User Interfaces for Mobile and Wearable Computing

Augmented Reality 2

COMS E6176
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Columbia University
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The Ultimate Display

"The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming, such a display could literally be the Wonderland into which Alice walked."

— I. Sutherland, The Ultimate Display, *Proc. IFIP 65*, 506–508, 1965

Sutherland's See-Through Head-Worn Display *Late 60's*

Research Challenges: Ubiquity/Wearability

- Size
- Weight
- Durability
- Run-time
- Comfort
- Appearance

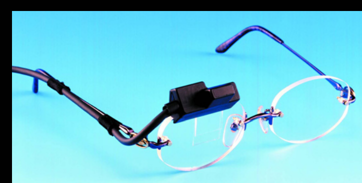
Columbia "Touring Machine"

Research Challenges: Displays

MicroOptical eyeglass display

[www.microopticalcorp.com]

Eyeglass displays



Minolta “forgettable display”

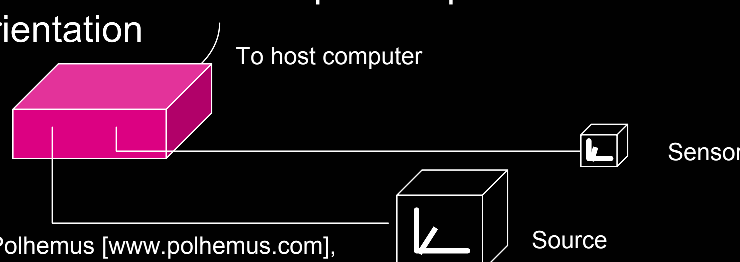
Technology: Spatial Trackers

Spatial Tracking Basics

- Usually a sensor determines position/orientation relative to a signal it detects from a source
- Source or sensor is fixed in a known position/orientation
- Technologies:
  - electromagnetic, ultrasonic, mechanical, video/optical, earth-relative, inertial, satellite, hybrid
  - coarse approaches: radio, RFID, IR

Electromagnetic (EM) Tracking

- Three orthogonal source coils emit a radio frequency electromagnetic signal in sequence
- Three sensor coils simultaneously measure the signal from each of the three source coils
- Nine measurements provide position and orientation



E.g., Polhemus [www.polhemus.com],
Ascension [www.ascension-tech.com]

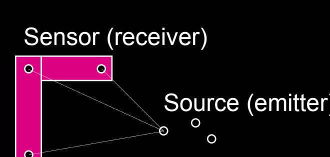
EM Tracking Advantages and Disadvantages

- Advantages
  - relatively unencumbering
  - do not need line-of-sight from source to sensor
- Disadvantages
  - large error in tracking, particularly dynamic error
  - short usable range (< 20’ for long-range xmtr)
  - highly sensitive to electromagnetic radiation and metal in environment

Ultrasonic Tracking

- An emitter emits an ultrasonic burst, and three receivers pick up the burst
- The time between emission and reception by each receiver gives emitter–receiver distance
- Can reconstruct 3D position of emitter if positions of receivers are known
- Three emitters allow full orientation measurement

E.g., Logitech “Red Baron”

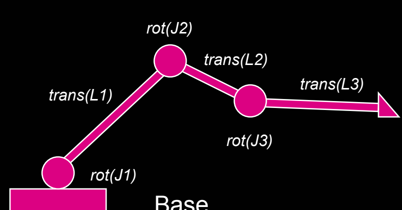


Ultrasonic Tracking Advantages and Disadvantages

- Advantages
  - low cost
  - easy to build
- Disadvantages
  - requires clear line-of-sight from emitters to receivers
  - very noisy, high dynamic distortion
  - very short range
  - Simple designs are susceptible to echos and environmental noise (e.g., jangling keys)

Mechanical Linkage Tracking

- Typically a jointed structure that measures the angle at each joint
- Using known angles and lengths of arms, compute relative positions/orientations of end



Mechanical Linkage Tracking Advantages and Disadvantages

- Advantages
  - very high quality tracking with low dynamic distortion
  - can support heavy displays (e.g., CRTs for head tracking)
  - mature off-the-shelf technology
- Disadvantages
  - restricted motion

