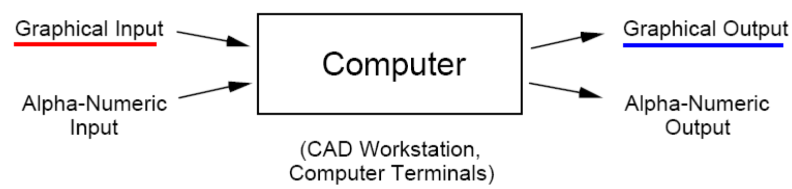
II. Hardware of a CAD System

- Computer System
  - **Mainframe Computer and Graphics Terminals**
    - Powerful
    - Inconvenient
    - High cost
  - **Turn-key CAD System**
    - Dedicated computer systems for CAD applications, consisting of a super-mini computer and several design work stations.
    - Following the "central control concept"
    - Inconvenient and not powerful enough for complex 3D modeling.
  - **Workstations & High-End Personal Computers**
    - Supporting multiple tasks
    - Supporting network and file-sharing – convenient
    - Low costs
    - Present and trend

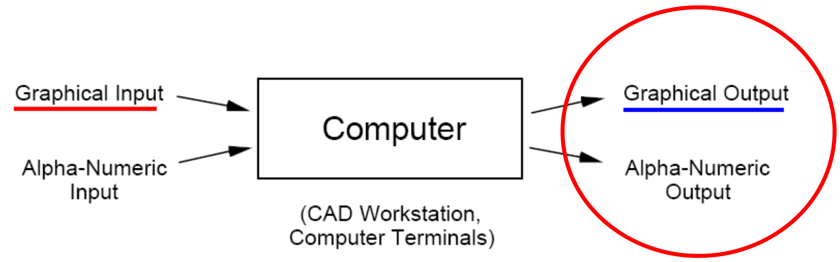
II. Hardware of a CAD System

- Input and Output Devices



Graphical Output Devices

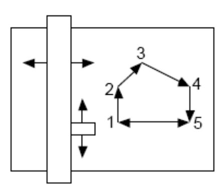
- Input and Output Devices



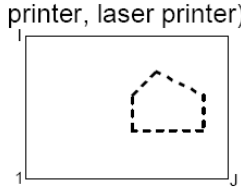
Graphical Output Devices:

(a) Two techniques:

Vector or Stroke Device (example - pen plotter)



Raster Scan Device (example - dot matrix printer, laser printer)



Instructions:

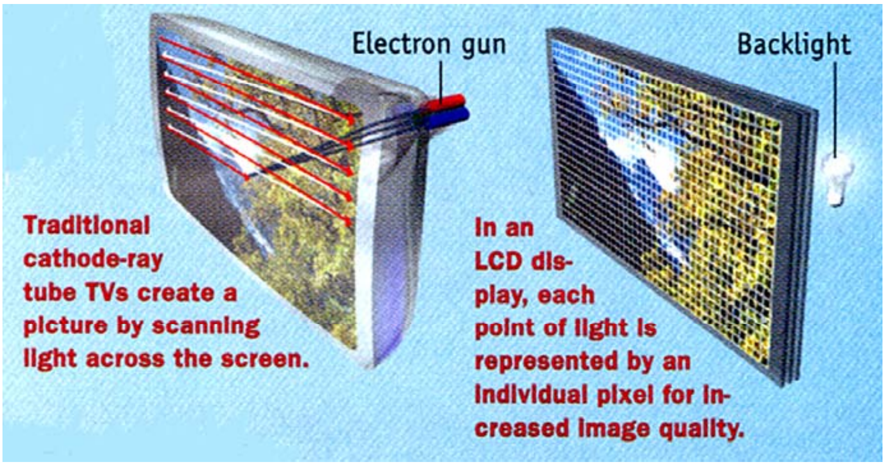
Pen up; X4, Y4;
X1, Y1; X5, Y5;
Pen down; X1, Y1;
X2, Y2; Pen up;
X3, Y3

Use an array A (I,J)

where each element is "0" or "1"

0 – blank
1 – dot

Two Raster Display Devices (CRT and LCD)



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Graphical Output Devices:

Advantages

Vector	Raster
(1) Good Resolution (a) straight lines (b) smooth curves	(1) Speed independent of image
(2) Requiring limited memory and few instructions	(2) Difficult to do halftones shading — Used to be

Disadvantages

Vector	Raster
(1) Slow for complex images - flicker on CRT	(1) Limited resolution — Used to be
(2) Shading difficult and slow	(2) Requiring large memory for array storage

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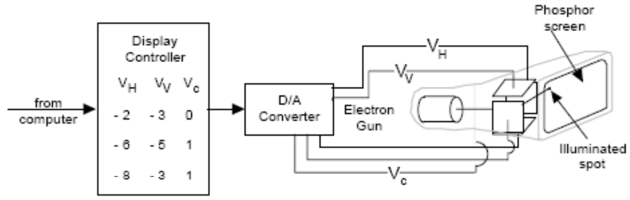
Graphical Output Devices:

(b) CRT (Cathode Ray Tube) - A Vector Device

The electron beam, which is deflected electrostatically or magnetically, causes phosphor coating to glow. Persistence depends on coating material (10-60 usec). The display is refreshed 30~60 times/sec. above the fusion frequency of the human eyes (23 times/sec).

