Collaborative Environment supported by Virtual and Augmented Reality

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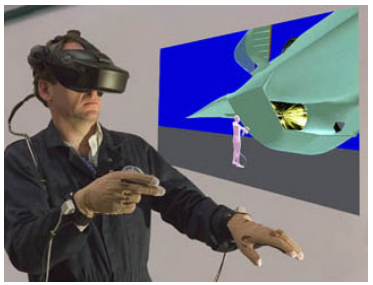
Outline

Virtual Reality

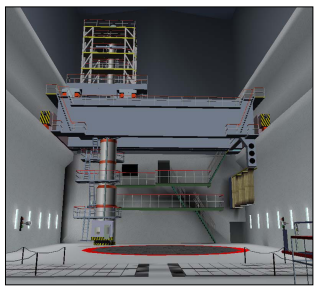
- Virtual Reality(VR)
  - Computer-generated world which is different from real physical world.
  - Shape and appearance are not completely the same as real ones, but its effect is essentially the same.
  - Beyond physical limitation to expand human ability

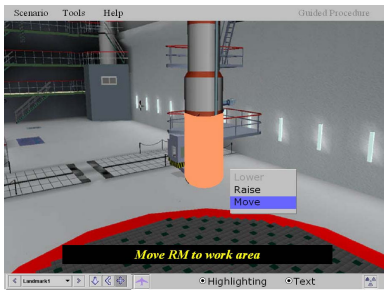
Focuses on “Artificial World”



VR Applications

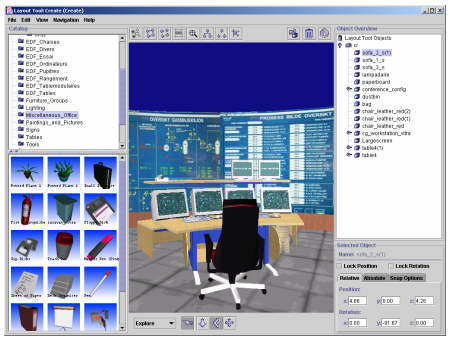
- Various VR applications have been introduced to operation & maintenance of Nuclear Power Plant(NPP) field.
- Examples by IFE (VR Applications)
  - Training System for Nuclear Fuel Exchange



