A Panorama-based Method of Personal Positioning and Orientation and Its Real-time Applications for Wearable Computers

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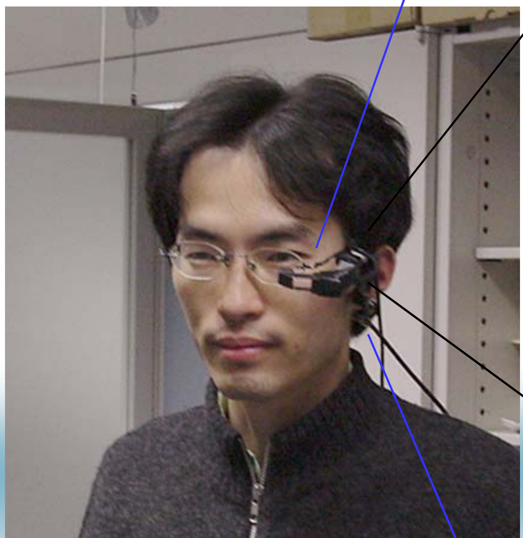
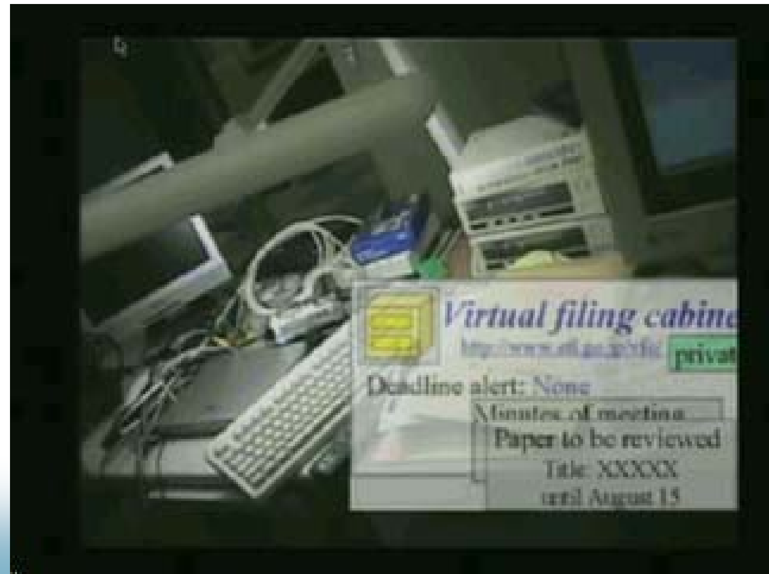
Purposes

- Personal positioning and orientation of wearable users which can be used for:
  - Personal navigation
  - Annotation overlay, smart reminder

Head-worn display



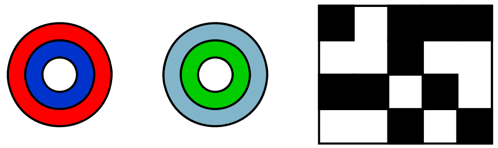
CCD camera



Actual output of our system

Previous works

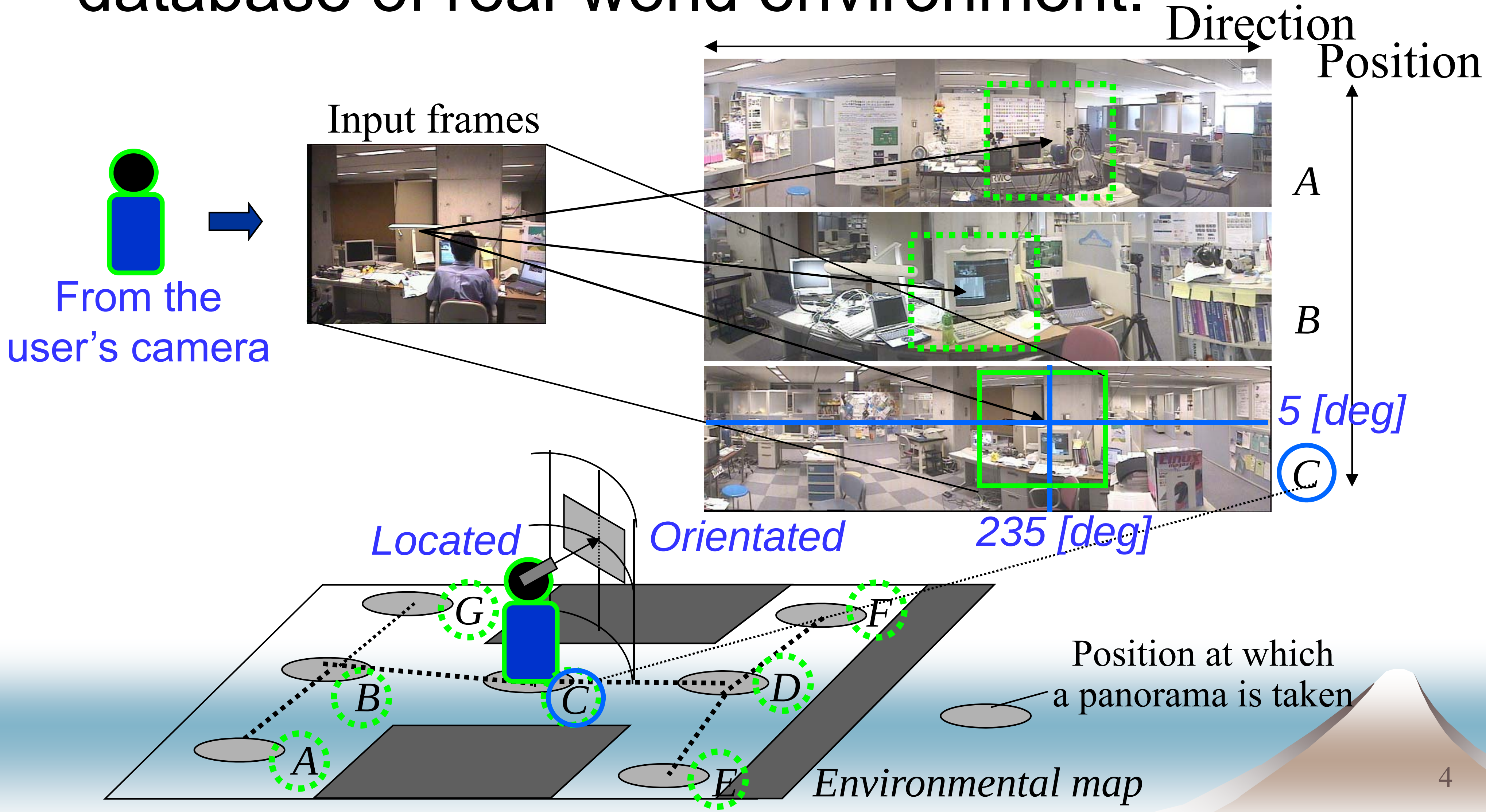
- Artificial markers (fiducials)



