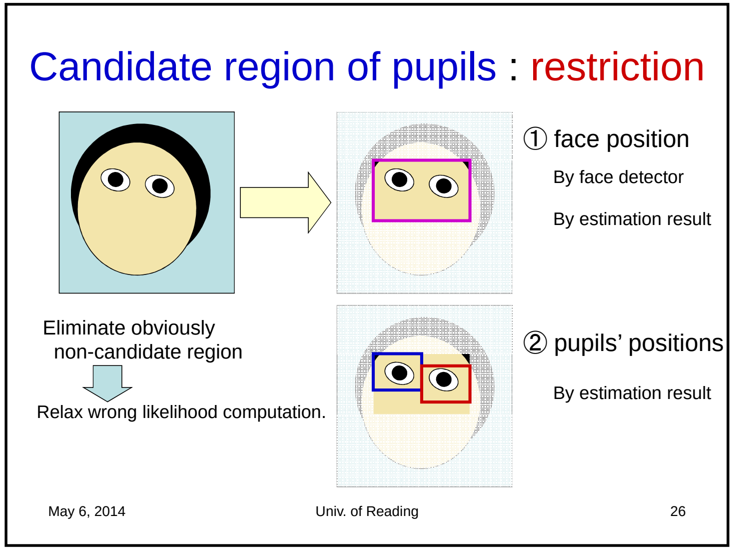
Candidate region of pupils : restriction
① face position
By face detector
By estimation result
② pupils’ positions
By estimation result
Eliminate obviously non-candidate region
Relax wrong likelihood computation.
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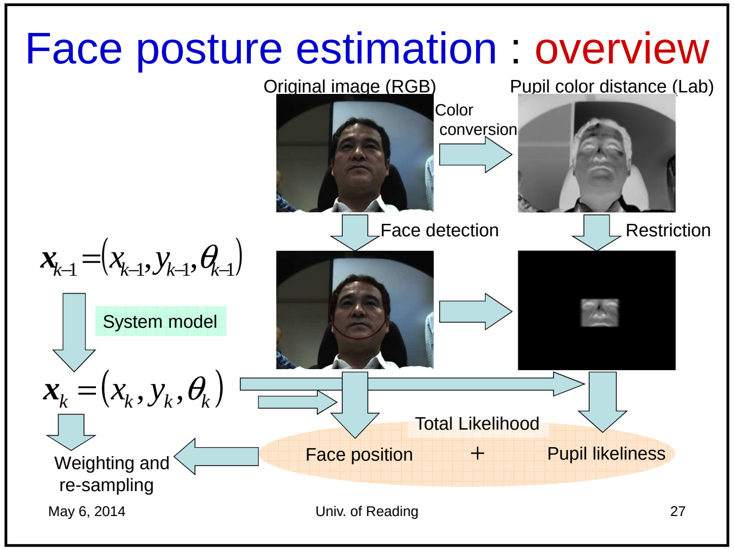
Face posture estimation : overview
Original image (RGB)
Color conversion
Pupil color distance (Lab)
Face detection
Restriction
$x_{k-1} = (x_{k-1}, y_{k-1}, \theta_{k-1})$
System model
$x_k = (x_k, y_k, \theta_k)$
Total Likelihood
Face position
+
Pupil likeliness
Weighting and re-sampling
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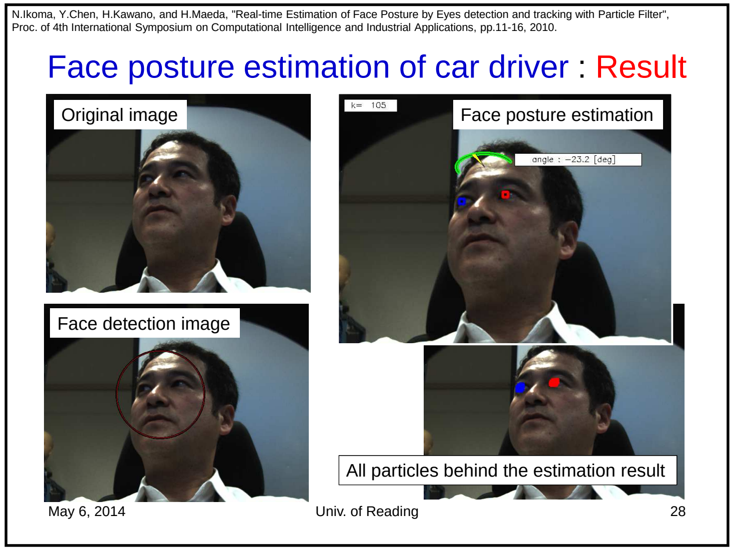
N.Ikoma, Y.Chen, H.Kawano, and H.Maeda, "Real-time Estimation of Face Posture by Eyes detection and tracking with Particle Filter", Proc. of 4th International Symposium on Computational Intelligence and Industrial Applications, pp.11-16, 2010.
Face posture estimation of car driver : Result
Original image
Face posture estimation
Face detection image
All particles behind the estimation result
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Hands motion estimation of car driver

Most complex motion in driving : Hands motion estimation

Camera above the seat-belt roller to capture the image

- Problem and approach
  - By discriminating left and right hands
    Estimate gripping positions over the steering
  - Focus on skin color
  - Estimate angles on circumference of steering
    - Projective transformation: look straight image
    - Skin color extraction
    - Time-varying angles of gripping for left/right hands

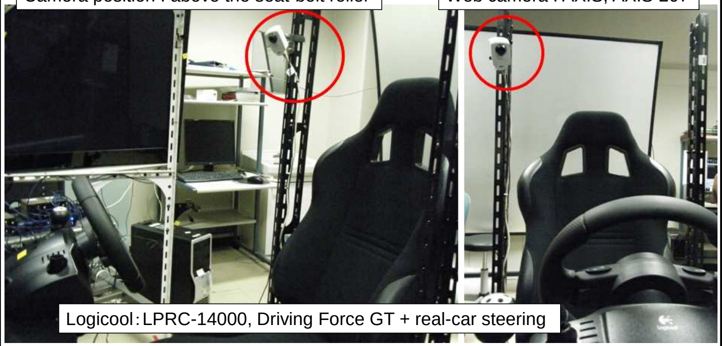
Hands motion estimation of car driver : available sensors

- Camera above the seat-belt roller
  - Capture the image of steering manipulation
- Steering manipulated variable
  - Steering angle
- Body motion sensor inside the steering
  - Incomplete : under consideration