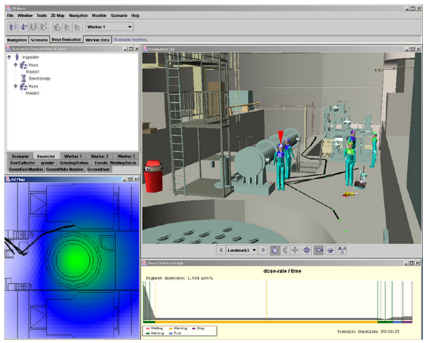


VR Applications

- Design of MCR
- Dose rate prediction & procedure planning for decommissioning

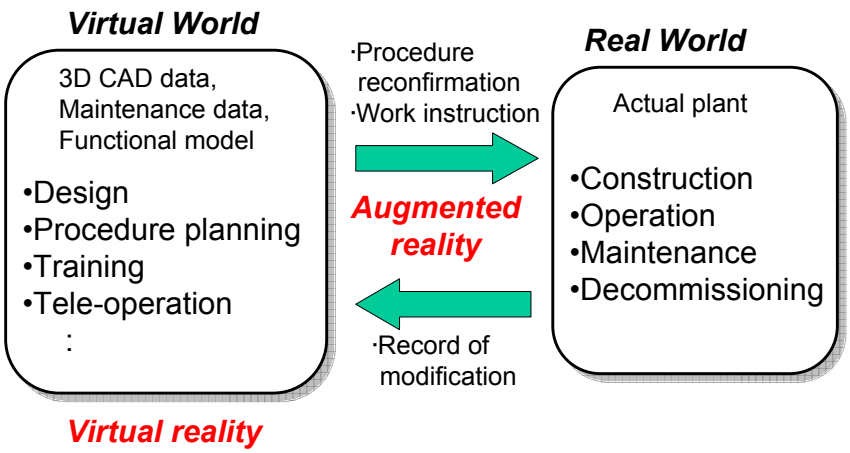


CREATE



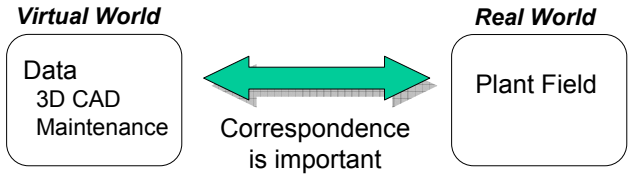
VRdose

Collaboration of Virtual and Real World



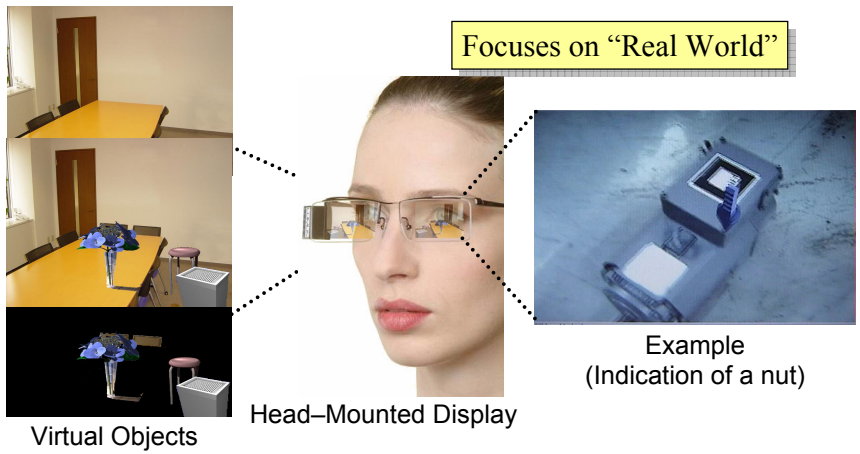
Correspondence between Virtual and Real

- Virtual world should be always essentially consistent with real world.
- It is difficult to correspond virtual world to real world.
  - Troublesome to create and maintain virtual world
  - Design changed, expanded, appended, updated and decommissioned
- AR (or Augmented Virtuality) is one of the solutions.
  - To realize close linkage between virtual and real world.



Augmented Reality

- Augmented Reality(AR) expands the surrounding real world by superimposing computer-generated information on the user's view.

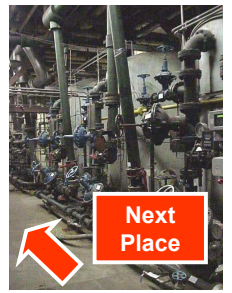


AR Applications

Under development

- Navigating workers to the workplace
- Indicating dangerous locations
- Viewing plant parameters
- Visualization of the radiation map

⇨ Viewing virtual information in real world



Problems to Apply AR to Plant Field

- Elemental technologies to realize AR applications must provide higher performance than conventional AR applications
  - Tracking Technology (measures position and orientation)
    - Wide area, High accuracy, High reliability
  - Display Technology
    - Safer, Light weight
- Cultural custom of workers
  - Workers are typically conservative about new technology
    - Not enough only better than the best current practice
    - Must prove and show that the new technology is sufficiently superior

    ⇒ Appropriate evaluation method for AR systems

Studies for Solving Problems

- Various fundamental studies have been conducted for 5 years with IFE and Fugen NPP(Japan)
  - Improvement of Tracking Technology
    - (1) Tracking method using line markers and circular markers
    - (2) Hybrid tracking method
    - (3) Marker arrangement optimization
  - Selection of Suitable Hardware
    - (4) Comparison of display devices
  - Prototype System Development
    - (5) Decommissioning work support system
  - User-Centered Evaluation of AR System
    - (6) Heuristic evaluation of AR system

Tracking Technology for AR

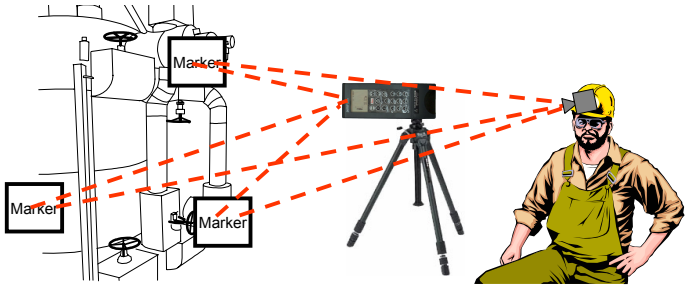
- Tracking
  - Measure position and orientation of user's view in real time to superimpose virtual objects at correct position.
- Many kinds of tracking technologies are developed
  - GPS
  - Ultrasonic/Magnetic Sensor
  - Infrared Sensor
  - Inertial Sensor
  - Marker-less
  - Indoor
  - complex obstacles
  - Magnetic source/object
  - Wide area tracking
  - Accurate/stable