  - Problems:
    - Difficulty to apply large-scale applications
    - Fiducials need to be captured closely
- Dedicated sensors such as inertial sensors, GPS, IR beacon, etc.
  - Problems:
    - Applicable environments restricted
    - Sensor precision limited

Our approach: panorama-based method

- A set of panoramic images are used as a database of real-world environment.



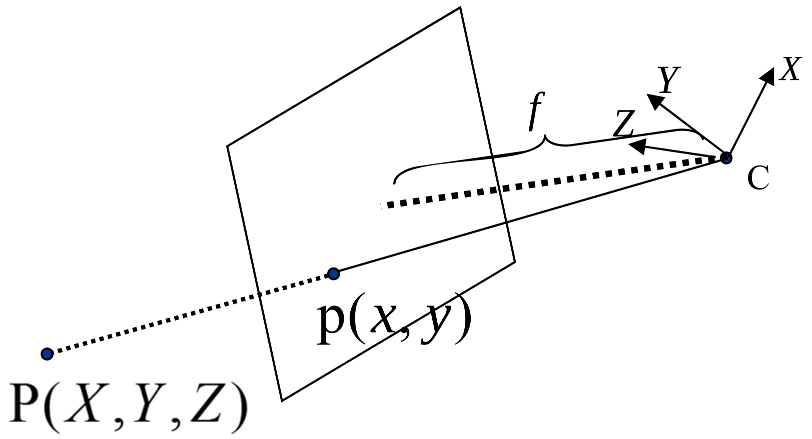
The problems

- We use *affine transform* that has difficulty to align input frames with panoramic images *if*...
  - User's view direction is apart from the horizontal line.
- Change of lighting condition severely affects the performance of registration.

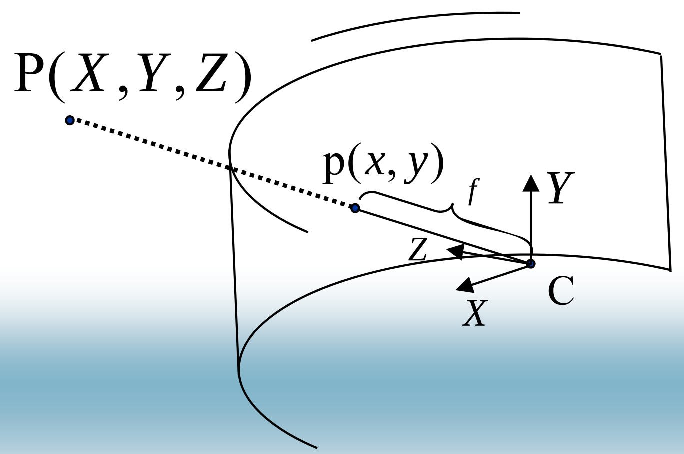
The problem

- Input frames cannot be aligned with a panorama that are mapped onto a cylindrical surface using *affine transform*.