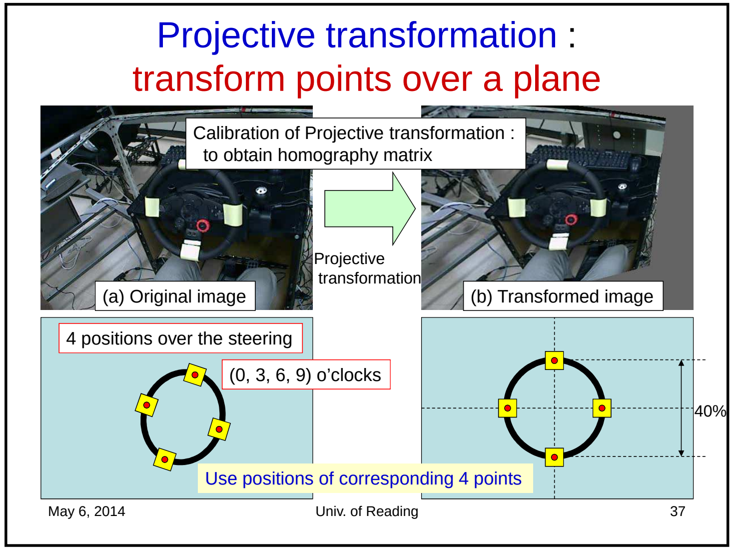
Experimental facility : camera set up

Camera position : above the seat-belt roller

Web camera : AXIS, AXIS 207



Camera set up above the seat-belt roller (upper right pillar)


Projective transformation :
transform points over a plane
Calibration of Projective transformation :
to obtain homography matrix
Projective
transformation
(a) Original image
(b) Transformed image
4 positions over the steering
(0, 3, 6, 9) o'clocks
40%
Use positions of corresponding 4 points
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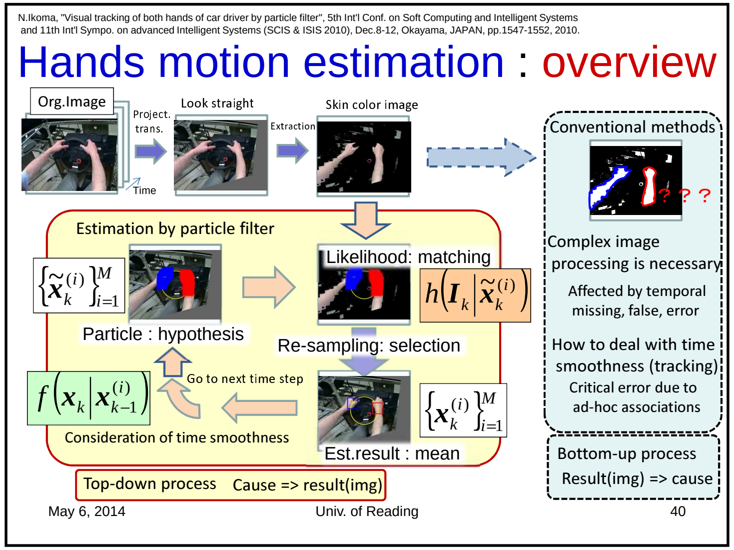
N.Ikoma, "Visual tracking of both hands of car driver by particle filter", 5th Int'l Conf. on Soft Computing and Intelligent Systems and 11th Int'l Sympo. on advanced Intelligent Systems (SCIS & ISIS 2010), Dec.8-12, Okayama, JAPAN, pp.1547-1552, 2010.
Hands motion estimation : overview
Org.Image
Project. trans.
Time
Look straight
Extraction
Skin color image
Conventional methods
? ? ?
Complex image processing is necessary
Affected by temporal missing, false, error
How to deal with time smoothness (tracking)
Critical error due to ad-hoc associations
Estimation by particle filter
Likelihood: matching
Particle : hypothesis
Re-sampling: selection
Go to next time step
Consideration of time smoothness
Est.result : mean
Top-down process Cause => result(img)
Bottom-up process Result(img) => cause
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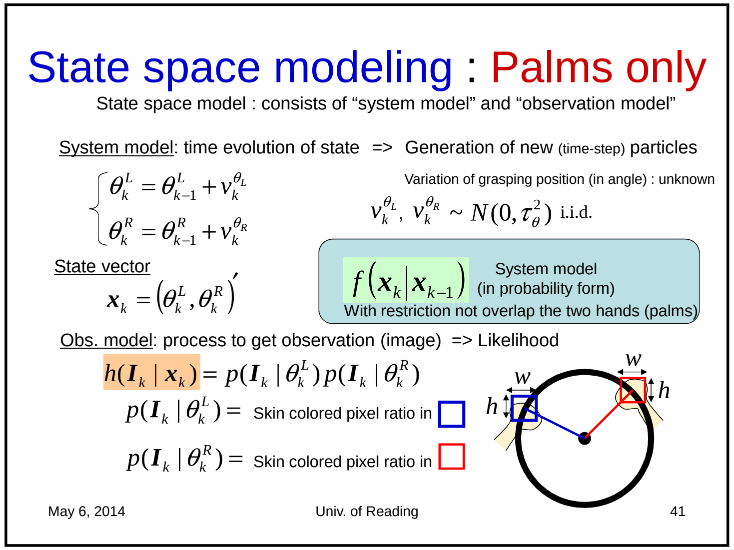
State space modeling : Palms only
State space model : consists of "system model" and "observation model"
System model: time evolution of state => Generation of new (time-step) particles
Variation of grasping position (in angle) : unknown
i.i.d.
State vector
System model
(in probability form)
With restriction not overlap the two hands (palms)
Obs. model: process to get observation (image) => Likelihood
Skin colored pixel ratio in
Skin colored pixel ratio in
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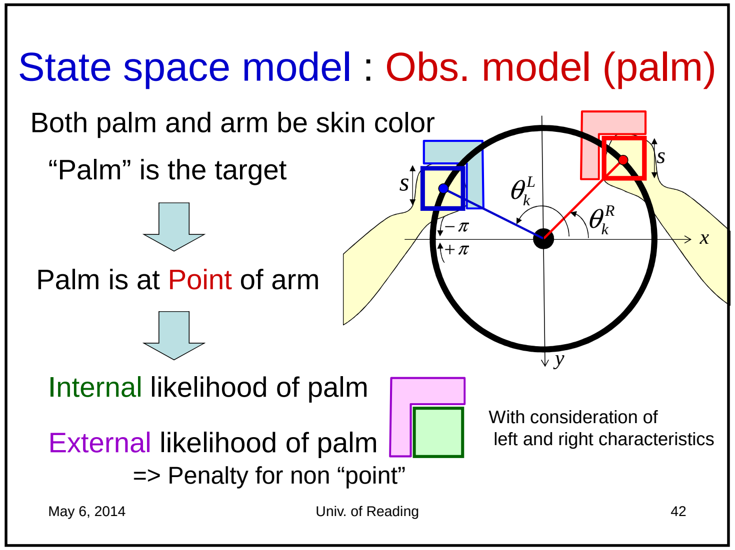
State space model : Obs. model (palm)
Both palm and arm be skin color
"Palm" is the target
Palm is at Point of arm
Internal likelihood of palm
External likelihood of palm
=> Penalty for non "point"
With consideration of
left and right characteristics
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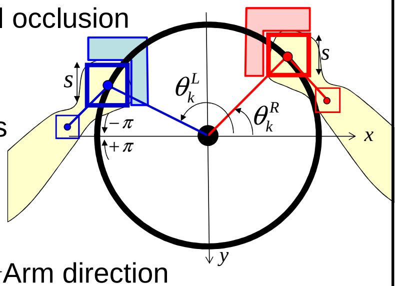
State space model : Obs. model (wrist)