⇒ **can not be used in plant field**

⇒ **Artificial marker technique has a possibility to be used in plant field**

Artificial Marker Technique

Calculate the position and orientation using positional relationship between camera and markers pasted in the environment



1. Paste plural markers in the environment in advance
2. Measure 3 dimensional position of markers in advance
3. Capture the markers with a camera mounted on the user
4. Recognize more than 3 feature points on the markers and calculate the position and orientation of the camera

Available Distance of Conventional Marker

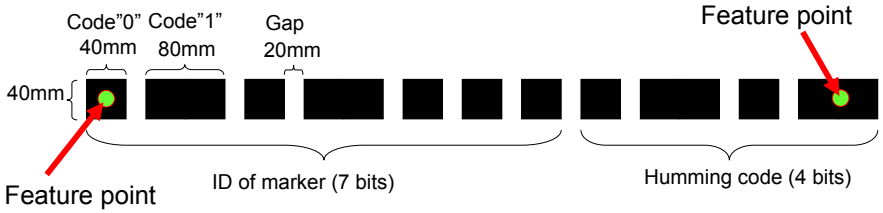
- Maximum distance between camera and marker
  - ARToolKit (VGA, f=4mm)
    80mm : 1 m,
    250mm : 3 m,
    400mm : 5 m

- Problem
  - There are many objects in plant.
  - Surface of the objects is not flat.
  - It is difficult to paste large markers.

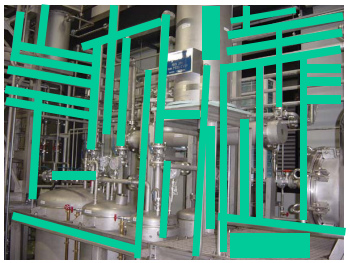
⇒ It is necessary to make the markers smaller or make it easier to be pasted in a complicated environment

(1)Tracking Method using Line Marker

- Design of line marker

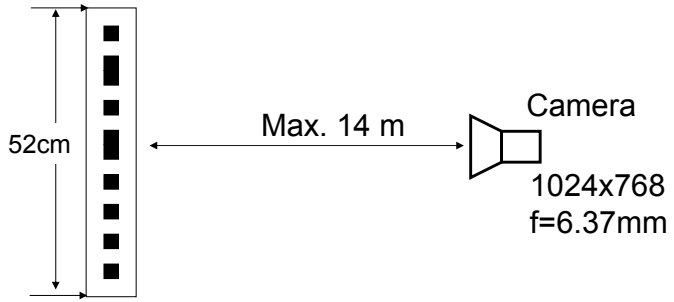


- In plant, there are many pipes which shape is "line"
- Easy to paste line-shaped markers on the pipes



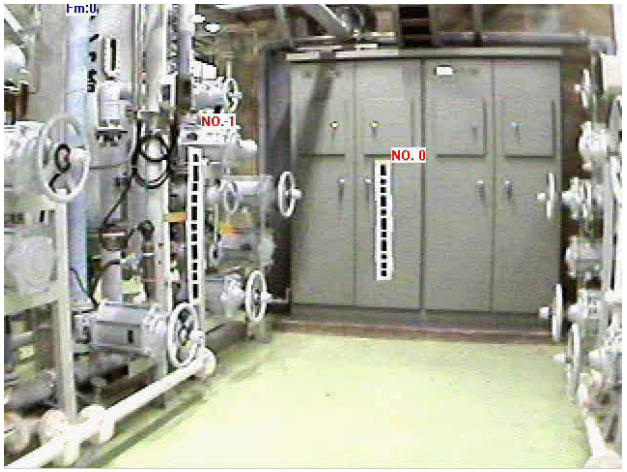
Maximum Available Distance

- Evaluation of the maximum available distance
  - Condition : Camera Dragonfly B&W XGA, f=6.37mm
    Marker Width : 3cm Length : 52cm