Video/Optical Tracking

- Video cameras monitor environment
  - track active LEDs or passive retroreflective markers
- "Outside-in": tracked user/object wears targets
- "Inside-out": tracked user/object wears cameras

E.g., ARToolkit [www.hitl.washington.edu/shared_space], Northern Digital [www.ndigital.com], Phoenix Technologies [www.ptiphoenix.com], 3rdTech [www.3rdtech.com]

Video/Optical Tracking Advantages and Disadvantages

- Advantages
  - very high quality
  - can use head-worn cameras for video see-through display
  - potentially supports object recognition
- Disadvantages
  - requires clear line-of-sight
  - multi-camera configurations can be difficult to calibrate

"Sourceless" Tracking

Earth-Relative Tracking

- magnetometer determines yaw from earth's magnetic field
- inclinometers determine roll and pitch from earth's gravitational field

E.g., Precision Navigation [www.precisionnav.com]

Earth-Relative Tracking Advantages and Disadvantages

- Advantages
  - no source needed (besides the earth!)
  - lightweight (< 2 oz.)
  - inexpensive
- Disadvantages
  - susceptible to magnetic field anomalies (large metal objects) and changes over time
  - angle limits caused by inclinometer and/or magnetometer gimbals

Inertial Tracking

- Linear accelerometers
- Angular rate gyroscopes
- Advantages
  - unlimited range
- Disadvantages
  - currently very difficult/expensive to make accurate systems
  - error accumulates over time

Satellite Position Tracking

- Constellations of US (GPS)/Russian (GLONASS) satellites
- Radio receiver(s) determine distance from multiple satellites (*ca.* 10m accuracy)
- *Differential* GPS uses correction signal broadcast from receiver at precisely known location (*ca.* submeter accuracy)
- *RTK carrier-phase measurement* GPS (*ca.* cm accuracy)

E.g., Trimble [www.trimble.com], Ashtech [www.ashtech.com]

Satellite Position Tracking Advantages and Disadvantages

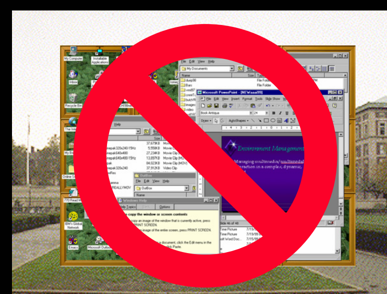
- Advantages
  - *Very* long range
- Disadvantages
  - must be within line-of-sight of satellites (not indoors or in “urban canyons”)
  - poor altitude tracking
  - governments own satellites (encryption, “selective availability”, politics)
  - low update rate

Hybrid Trackers

- Combine different technologies
- Examples
  - Inertial tracker (fast, but drifts) and
    - ultrasonic tracker (–slower, +ground truth, → position and orientation): InterSense IS 900
    - magnetometer (–slower, +ground truth, +sourceless, → orientation): InterSense IS 300
    - www.isense.com
  - Orientation tracker, GPS, and dead reckoning: Point Research Systems

Research Challenges: UI Design

- What should we see, hear, feel, . . .?
- How should we interact with it?

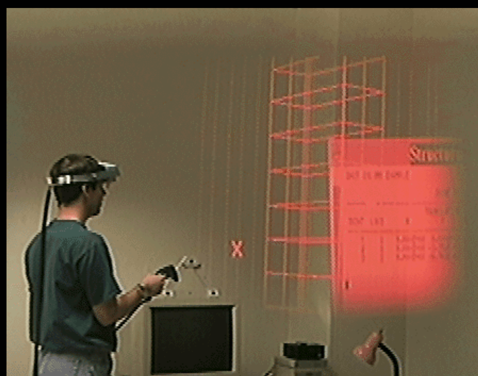


Windows on the World *1993*

- X11 server
- Track head/body/hand and selected objects
- User “wears” virtual information surround
- Windows fixed to display, surround, world
- Hypermedia links between physical and virtual objects