Arms : possible mutual occlusion

Estimate arm directions

"Palm" position + "Wrist" position } Arm direction



Eliminate Other arm from this arm's image

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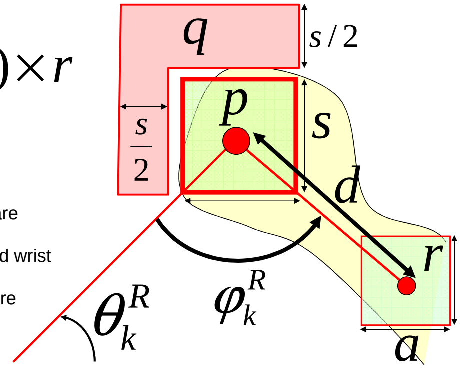
Obs. model (wrist) : Detail

Likelihood:

$$p \times (1-q) \times r$$

Fixed parameters:

- S : size of palm square
- d : dist. Btw palm and wrist
- a : size of wrist square



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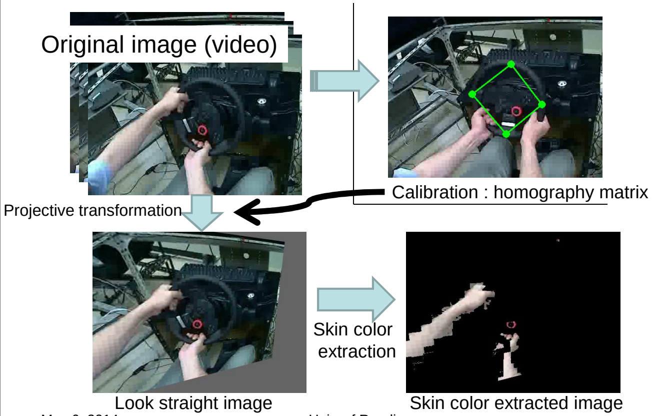
Pre-processing on captured image



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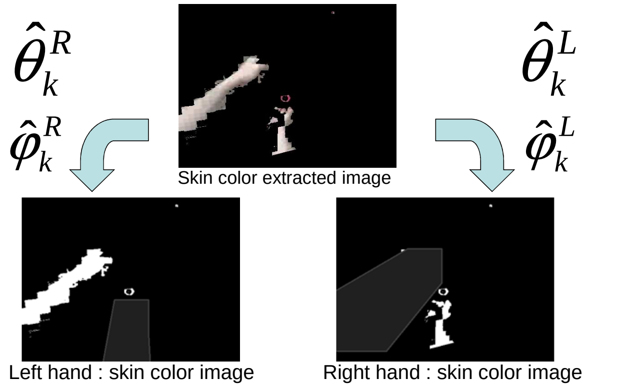
Mutual occlusion : elimination of other arm



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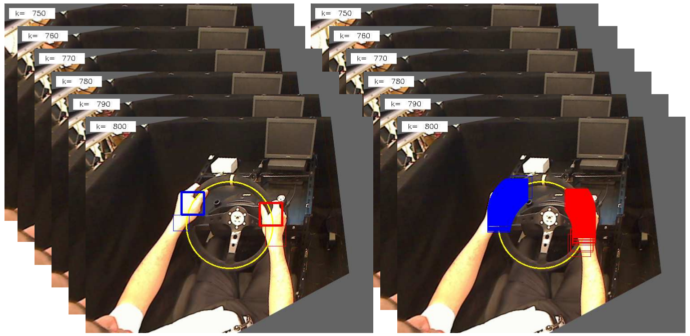
N.Ikoma, "Visual tracking of both hands of car driver by particle filter", 5th Int'l Conf. on Soft Computing and Intelligent Systems and 11th Int'l Sympo. on advanced Intelligent Systems (SCIS & ISIS 2010), pp.1547-1552 , 2010.

Hands motion estimation : result



Estimated hands motion

All particles behind the estimation result

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[5] Norikazu Ikoma, "Real-Time Motion Estimation of Car Driver 's Hands and Arm's Direction in Vision under Possible Mutual Occlusion by Particle Filter", 6th Int 'l Conf. on Soft Computing and Intelligent Systems and 13th Int 'l Sympo. on advanced Intelligent Systems (SCIS & ISIS2012), pp.701-704, 2012.

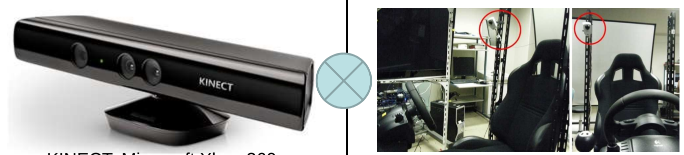
Background and Motivation

Depth Image Sensor

Rich information than simple vision sensor

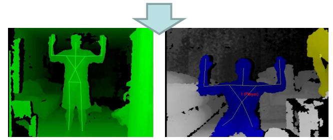
Car driver's hands motion

Basis of safety driving support

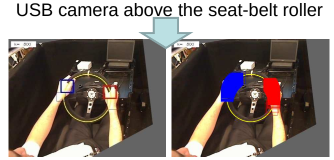


KINECT, Microsoft Xbox 360

USB camera above the seat-belt roller



Frontal body motion by skeleton model.