An input frame

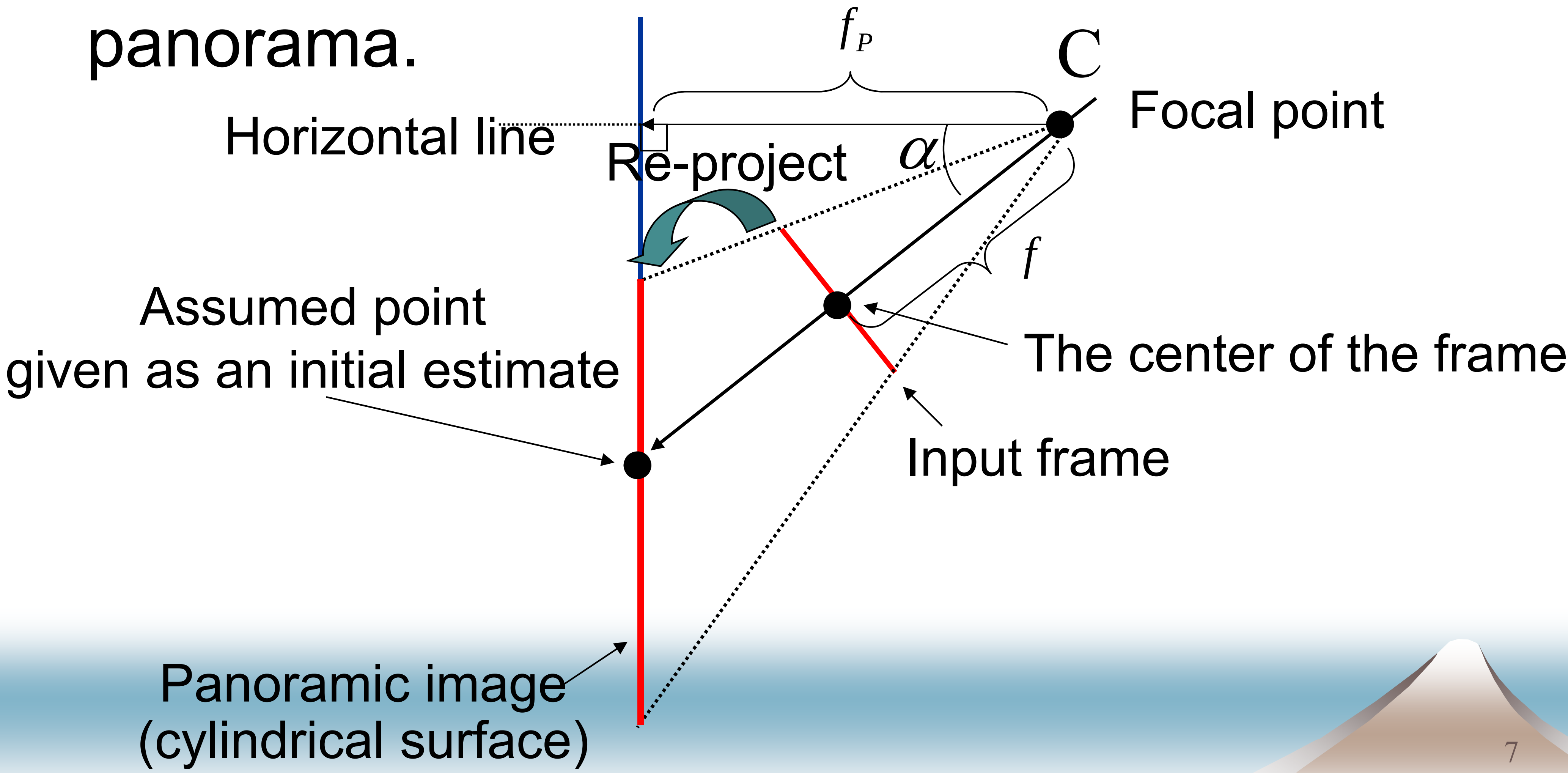


A panorama



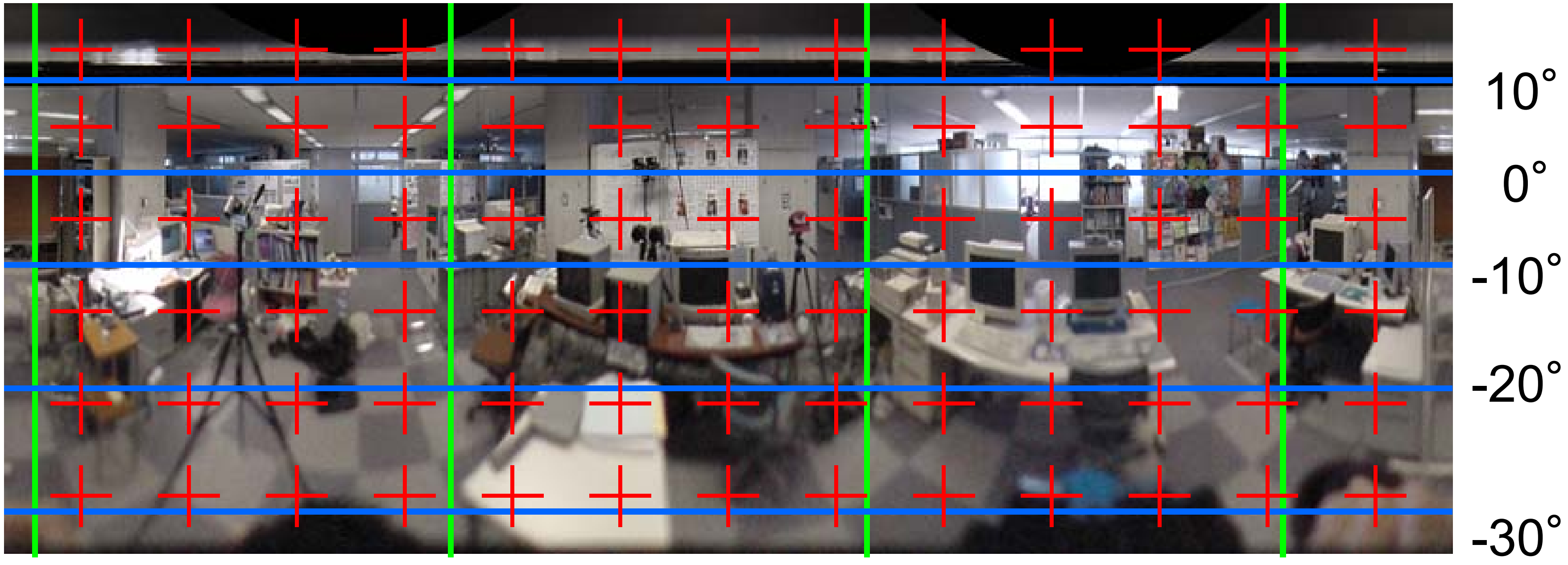
The solution

- To re-project the input frames onto a cylindrical surface and align the projected frame with the panorama.