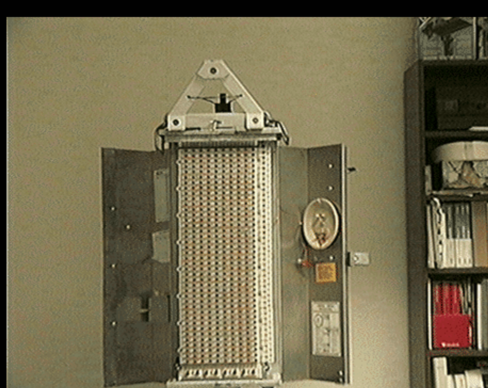
Architectural Anatomy *1995*

Webster, Krueger, MacIntyre, & Keller



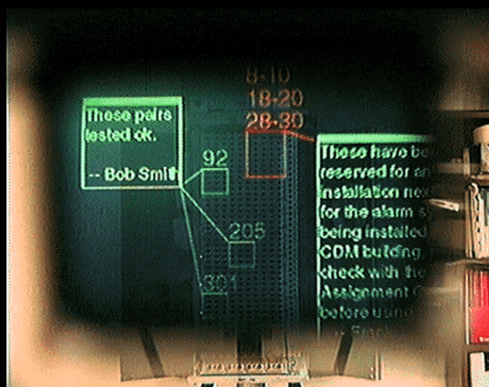
- User examines building support systems *in situ*
- 3D graphics reveal hidden physical elements
- 2D graphics overlay output of analysis tools

Field Service *1996*



- “Crossbox” telecom junction panel connects clients to main switch

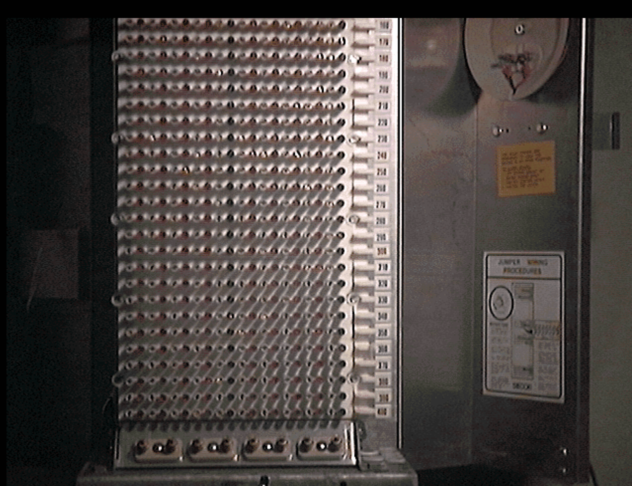
Field Service *1996*



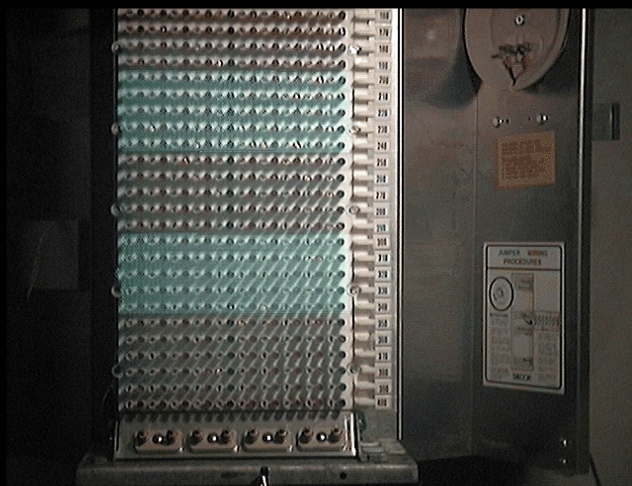
- 3D graphics identify groups of connection posts
- 2D windows describe connection status
- 2D windows can be pulled in/out to avoid clutter