Hands motion by particle filter.

* These images are obtained through the internet.

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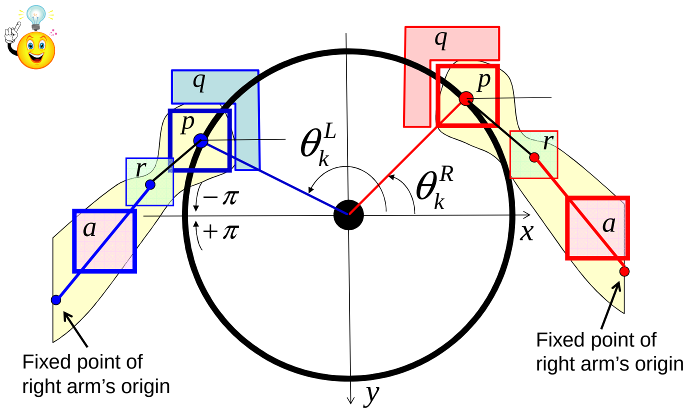
Observation model : arm likelihood



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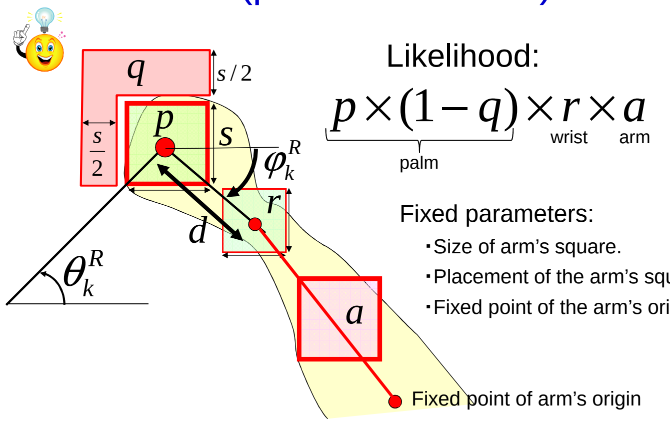
Obs. model (palm+wrist+arm) : Detail



Likelihood:

$$p \times (1-q) \times r \times a$$

palm, wrist, arm

Fixed parameters:

- Size of arm's square.
- Placement of the arm's square.
- Fixed point of the arm's origin.

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Intentional switching of left and right

In previous works : separate system models for left/right

System model (LEFT hand/arm)

$$\begin{cases} \tilde{\theta}_k^L = \theta_{k-1}^L + v_k^{\theta_L} \\ \tilde{\varphi}_k^L = \varphi_{k-1}^L + v_k^{\varphi_L} \end{cases}$$

System model (RIGHT hand/arm)

$$\begin{cases} \tilde{\theta}_k^R = \theta_{k-1}^R + v_k^{\theta_R} \\ \tilde{\varphi}_k^R = \varphi_{k-1}^R + v_k^{\varphi_R} \end{cases}$$

$$\boldsymbol{x}_k = \left[\boldsymbol{x}_k'^L , \boldsymbol{x}_k'^R \right], \quad \boldsymbol{x}_k^\bullet = \left[\theta_k^\bullet , \varphi_k^\bullet \right], \bullet \in \{L, R\}$$

With small probability δ, swap left and right :

$$\boldsymbol{x}_k = \begin{cases} \left[\tilde{\boldsymbol{x}}_k'^R , \tilde{\boldsymbol{x}}_k'^L \right] & with \ \ prob. \ \ \delta \\ \left[\tilde{\boldsymbol{x}}_k'^L , \tilde{\boldsymbol{x}}_k'^R \right] & with \ \ prob. \ \ 1-\delta \end{cases}$$

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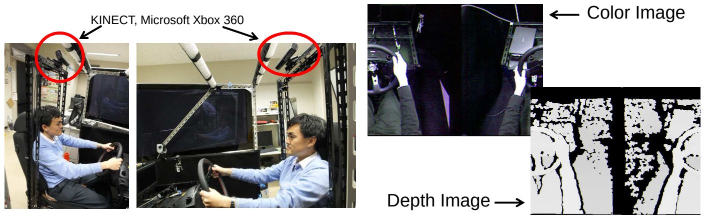
Experiment : recording the videos

Video recording with the depth image sensor, KINECT Xbox360

- Driving Simulator in the Laboratory
  - Recorded date : April 22, 2013.
  - Two test subjects (A and B), three runs for each subject.
  - Driving in an elaborated road in the simulator.



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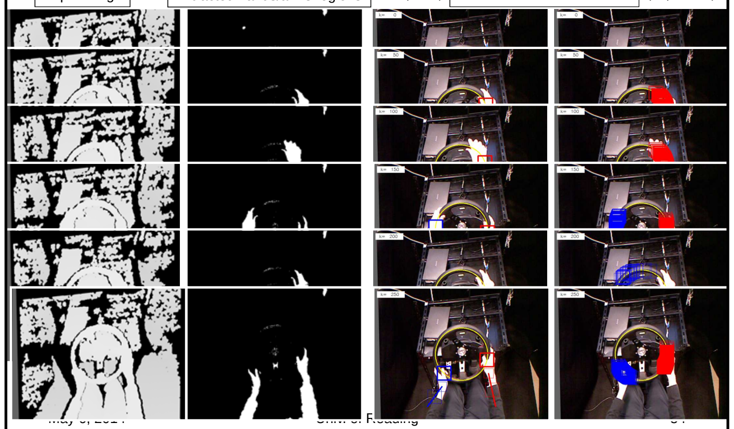
Data : test subject-A (Apr22-1_2013)