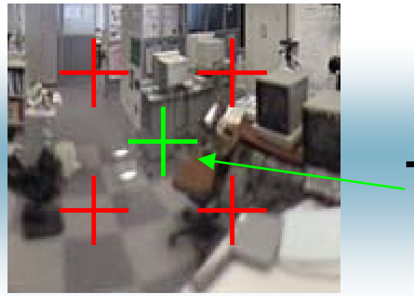


The solution

- *Thorough search*: initial estimates are given to cover the whole part of the panorama.



- *Partial search*: initial estimates are given around the previous result to save computational costs.



Omni-directional camera

- We use an *omni-directional* camera, HyperOmni Vision, to acquire panoramas.
  - Easy to generate
  - Geometrically correct

An omni-directional image

Geometrically transformed panorama

The problem

- Image registration is prone to change of lighting conditions.
  - A panoramic image was captured at different time and with a different camera system.

Different lighting condition gives totally different brightness.

The method: motion vector

- Pseudo motion vector is computed and selected or discarded at each pixel.

Compute pseudo-motion vector

⇓

Select motion vectors by confidence value

⇓

Estimate parameters using M-estimator

$$c = 2.0, w = 0.25$$

<u>*Pseudo motion vector*</u>

$$u_p = -(1-w)\frac{\partial I}{\partial t}\Big/\frac{\partial I}{\partial x} - cw\frac{\partial I'}{\partial t}\Big/\frac{\partial I'}{\partial y}$$

$$v_p = -(1-w)\frac{\partial I}{\partial t}\Big/\frac{\partial I}{\partial y} - cw\frac{\partial I'}{\partial t}\Big/\frac{\partial I'}{\partial y}$$

where $I'(x, y, t)$ *is gradient-intensity of* $I(x, y, t)$

The method: confidence value

- Weighted sum of absolute difference (wSAD) of brightness and gradient is used as a evaluation measure to be minimized.

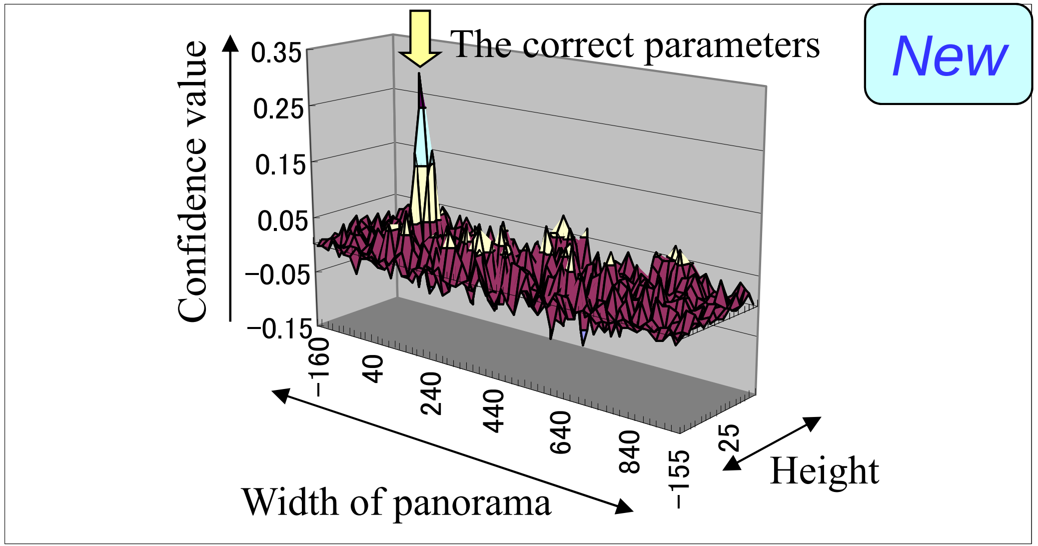
$$wSAD = (1-w)\sum_{x,y} | I_P(x+u, y+v) - I_f(x,y) |$$

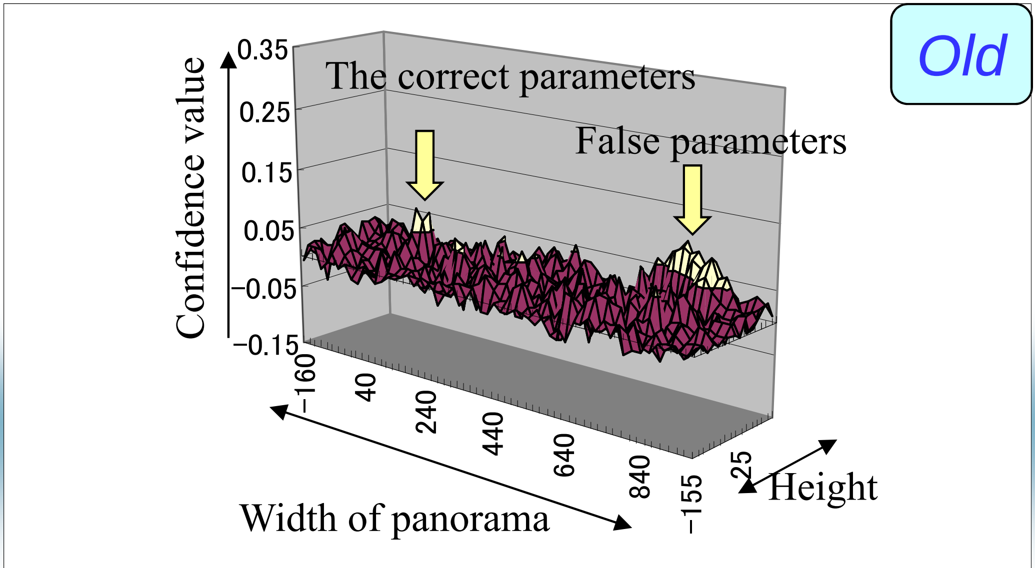
$$+ cw\sum_{x,y} | I'_P(x+u, y+v) - I'_f(x,y) |$$