Field Service: Telecom Crossbox

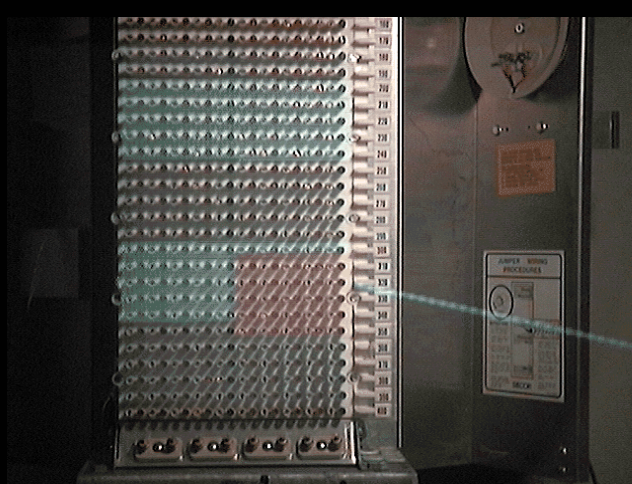
Normal view



Field Service: *Telecom Crossbox*
Augmented view: Blocks of posts

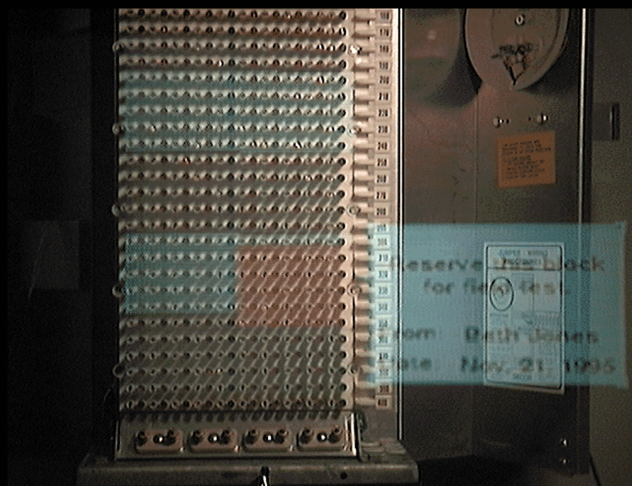


Field Service: *Telecom Crossbox*
Augmented view: Selected group connected to note



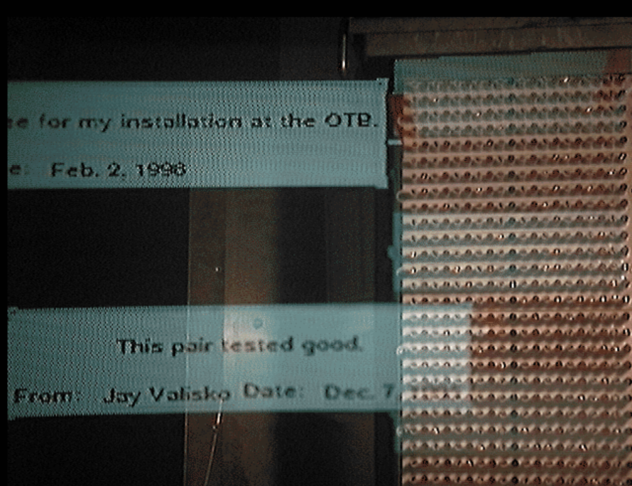
Field Service: *Telecom Crossbox*

Augmented view: Note "pulled in" for inspection



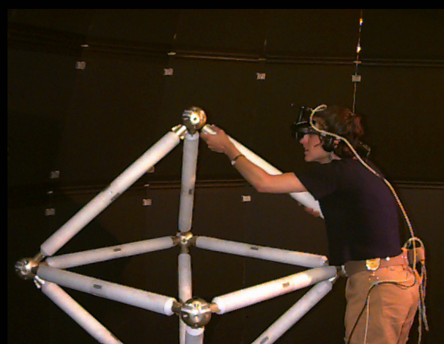
Field Service: *Telecom Crossbox*

Augmented view: Additional notes



ARC: Augmented Reality for Construction *1996–98*

(Joint with Building Technologies Lab)



- Assist worker in assembling spaceframe building
- Goal
  - Right piece
  - Right place
  - Right sequence