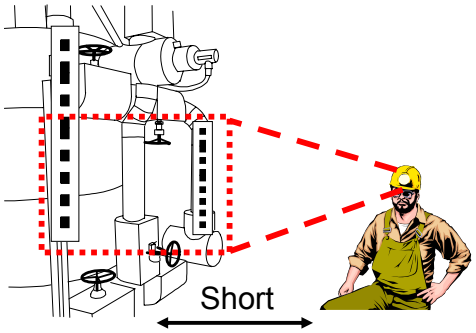
  - Maximum available distance is much longer than the conventional tracking methods

Example : Tracking in Plant



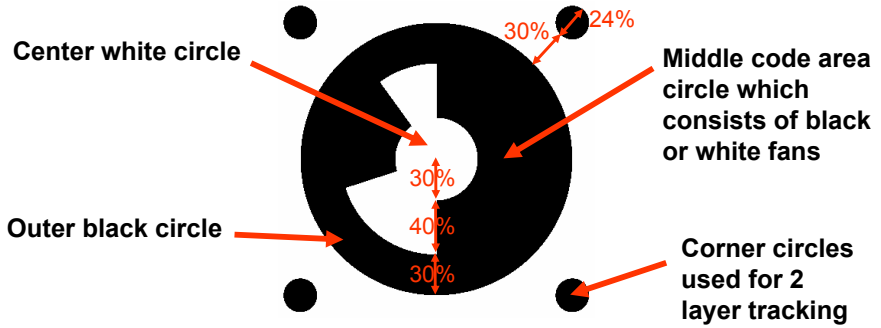
Disadvantage of Line Marker

- More than 2 markers must be recognized at the same time (At least 3 feature points need to be recognized).
  - It is difficult to recognize enough markers if the distance between the markers and the user is very short



Tracking Method using Circular Marker

- Design of circular marker

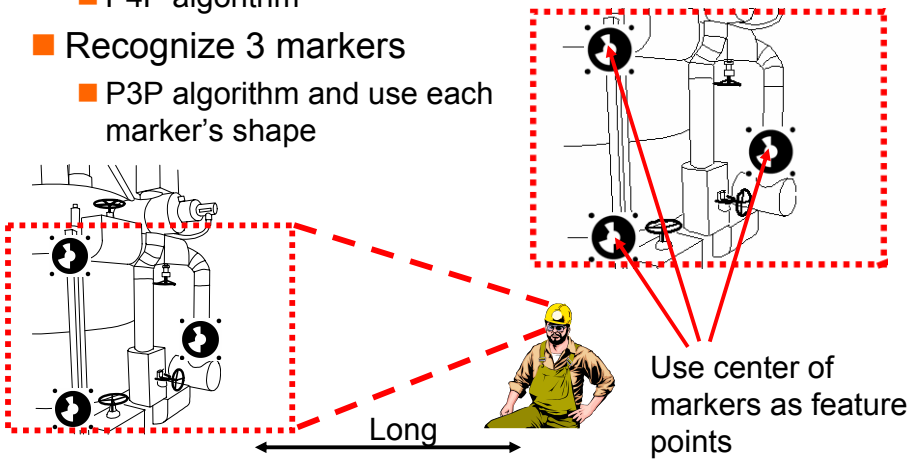


- Features
  - 99 unique markers
  - 2 layer recognition

Centers of circles are used for the tracking calculation

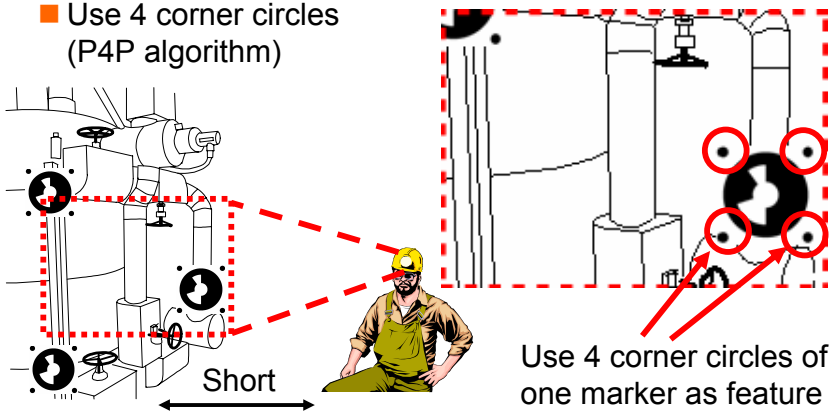
Tracking in a Long Distance

- Recognize more than 4 markers
  - P4P algorithm
- Recognize 3 markers
  - P3P algorithm and use each marker's shape