Hands motion estimation : result



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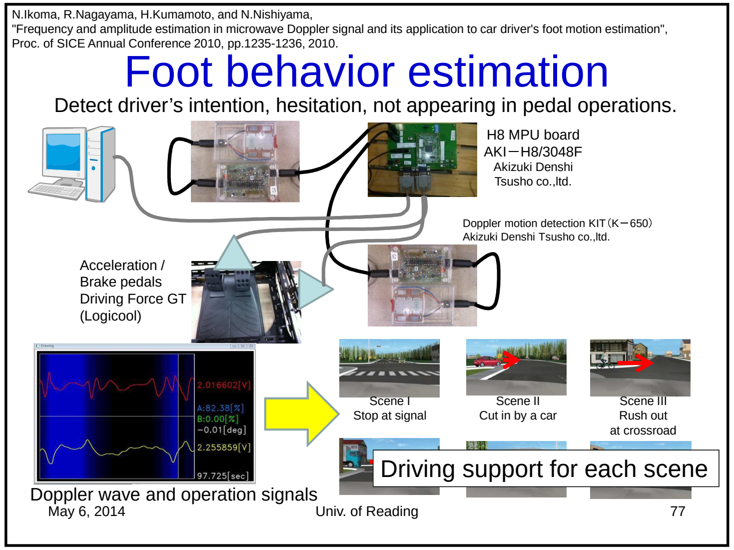
N.Ikoma, R.Nagayama, H.Kumamoto, and N.Nishiyama,
"Frequency and amplitude estimation in microwave Doppler signal and its application to car driver's foot motion estimation",
Proc. of SICE Annual Conference 2010, pp.1235-1236, 2010.
Foot behavior estimation
Detect driver's intention, hesitation, not appearing in pedal operations.
H8 MPU board
AKI−H8/3048F
Akizuki Denshi
Tsusho co.,ltd.
Doppler motion detection KIT (K−650)
Akizuki Denshi Tsusho co.,ltd.
Acceleration /
Brake pedals
Driving Force GT
(Logicool)
Scene I
Stop at signal
Scene II
Cut in by a car
Scene III
Rush out
at crossroad
Driving support for each scene
Doppler wave and operation signals
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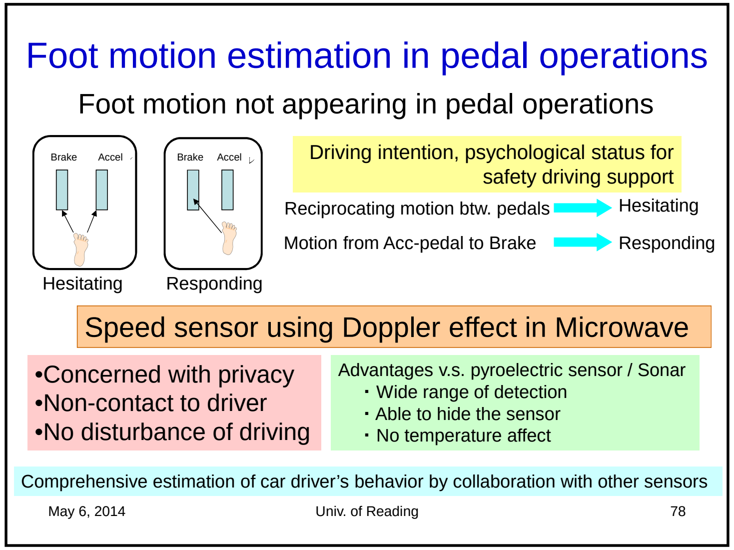
Foot motion estimation in pedal operations
Foot motion not appearing in pedal operations
Brake
Accel
Hesitating
Responding
Driving intention, psychological status for safety driving support
Reciprocating motion btw. pedals
Hesitating
Motion from Acc-pedal to Brake
Responding
Speed sensor using Doppler effect in Microwave
•Concerned with privacy
•Non-contact to driver
•No disturbance of driving
Advantages v.s. pyroelectric sensor / Sonar
・Wide range of detection
・Able to hide the sensor
・No temperature affect
Comprehensive estimation of car driver's behavior by collaboration with other sensors
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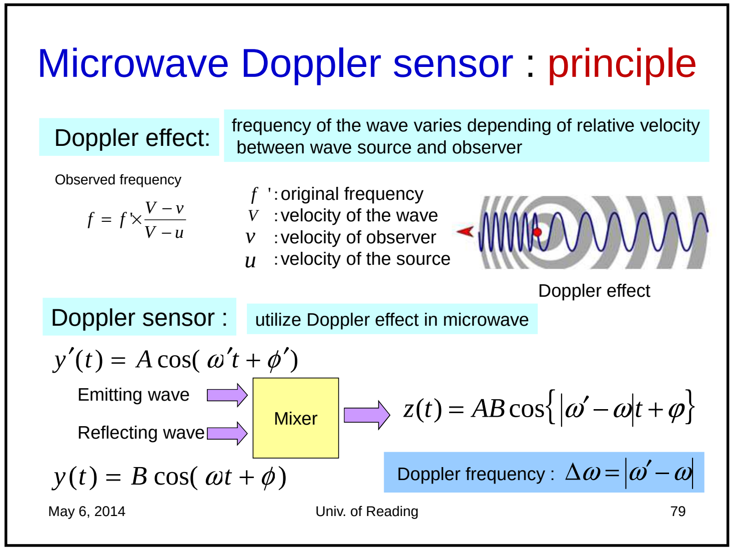
Microwave Doppler sensor : principle
Doppler effect:
frequency of the wave varies depending of relative velocity between wave source and observer
Observed frequency
$f = f' \times \frac{V - v}{V - u}$
f' : original frequency
V : velocity of the wave
v : velocity of observer
u : velocity of the source
Doppler effect
Doppler sensor :
utilize Doppler effect in microwave
$y'(t) = A\cos(\omega' t + \phi')$
Emitting wave
Reflecting wave
Mixer
$z(t) = AB\cos\{|\omega' - \omega| t + \varphi\}$
$y(t) = B\cos(\omega t + \phi)$
Doppler frequency : $\Delta\omega = |\omega' - \omega|$
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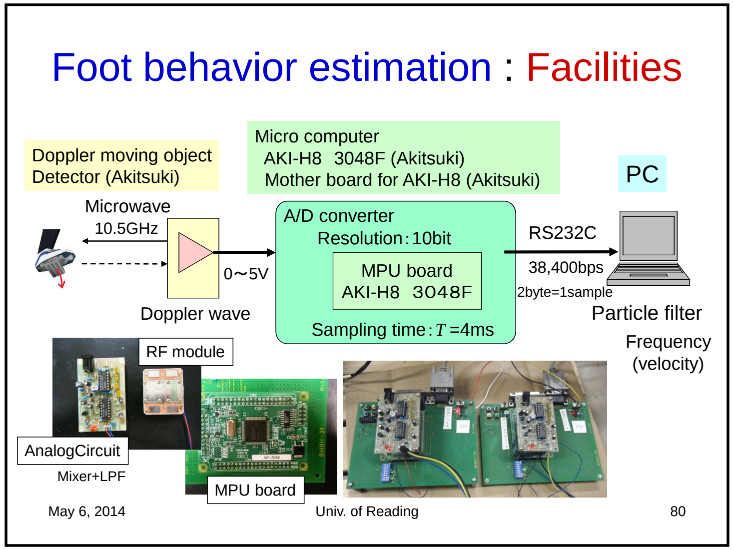
Foot behavior estimation : Facilities
Doppler moving object Detector (Akitsuki)
Micro computer
AKI-H8 3048F (Akitsuki)
Mother board for AKI-H8 (Akitsuki)
PC
Microwave
10.5GHz
0~5V
A/D converter
Resolution : 10bit
MPU board
AKI-H8 3048F
Sampling time : T =4ms
RS232C
38,400bps
2byte=1sample
Doppler wave
Particle filter
Frequency
(velocity)
RF module
AnalogCircuit
Mixer+LPF
MPU board
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Foot behavior estimation : Microwave Doppler sensor implementation