We use $c = 2.0, w = 0.25$

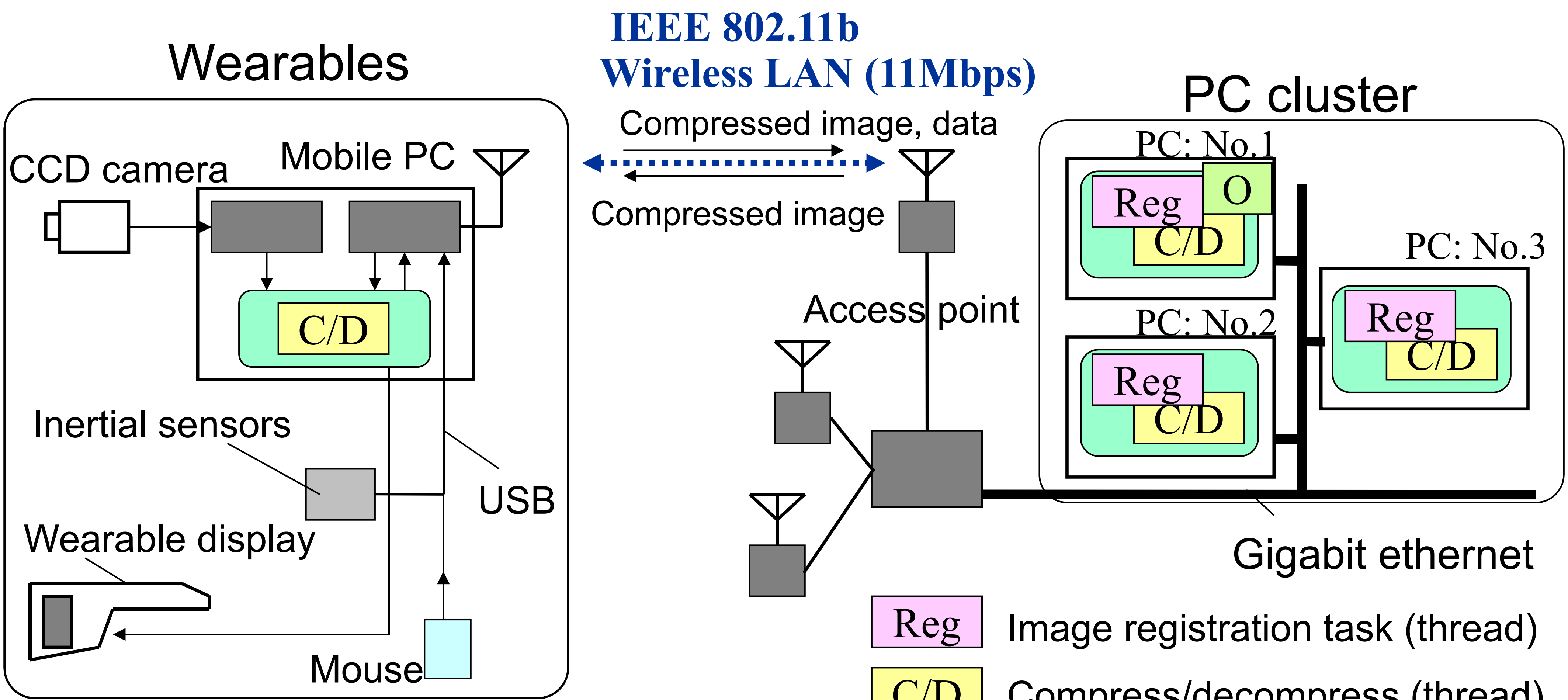
Experiments

- The proposed method can robustly handle most of difficult situations, empirically.





The *VizWear*: system overview



Each task is running
in distributed and parallel manners

Input/output image is compressed
and sent via wireless network.

The *VizWear* : outlook

Head-set

Camera *Inertial sensors*

Wearable display

MicroOptical Clip-On display

Wristwatch display

Antenna

Mobile PC (B5-size)

Video capture card

1.53kg

Wireless LAN card

The *VizWear* : hardware

- Computers and wired/wireless network
  - PC cluster consisting of 3 PCs (OS: Linux)
    - Dual Intel PentiumIII-1.2GHz, 850MHz, connected via *Gigabit ethernet*
    - 5 access points for roaming (Conformed to *IEEE 802.11b, 11Mbps*)
  - Wearable PC （OS: Windows Me）: B5-size notebook PC
    - CPU: Intel Mobile PentiumIII-600MHz
    - Connected via Wireless LAN (Conformed to *IEEE 802.11b, 11Mbps*)
- Inertial sensor, CCD camera
  - InterSense, InterTrax2 (connected via USB)
  - Kanagawa Bettery Co., Ltd, Very small Color CCD camera