Spaceframe Construction Task

for each spaceframe piece in sequence {

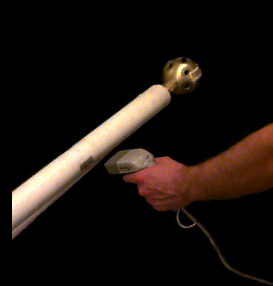
select piece and verify identity

install piece

verify location and identity

}

User Interface

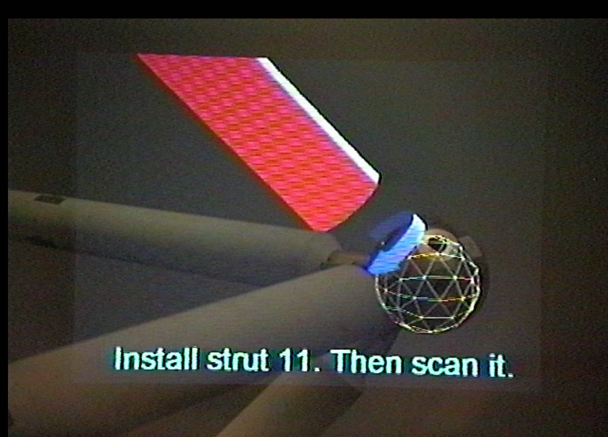


- See-through head-worn display
  - provides visual and audio instructions
- Bar code reader
  - verifies part identity and placement
- Display and reader are tracked

Real World

Virtual World

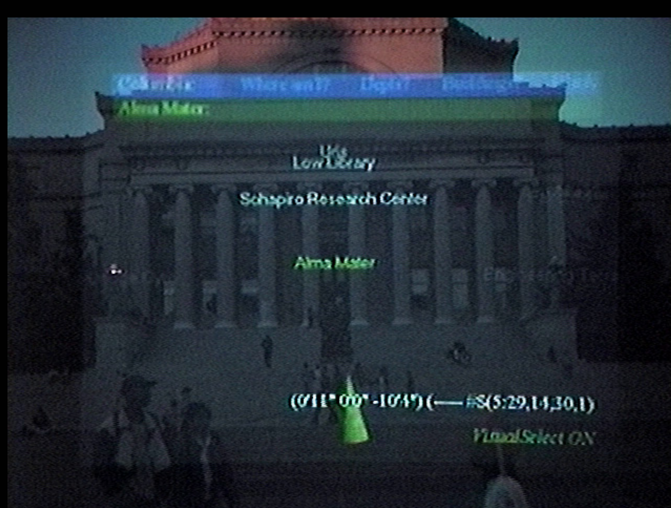
Real World + Virtual World



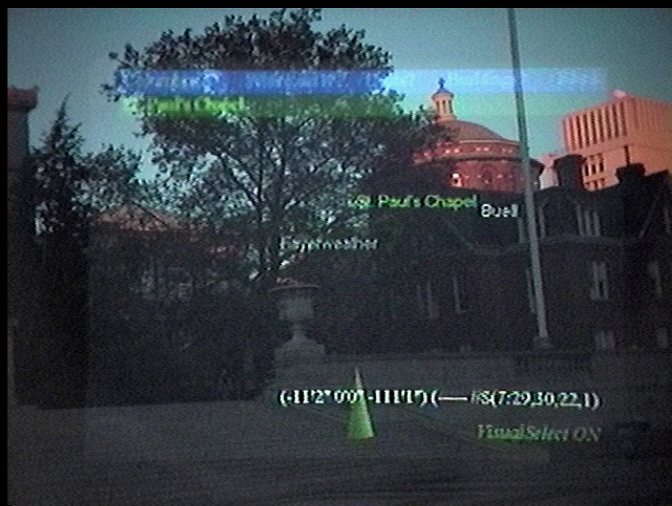
Touring Machine *1996–*

- Assist mobile user in exploring an unfamiliar environment
- User interface
  - See-through head-worn display
  - Hand-held pen computer/tablet
- Backpack contains
  - computer with 3D graphics card
  - differential GPS system
  - spread-spectrum radio modem