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Model: amplitude and frequency

Observation model (signal model) T: sampling time [s]

$$y_k = d_k + a_k \sin(\omega_k T + \phi_k) + w_k \qquad w_k \sim N(0, \sigma^2)$$

System model (time evolution model)

- DC: $d_k = d_{k-1} + v_k^d$: constant parameter $v_k^d \sim N(0, \tau_d^2)$ (small)
- Ampl: $a_k = a_{k-1} + v_k^a$ $v_k^a \sim N(0, \tau_a^2)$
- Freq: $\omega_k = \omega_{k-1} + v_k^\omega$ $v_k^\omega \sim N(0, \tau_\omega^2)$

(Ampl, Freq): time-varying parameters

- Phase: $\phi_k = \phi_{k-1} + \omega_{k-1} T + v_k^\phi$ $v_k^\phi \sim N(0, \tau_\phi^2)$ (tiny)

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Model: velocity and position

Observation model (signal model)

$$y_k = d_k + a_k \sin(\omega_k T + \phi_k) + w_k \qquad w_k \sim N(0, \sigma^2)$$

System model (time evolution model)

- DC: $d_k = d_{k-1} + v_k^d$: constant parameter $v_k^d \sim N(0, \tau_d^2)$ (small)
- Pos, Vel: $\begin{bmatrix} x_k \\ s_k \end{bmatrix} = \begin{bmatrix} 1 & T \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_{k-1} \\ s_{k-1} \end{bmatrix} + \begin{bmatrix} T^2/2 \\ T \end{bmatrix} v_k^x$: velocity almost constant $v_k^x \sim N(0, \tau_x^2)$
- Ampl: $a_k \propto (c_a + x_k - X_0)^{-4}$ Origin of the position $x_k \geq X_0$
- Freq: $\omega_k \propto |s_k|$
- Phase: $\phi_k = \phi_{k-1} + \omega_{k-1} T + v_k^\phi$ $v_k^\phi \sim N(0, \tau_\phi^2)$ (tiny)

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Model switching: with pedal signal

No pedal operation

- Pos, Vel: $\begin{bmatrix} x_k \\ s_k \end{bmatrix} = \begin{bmatrix} 1 & T \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_{k-1} \\ s_{k-1} \end{bmatrix} + \begin{bmatrix} T^2/2 \\ T \end{bmatrix} v_k^x$: velocity almost constant $v_k^x \sim N(0, \tau_x^2)$
- Ampl: $a_k \propto (c_a + x_k - X_0)^{-4}$ Origin of the position $x_k \geq X_0$
- Freq: $\omega_k \propto |s_k|$

With pedal operation

- Pos, Vel: $\begin{bmatrix} x_k \\ s_k \end{bmatrix} = \begin{bmatrix} x(p_k) \\ 0 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} v_k^p$ $v_k^p \sim N(0, \tau_p^2)$

Pedal peration signal

$$x(p_k) = \begin{cases} X_{Acc} & p_k = Accel \\ X_{Brk} & p_k = Brake \end{cases}$$

Accel pedal position; Brake pedal position

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Foot behavior estimation : Results so far

1. Doppler sensor system for foot motion
   – RF + AnalogCircuit + MPU + PC (Mixer+LPF)
2. Time-varying freq/ampl model
   – Linear sliding machine
   Freq/ampl:○
3. Foot motion model
   – Simulation signal of foot motion
   Freq/ampl:○ Motion:△
   – Real signal of foot motion
   Freq/ampl: ? Motion: ×

Sampling: T=4ms

Particle filter
State space model
State estimation

1ch Doppler signal

Estimation: T=30ms

Problem: loss of sign information

Freq $\omega_k \propto |s_k|$ Vel

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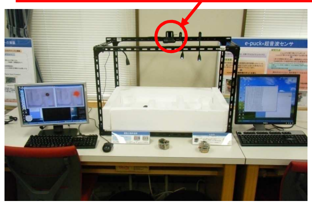
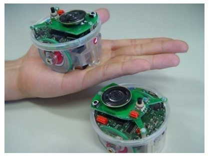
Norikazu Ikoma, "Likelihood adjustment among multiple targets for particle dependent tracking in particle filters", Proc. of IEEE Workshop on Statistical Signal Processing 2009, Cardiff, UK, Aug.31-Sep.3, pp.477-480, 2009.

Multiple target tracking in vision

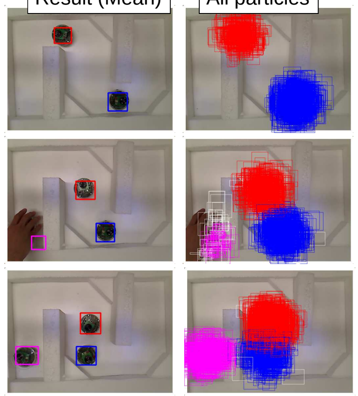
Camera : Logicool Webcam Pro 9000(QCAM-200SX)





Small mobile robot: e-puck

Result (Mean) All particles



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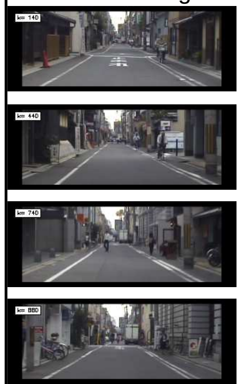
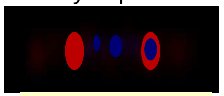
N.Ikoma, H.Hasegawa, Y.Haraguchi, "Multi-target tracking in video by SMC-PHD filter with elimination of other targets and state dependent multi-modal likelihoods", 16th International Conference on Information Fusion, July 9-12, 2013, Istanbul, Turkey, #5-081-304, 2013.