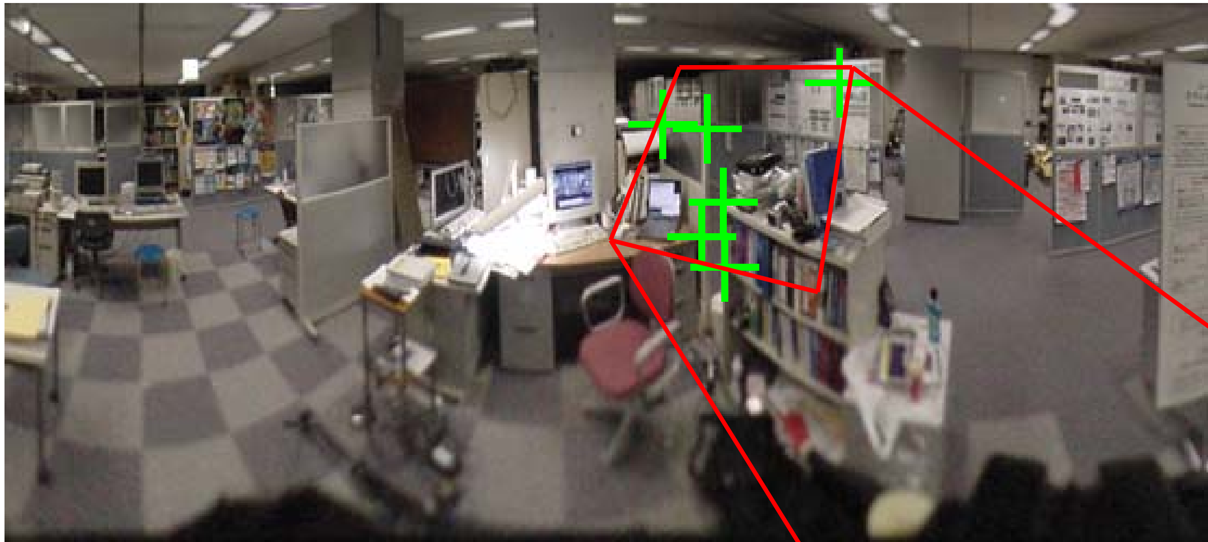
The *VizWear* : software

- The software is designed for parallel and distributed computing.
  - Each task is implemented as a *thread*.
    - Image registration task is further divided so that it can exploit data parallelism of the task.
  - Inter- and intra-PC communication is achieved by our open library. It internally uses:
    - PVM (Parallel Virtual Machine) library
    - POSIX or Win32 thread APIs
    - Berkley socket APIs

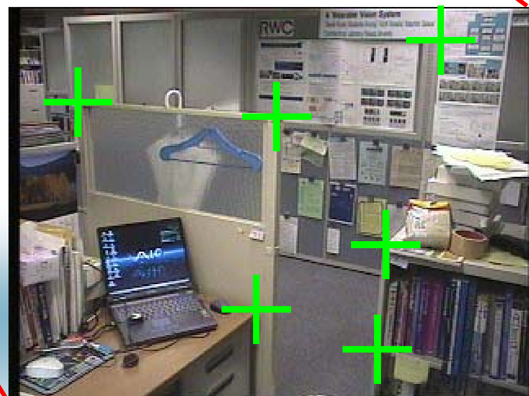
Experiments (off-line) : Registration

- Evaluate accuracy of registration between input frames and the panoramic image.

Panoramic image



Input frame

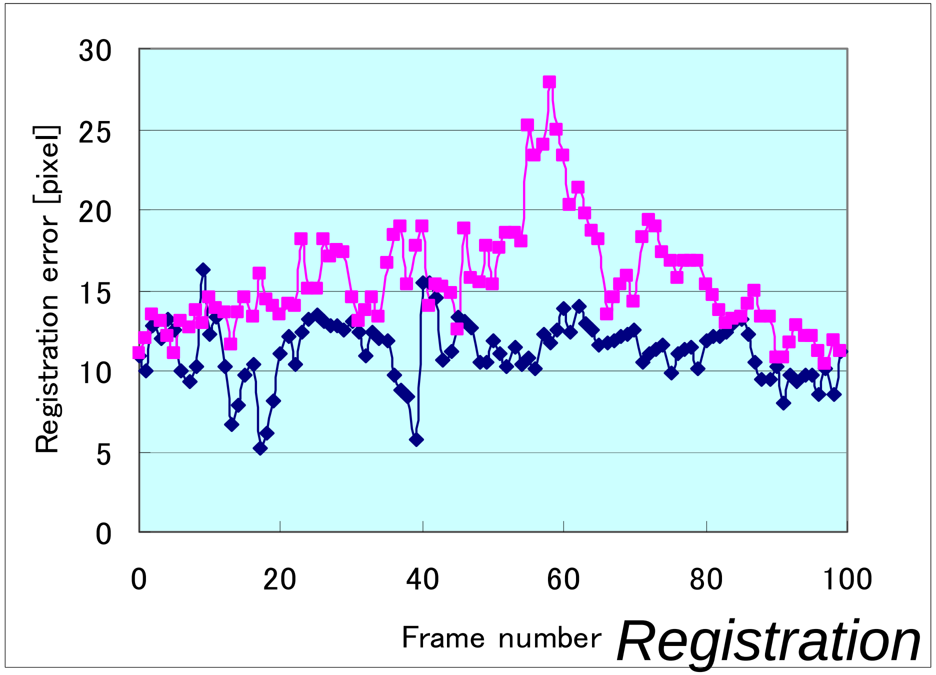


- *Manually* select and find matching between input frames and the panorama.

