Position/Orientation-Aware Physical Tags Using Photo Sensors and Accelerometers for a Tangible Tabletop Interface

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1st TTT
(Tangible TableTop Interface)

Direct and intuitive operations
- Direct manipulation of GUI objects using physical tags
- Affordances of physical tags
- Asymmetric bimanual manipulation

Interfaces (experts side)
- Physical tags
- Ultrasonic receivers
- Large touchscreen LCD

Operating GUI objects using tags
A Measuring method in 1st TTT

- 3D ultrasonic tagging system

Problems of this method
- Time lag when a window follows a tag
- Difficulty to measure the orientation
- Difficulty to simplify the equipment
- Interruption by user’s hand

Examples of time lag of following windows and interruption by user’s hand
A novel method for measuring the position and orientation of the tags

The proposed method using...
- Photo sensors
  - Observing fiducial marker patterns
- Accelerometer

Advantages of proposed Method
- Measurable tag’s orientation
- High rate measurement
- Resistant to obstacles
- Simple equipment
- Only tags and a display

Tracking tag’s motion by using photo sensors and a fiducial marker pattern

An example of fiducial marker pattern
Related works
~ measuring physical objects ~

- Multiple LC tags
- Cameras (& markers)

- Need complicated device
  - Special display
- Difficult to measure 3D motion

SenseTable

Microsoft Surface
The measuring method with photo sensors

Measuring relative position/rotation between a tag and a marker pattern

1. Show a fiducial marker pattern under a tag
   - When a tag lands on a display
2. Calculate output signals of photo sensors
3. Do 1&2 recursively
Improvement of a circular marker pattern

New circular marker pattern

Conventional circular marker pattern

\[ l_x = l_y = 0 \text{ in these figures} \]
Advantages of the new circular marker pattern

1. Fewer photo sensors
2. Smaller marker size $\rightarrow 65\%$
3. Smaller tag size $\rightarrow 50\%$
4. More robust measurement
   - In boundary regions

New circular marker

Conventional circular marker

65% smaller
Measuring position/orientation of a tag using circular marker pattern (Low-speed measuring mode)
Hybrid measurement method with photo sensors and accelerometers

- Measurement using photo sensors
  - Measurable position/rotation precisely

- Measurement using accelerometers
  - Measurable 3D position/orientation

Hybrid measuring method
- Measurable position/orientation precisely in wide area
- Four measurement modes
  - for typical motion of a tag
High-speed measurement mode

~Rectangular marker pattern~

Predicting the size & direction of the pattern

- Extend the size of the pattern as a tag translates fast
  - Allow the movement in wide range per frame
  - Circular marker pattern limits the motion per frame

- Prediction the direction & the size
  - Accelerometer
  - Result of Low-speed measurement mode
    - Just before this mode

Measuring the position by using a rectangular pattern
Measurement of fast translation using a rectangular marker pattern (High-speed measurement mode)
Wide-area search mode
~Rectangular marker pattern~

- Measure 3D motion of a tag
  1. Detect a tag’s levitation
  2. Detect a tag’s landing
  3. Estimate tag’s landing point
     - Flying time
     - Acceleration detected in step 1
  4. Search for the tag in a wide area
     - Around the estimated landing point
     - Sequentially Shrinking and rotating rectangular pattern

Step 4. Searching for tag in a wide area by using rectangular pattern
Measuring 3D motion of a tag (wide-area search mode)
Static mode

~Hidden marker pattern~

- Detect whether a tag is static or not
  - An accelerometer
- Less obstacle marker
  - Cut marginal area of a circular pattern
- More sparse interval of tag’s communication

Circular pattern

Hidden pattern

Display hidden pattern (static mode)
Wireless tags & measuring multiple tags

- Wireless tags
  - Photo sensors
  - An Accelerometer
  - (Gyro sensors)
  - A Radio communication device

- Multiple communication
  - 60-90Hz per tag
  - 5 tags’ communication

- Clear the problems of the 1st TTT
  - High rate measurement
  - Resistant to obstacles
  - Measurable tag’s orientation
  - Simple equipment
Conclusion

Novel method of measuring position/orientation of physical tags for the TTT
- Need tags and a display only
- Use photo sensors and accelerometers
- Use the new fiducial marker patterns
  - The size of a tag & a marker got smaller
- Measure the position/orientation of Multiple wireless tags

New circular pattern
Rectangular pattern
Hidden pattern

A wireless tag on a marker pattern
Photo sensors embedded on bottom face of a tag
Future works

- Improve this method
  - Using gyro sensors in combination
    - Enhance interaction
- Improve tag hardware
  - Battery capacity
  - Changing Shape
    - Enhance affordance
- Evaluate the system

I’ve brought the wireless tags
  - Please contact me