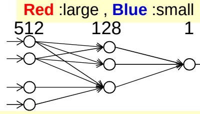
Multi-pedestrian tracking : on-board

On-board image Intensity of pedestrian Tracking result

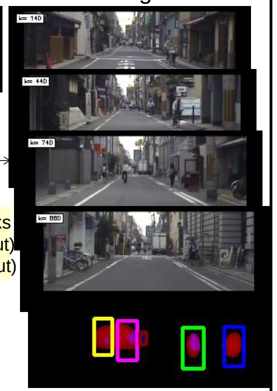




Red :large , **Blue** :small



Multi-modal : two networks
large size rectangle (input)
small size rectangle (input)



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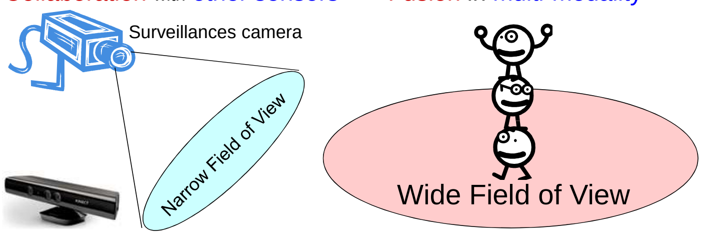
Wide Field of View Sensor
with Fusion and Collaboration

To observe the whole of the scene at once.

Collaboration with other sensors — Fusion in multi-modality



Camera with depth sensor : KINECT — Omni-camera and range sensor

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Composite sensor

LRF — ODC

Laser range finder & Omni-direction camera

Composite sensor

Omni-direction camera (Upper) and Laser range finder (Lower)

LRF : non-labeled range information

ODC: visual appearance information

Detection of new object
- LRF : detect new object
- ODC: register visual feature

Tracking of objects
- LRF : range measurement
- ODC: matching visual feature

Multiple targets :
- discrimination of individual target
- mode identification of target

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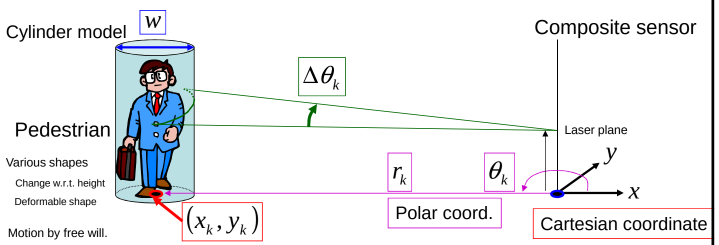
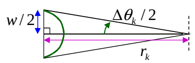
Modeling of Pedestrian : Cylinder



$$\Delta\theta_k = 2\tan^{-1}\frac{w}{2r_k}$$



$$r_k = \sqrt{(x_k)^2 + (y_k)^2}$$

$$\theta_k = \tan^{-1}(x_k, y_k)$$

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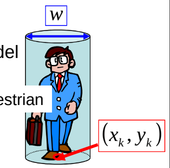
Motion model of pedestrian

Loosely describe arbitrary (Free will) motion (unknown) of pedestrian

State vector: Position, velocity, and width.

$$\boldsymbol{x}_k = (x_k, y_k, x_{k-1}, y_{k-1}, w_k)'$$



System model:

$$\begin{bmatrix} x_k \\ y_k \\ x_{k-1} \\ y_{k-1} \\ w_k \end{bmatrix} = \begin{bmatrix} 2 & 0 & -1 & 0 & \\ 0 & 2 & 0 & -1 & \\ 1 & 0 & & & \\ 0 & 1 & & & \\ & & & & 1 \end{bmatrix} \begin{bmatrix} x_{k-1} \\ y_{k-1} \\ x_{k-2} \\ y_{k-2} \\ w_{k-1} \end{bmatrix} + \begin{bmatrix} 1 & 0 & \\ 0 & 1 & \\ & & \\ & & \\ & & 1 \end{bmatrix} \begin{bmatrix} v_k^x \\ v_k^y \\ v_k^w \end{bmatrix}$$

Gaussian System noise

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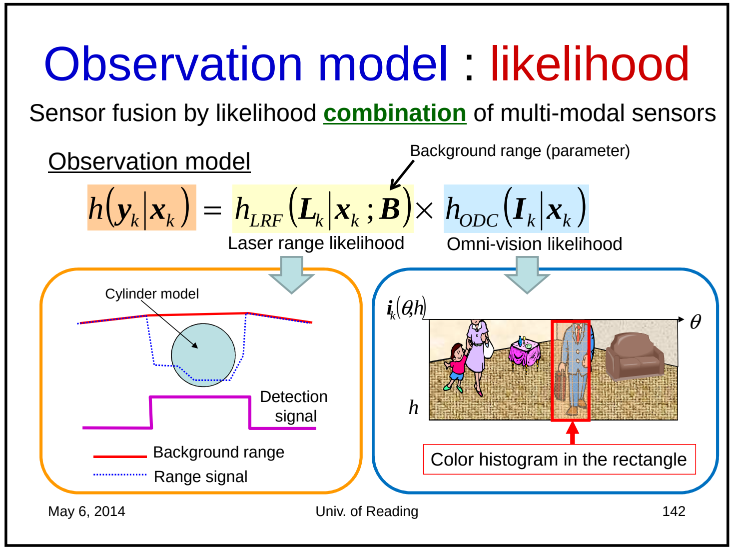