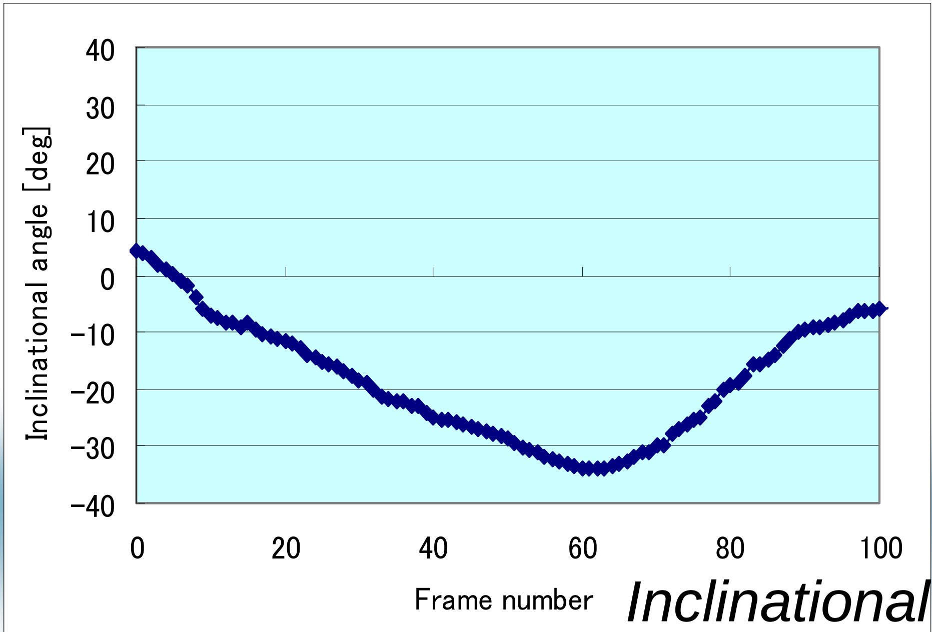
  100 frames are used in the experiments.

- Compare accuracy of the previous and the improved method.

Results: accuracy of registration



Registration error



Inclinational angle

- The proposed method improves accuracy of registration 3-10 pixeles
  - Imminent when inclination angle is apart from the horizontal line.

Results： computational cost

- The old method *vs.* the new method.