Tracking in a Short Distance

- Recognize less than 2 markers
  - Use 4 corner circles (P4P algorithm)



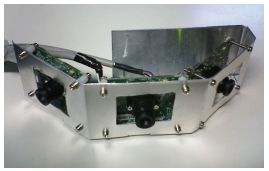
Example : 2 Layer Tracking

Original　　Augmented

- Newly designed markers can cover both of short and long distance

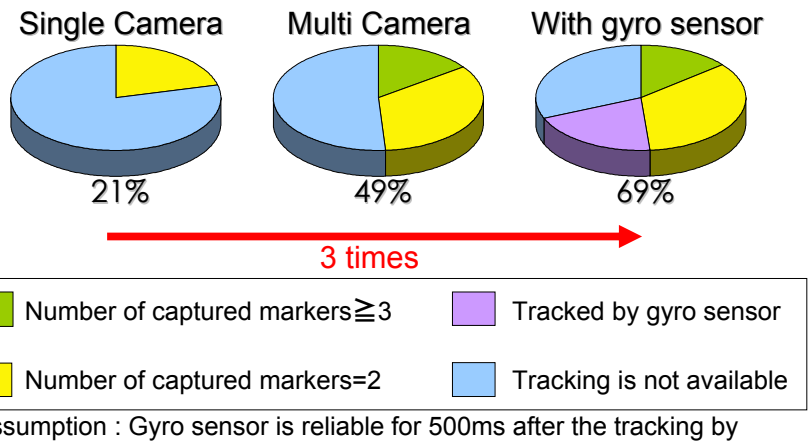
(2) Hybrid Tracking Method

- Number of markers which must be pasted in advance affect on the load for introducing the tracking system
- Preparation of AR environment
  - Make markers
  - Paste the markers in the environment
  - Measure 3 dimensional position of the markers
- Number of the markers which must be pasted in the environment should be small
- Extension of the tracking system
  - Using multi camera
  - Sensor fusion



Result of the Evaluation

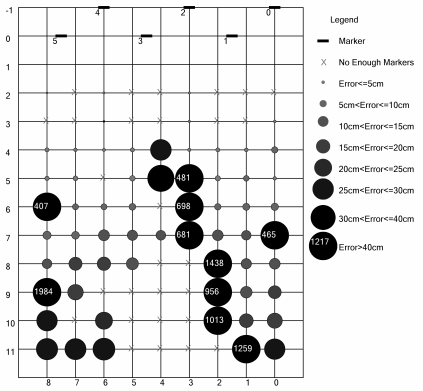
- Proportion of frames where the tracking is available



Assumption : Gyro sensor is reliable for 500ms after the tracking by multi camera is not available.

(3) Marker Arrangement Optimization

- Accuracy of tracking used in plant must be high



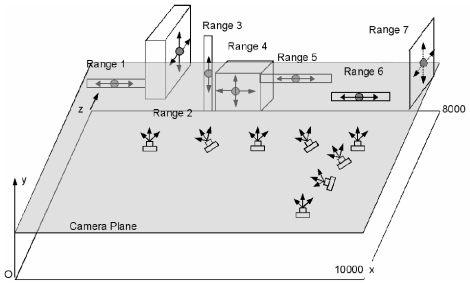
Example of Accuracy Evaluation

- Accuracy of tracking depends on not only the distance from markers but also the arrangement.
- Inappropriate marker arrangement may spoil accuracy.
- It is difficult to decide appropriate marker arrangement without any reference.