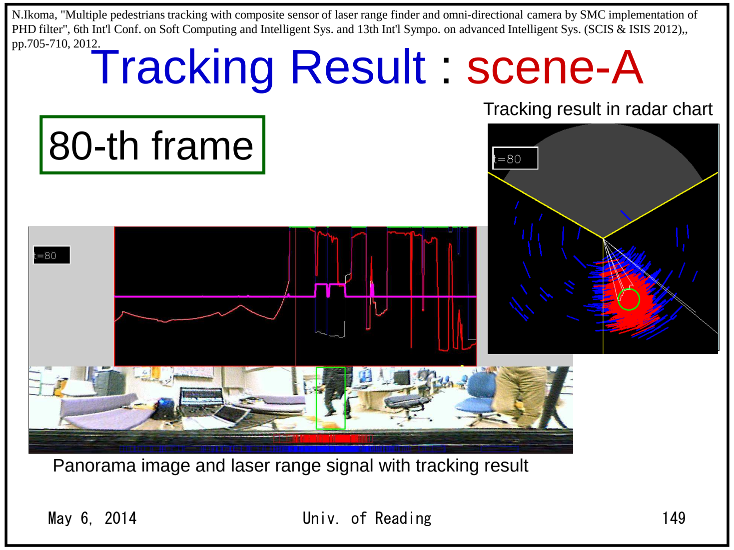

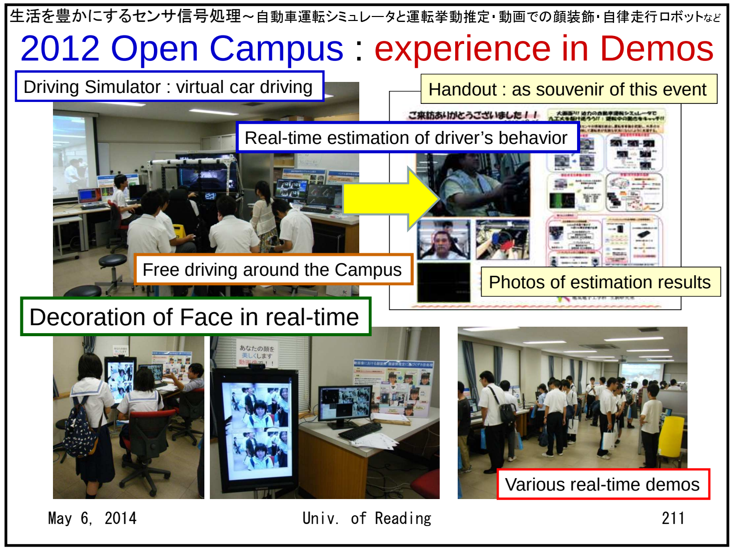

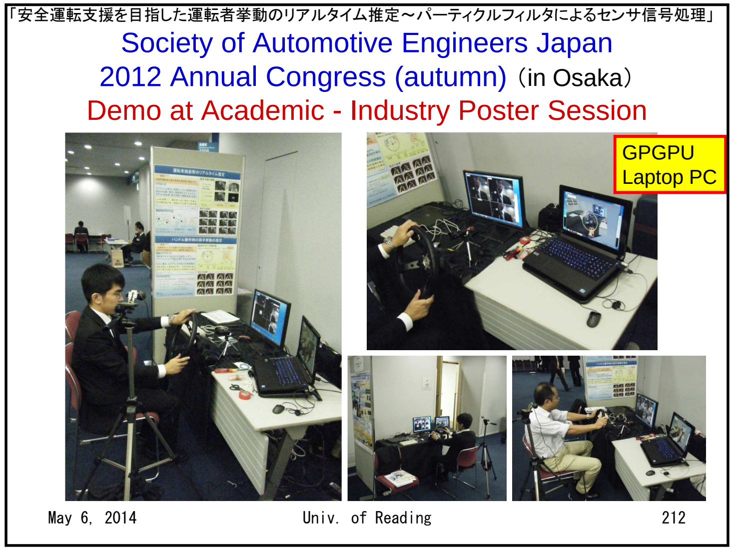

Real-time applications of particle filters in the engineering field

「パーティクルフィルタが拓くリアルタイム状態推定の世界」

2012 Academic–Industry Fair (Kita-Kyushu)

Demonstration booth

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“Research Meetings of Particle Filters”

- Prospectus
  - Enlightenment and popularization in Japan
  - Leadership especially domestic in Japan
- Organization
  - Independent of any academic societies/associations
  - To join : register to the Mailing List
  - Homepage : announcement and record of activities
- Activities
  - Monthly events at various domestic places (some in oversea)
  - Lecture, observation tour, seminar, lodge together

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“Research Meetings of Particle Filters”: HP

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"Res. Meet. of PF": organization ML/HP

- HomePage for information
- Mail List for announcement
- Attending free and optional
- Mailing List : receive only
- How to join RMPF? Register to the Mailing List
- More than 250 members (Apr.2014)

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"Res. Meet. of PF": Initial Stage

The name : Eng./Jap.

Foundation : 2005 May

Members (8 => 12)

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"Res. Meet. of PF": Initial Members

Founding members : 8 persons

- Norikazu Ikoma (Statistical signal processing, Associate Professor)
- Seiji Ishikawa (Vision and Control, Professor)
- Hideaki Kawano (Soft computing, Research Associate)
- Kazuhiko Kawamoto (Visual tracking, Associate Professor)
- Yoshio Komori (Numerical analysis, Research Associate)
- Masahiro Nagamatsu (Numerical optimization, Professor)
- Hideki Noda (Probability models and systems, Professor)
- Mitsunori Mizumachi (Acoustic signal processing, Research Associate)

Extended member : 12 persons

- Shuuichi Enokida (Automotive safety system, Research Associate)
- Hyoungseop Kim (Medical image processing, Associate Professor)
- Takeshi Nishida (Robotics and control, Research Associate)
- Tetsuo Furukawa (Self Organizing Map, Professor)

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New Structure : photo upload to HP

Since 2009 April

Small photos are uploaded after having monthly event

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2012 Dec. : Observation Tour

Railway Technical Research Institute (Tokyo) with a lecture meeting.

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Special workshop 100th anniversary :photo

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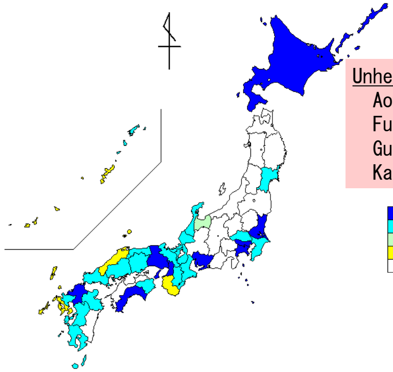
Future plan : conquer all prefectures



Unheld prefectures:
Aomori, Akita, Iwate, Yamagata, Fukushima, Niigata, Tochigi, Gunma, Nagano, Shizuoka, Gifu, Kagawa, Ehime, Miyazaki

Multiple event
Single event
Virtually had a event
Planned event
None

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Future plan : activities in 2014

Call for Lectures : July in Okinawa (open), Aug. in Hawaii (closed)

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