UI: Overlaid Labels



UI: Overlaid Labels



Touring Machine: Columbia Campus

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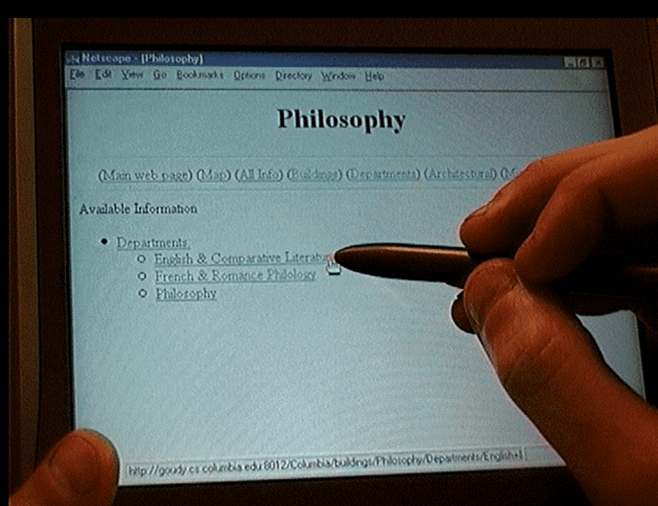
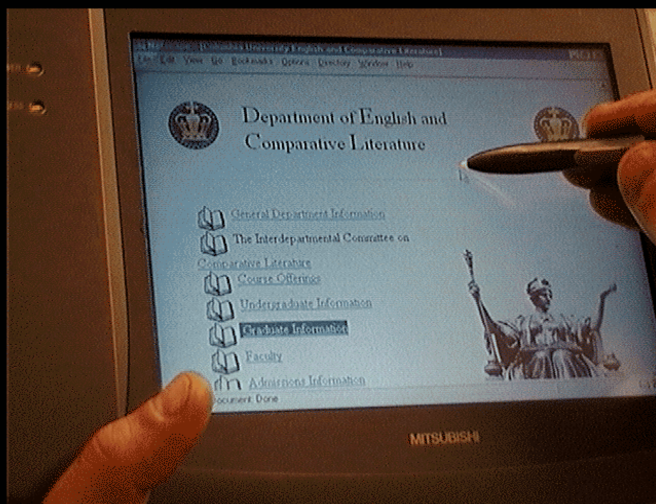


Touring Machine: Columbia Campus



Research Challenges: Environment Management

- Task of managing
  - *large numbers of objects* on
  - *large numbers of displays* for
  - *large numbers of users*
- Develop methods to
  - organize, filter, modify, navigate

  interactive information spaces that are
  - large, shared, 3D, multimedia

Environment Management Architecture

World, User, Hdw, Situation, Tasks → **Information Filtering** → **UI Component Design** → **View Management** → AR UI

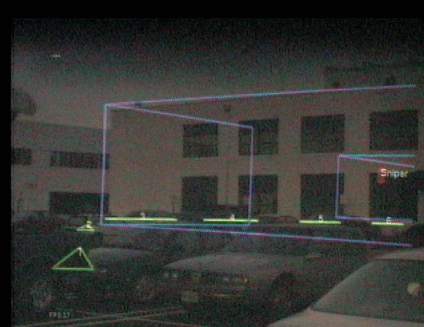
Information Filtering	UI Component Design	View Management
Choose data to display	Map data to UI components	Lay out UI components

Dynamically redesign UI

Information Filtering 2000

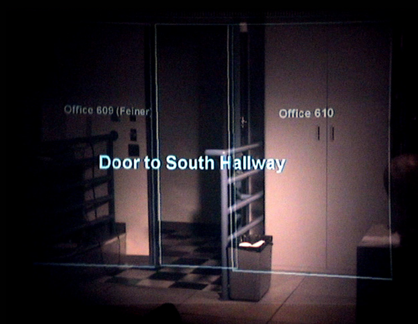
(Imaged with Naval Research Lab BARS)

Unfiltered: All objects shown

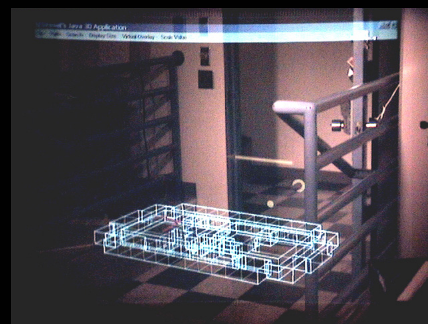


Filtered: Only objects relevant to route-finding task are shown

UI Component Design 2001



Precise position tracking: labels registered with real world



Imprecise position tracking: scaled world model displayed

Problem

- Arbitrary viewpoint
- Arbitrary scene configuration
- Dynamic environment

→

- Annotation soup

View Management 2001

- Dynamic layout of 3D information to avoid occlusion, overlap:
  - Labels
  - Annotations
  - UI components

View Management
Naïve Annotation

Annotation based on centroids

- Misplaced, overlapped, ambiguous

View Management
Automated Annotation

Annotation based on centroids
- Misplaced, overlapped, ambiguous

Annotation using new approach
- Correctly placed, overlap and ambiguity avoided

View Management
Campus Overview