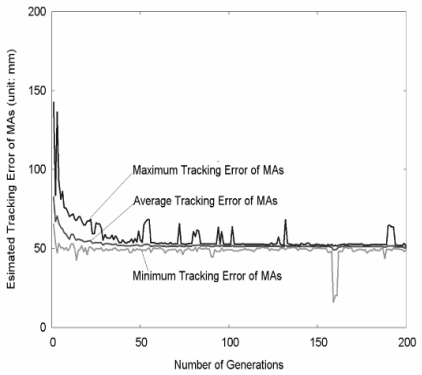
→ Development of marker arrangement optimization method

Optimization using Genetic Algorithm

- Various marker arrangements are evaluated and the best arrangement is selected based on a genetic algorithm.



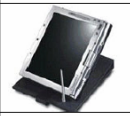
Pseudo working environment and marker arrangement



Optimization of marker arrangement

(4) Comparison of Display Devices

- "Water System Isolation Task" was simulated
- Subjects were required to find the specified valve by an AR system
- Measured Indices
  - Task performance (trial time and errors), Mental workload (NASA-TLX), Situation awareness (10-D SART), Eye fatigue (Flicker test), and Usability (Questionnaire)

Device	Dataglass 2	SCOPO	Glasstron	Tablet PC	Compact TV
Appearance					
Type	Wearable	Wearable	Wearable	Handheld	Handheld
Model	Dataglass2, Shimadzu Corp.	SCOPO, Mitsubishi Electric Corp.	Glasstron, Sony Corp.	Travel Mate C100 TMC102L Acer	SY-4100, Casio Corp.
Features	One-eye optical see-through	One-eye video see-through	Both-eye video see-through	10.4 inch display, 1.4 kg weight	4 inch display, 0.58 kg weight

(5) Decommissioning Work Support

- Development of a prototype system for supporting field work of decommissioning in Fugen NPP.
  - Outline of Decommissioning Work
    - Planning
    - Preparation
    - Pre-work meeting
    - Dismantling work
    - Recording work progress
  - Realizing two functions by AR
    - Confirmation of work procedure
    - Recording work progress as 3D CAD data

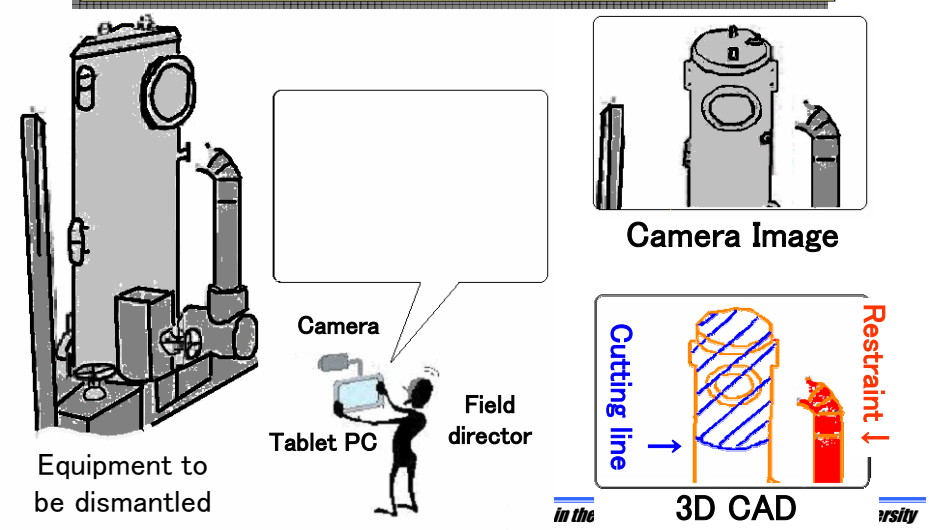
Prototype System: Outline

- Small tablet PC, SONY VGN-UX90PS

CPU	Intel CoreDuo U1400(1.20GHz)
Display	4.5Inch TFTColorLCD
Size	150.2mm × 38.2mm × 95.0mm
Weight	492 g
Camera Resolution	VGA(640 × 480)
Focal Length	3.8 mm