The proposed method	50-100 msec/frame
Previous method (affine)	40-80 msec/frame

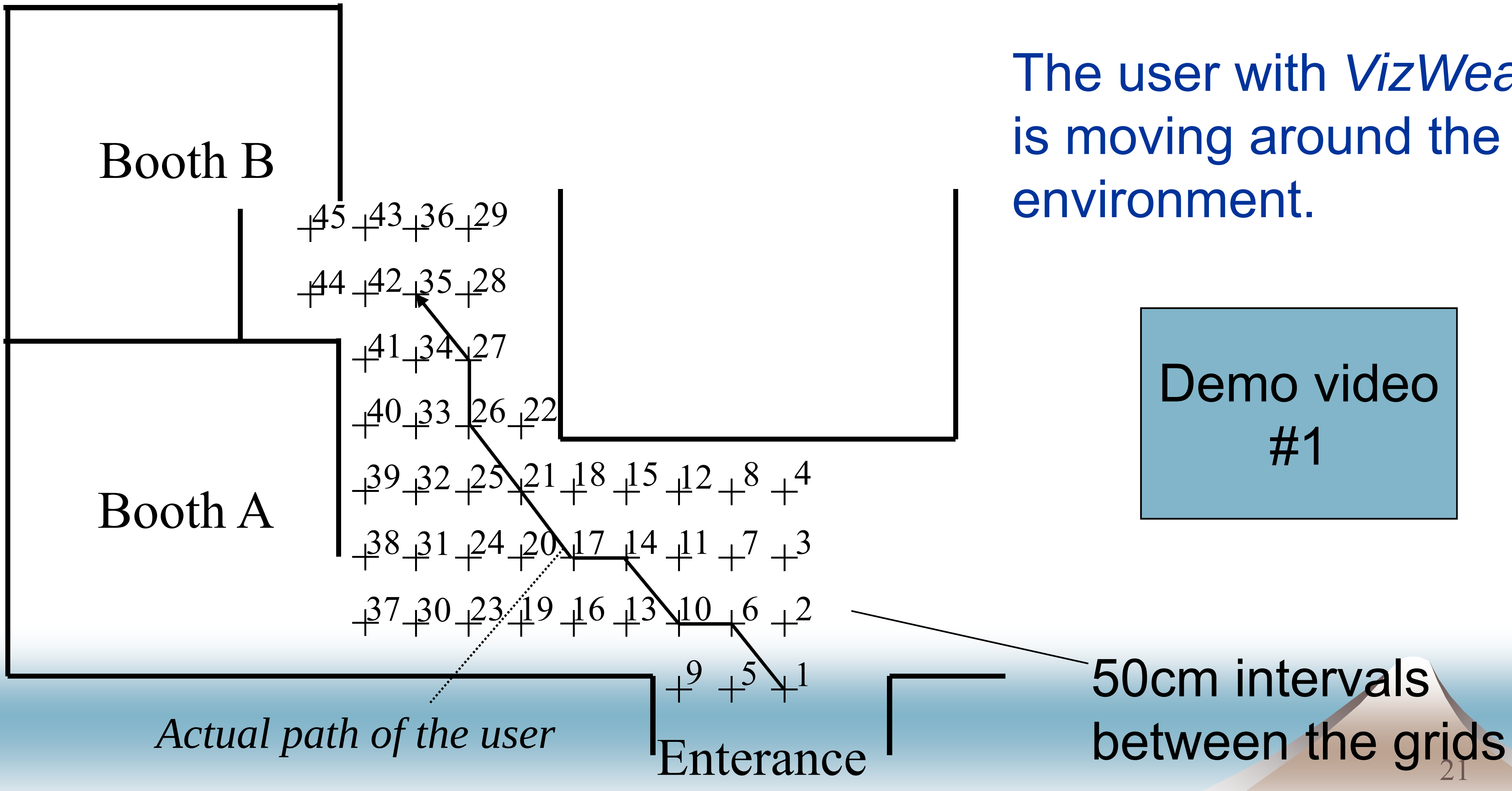
Breakdown of cost

Re-projection onto the surface	5-10 msec
Image registration (affine)	40-80 msec
Compute confidence value	5-10 msec
Total	50-100 msec

Computational cost increased by 10-20%.
Real-time processing can be still achieved.

Experiments (on-line) : Positioning

- Panoramic images were captured at 45 points of the environment shown below:

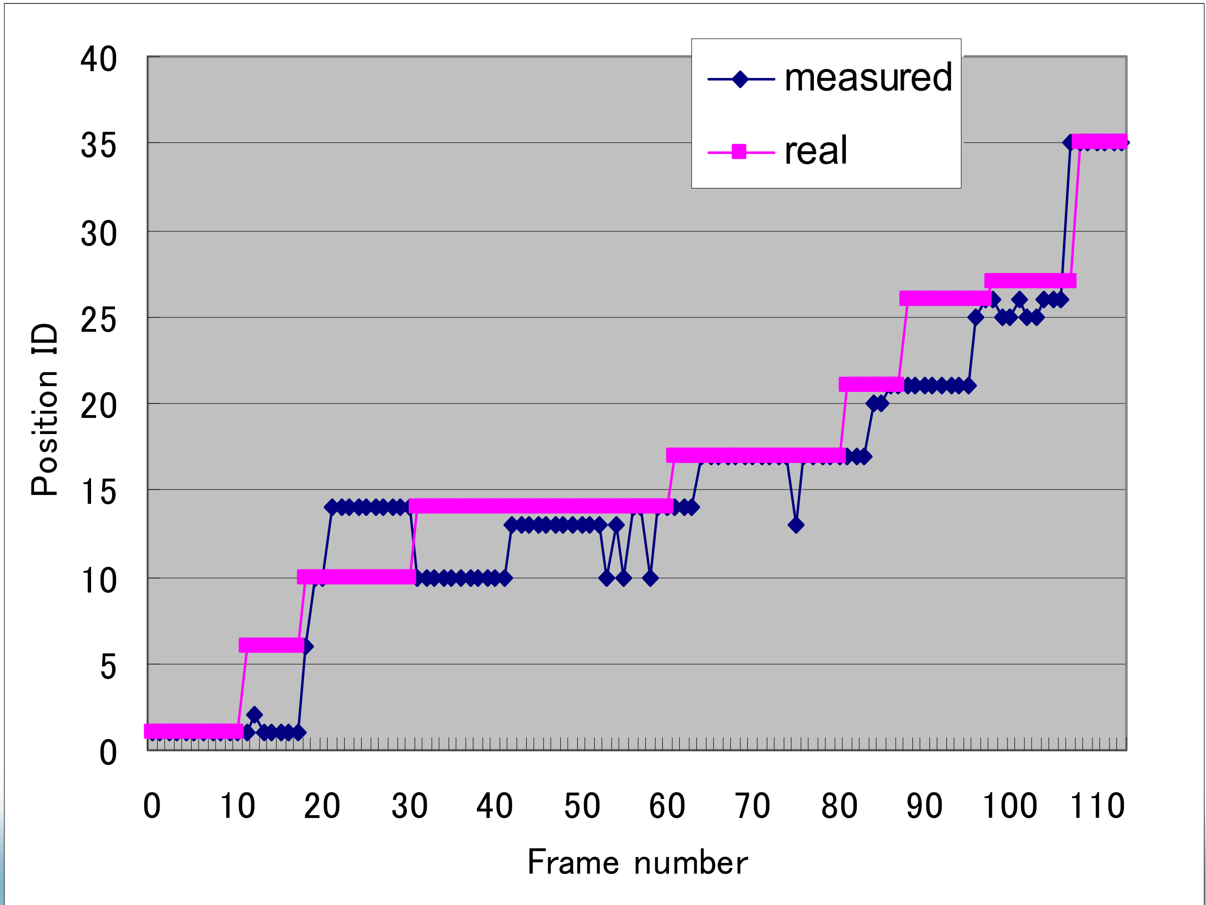


The user with *VizWear* is moving around the environment.

Demo video #1

Results：Positioning

- 100cm accuracy of positioning achieved for a typical office environment.



- Annotation overlay is very stable.
- Positioning is accurate where motion parallax is large.

Demo video clip

Demo video #2
Exhibition held in Japan

Demo video #3
Wearer's view

Conclusion

- We proposed an improved panorama-based method of personal positioning and orientation.
  - Input frames are re-projected onto panorama surface.
  - Gradient-based motion vector is used.
- Real-time applications are demonstrated.
  - The *VizWear* system is implemented.
  - Personal navigation and annotation overlay.