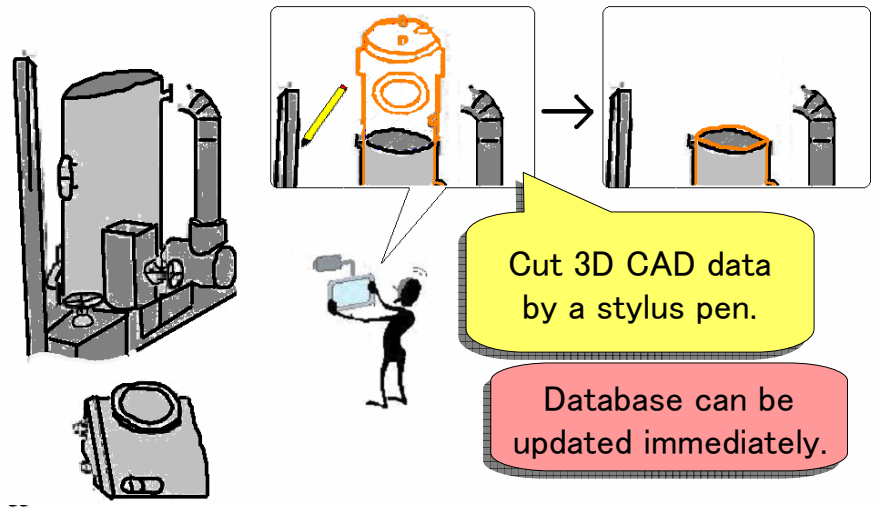
Confirmation of Work Procedure

Support marking work for cutting lines and restraint area



Recording Work Progress

Support recording work progress of the day as CAD data



Example Video

Target: Ion Tank of Pure Water Facility

(6) Heuristic Evaluation of AR System

- Scenario-based evaluation of prototype system
- Three evaluators (all belong to Fugen NPP)
  - A: a leader of operator group
  - B: belongs to decommissioning team
  - C: an engineer developing decommissioning technology
- Procedure
  1. Explanation of prototype system and scenario
  2. Use prototype system
  3. Answer questionnaires
  4. Group interview
- Questionnaire (5 grade)
  - 14 questions for system function
  - 13 questions for usability
  - Free description (other problems, points to be improved)

Evaluation Results

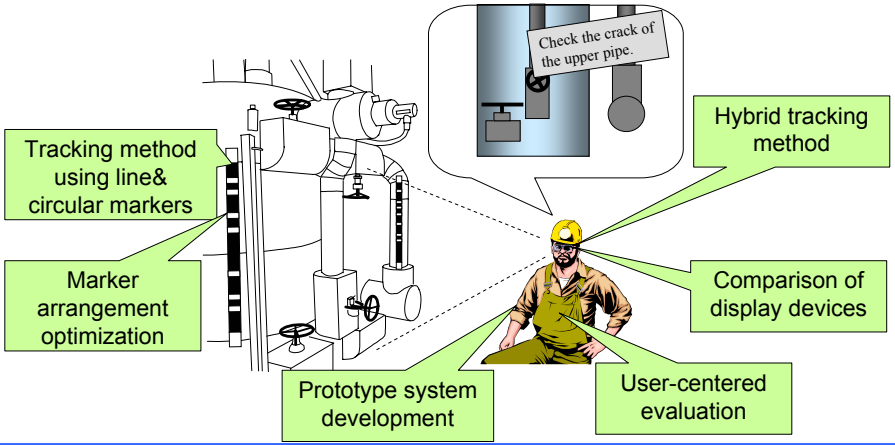
- Colored display of 3D CAD is comprehensive.
  - More comprehensive if not only colored CAD data but also text information is displayed near CAD data.
- Recording function of work progress is useful.
  - Design of recording function is also appropriate.
- CAD data operation is enough easy.
- Processing speed of tablet PC is enough fast.

- Display of tablet PC is too small
  - PC is heavy even for small tablet PC (492g)
  - Lighter PC with a larger display is required.

- Others
  - Memorandum should be also input to work record
  - Effective for training of novice workers
  - One of advertisement method to the public
  - May be difficult to understand if work environment is complicated.

Summary of Presentation

- Proposal of collaborative environment supported by VR and AR
- Introduction of five year activities



Future Works

- Improvement of Tracking Technology
  - Reducing the number of markers which must be pasted in advance
  - Simultaneous use of fiducial markers and feature points

- Easy construction and maintenance of virtual world for correspondence between virtual and real world
  - Easy modification of 3D CAD in plant field by AR
  - Application of Augmented Virtuality

- Development of specialized hardware for AR
  - Commercially developed hardware can not meet the requirements
    - Safety, Weight, Viewing angle, Reliability

- Effective collaboration of virtual and real world for integrated plant operation & maintenance