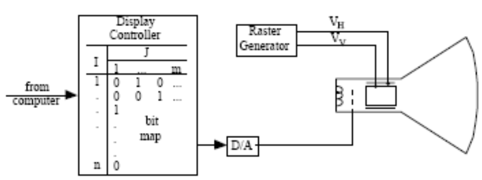


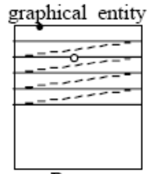
V_H – Horizontal Voltage $V_c = 0$ Beam off
V_C – Vertical Voltage $V_c = 1$ Beam on

$$\text{Line intensity} \approx \frac{\text{time}}{\text{Length}} = \frac{1}{V} \text{ needs to be constant.}$$

Graphical Output Devices:

(c) Raster Device (Television Monitor)





$$V_c(I, J) = \begin{cases} 0 & \text{pixel off} \\ 1 & \text{pixel on} \end{cases}$$

The resolution of the display is determined by the size of the screen pixel. This size is limited by the beam resolution (~ 0.01 u) and display memory.

An example: a 13-inch screen (8 inch x 10 inch),
100 x 100 pixels/in^2 for a monochrome monitor,
1 bit/pixel (8 bits for color or multiple gray levels)
80 in^2 x 10,000 pixels/in^2 = 800,000 bits.

Graphics Card Selection

- Graphics card is as important as the CPU, RAM and hard drive for CAD, video, or graphics applications;
- The default graphics cards (GPU) listed by the computer manufacturer is mainly for regular business applications or video gaming, and is not appropriate for heavy graphics usage;
- Low-cost (under $200) graphics cards or cards from unknown manufacture do not provide full OpenGL support that is required by CAD or graphics applications, affecting the performance and stability of the CAD and graphics application;
- CAD software vendors normally provide a constantly updated list of tested graphics cards and drivers.

Flat Panel Display (FPD)Technology

- LCD (Liquid-Crystal Display) (<52'')
- Plasma Display (52-80")
- DLP™ (Digital Light Processing™) (>52'')
- Organic LED or OLED (Organic Light-emitting Diode)

Notes:

Plasma will outperform LCD by providing lots of dark and better contrast, but LCD outperforms plasma in brightness and color.

Cost of Plasma for larger size screen is lower, but it suffers from burn-in.

DLP shows its advantage for very large projection screens.

OLED represents future FPD technology.

Future Display Technologies – 3D Display

Gas-Plasma Display

Plasma display employs neon and xenon gases which are trapped between two thin layers of glass to create a digital image.

A small electric pulse is applied to each pixel to excite the gases to produce the color information and light.

These rare gases actually have a life and fade over time. The life of these phosphors is around 25,000 to 30,000 hours (not replaceable).

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LCD (Liquid-Crystal Display)

- A matrix of thin-film transistors (TFTs) supplies voltage to liquid crystal-filled cells sandwiched between two sheets of glass.
- A trio of red, green, and blue cells make up one pixel.
- When hit with an electrical charge, the crystals "untwist" to an exact degree to filter light generated by
  - fluorescent or LED array backlight behind the screen (for flat-panel LCDs)
  - one shining through a small LCD chip for front projection LCD projectors or rear projection LCD TVs.
  - LCD has an expected life between 50,000 and 75,000 hours, as long as the backlight (often replaceable)
  - (first appeared in calculators in 1970s reflected light from back mirror)




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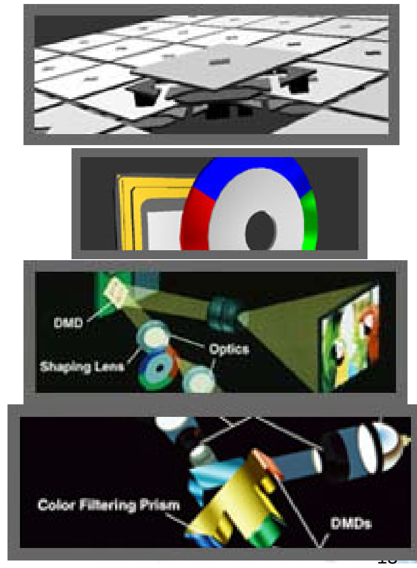
DLP™ (Digital Light Processing™)

- A semiconductor-based display, from Texas Instruments (1993)
- A panel of micromirrors are mounted on tiny hinges that enable them to tilt either toward or away from the light source in a DLP™ projection system (ON/OFF) - creating a light or dark pixel on the projection surface.
- The white light generated by the lamp in a DLP projection system passes through a color wheel as it travels to the surface of the DMD panel - **1-chip system**
- 3-chip DLP™ projection system has three light sources (RGB) and no color wheel.



Light Valve Display

Organic Light-emitting Diode (OLED),

- OLED, also Light Emitting Polymer (LEP)
- The whole display can be built on one sheet of glass or plastic with a light emitting layer (rigid or flexible)
- The light emitting layer contains a polymer substance on which a layer of organic compounds are deposited/printed.
- It provides better performance at lower costs and use much less power.
- It displays full-color, video-rate imagery with much faster response times, wider viewing angles, and brighter, more saturated colors.

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Key Technical Terms

- **Traditional**
  - Refresh Rate of CRTs is refers to how often the screen is redrawn per second. With low refresh rates you can get screen flicker and eye strain. Aim for a rate of 75 Hz for a monitor up to 17 inches in size and 85 Hz for any larger monitor.
  - LCDs are basically flicker free so refresh rates are not as important..
  - Dot Pitch is the distance in millimeters between phosphors of the same color. The smaller the dot pitch, the sharper the image. Opt for a dot pitch of 0.26 mm or smaller (usually quote horizontal dot pitch).
- **New**
  - Brightness: LCD monitors have several backlights that provide illumination. Brightness is measured in units called nits. The majority of LCDs produce 150-200 nits which is fine for most users. The backlights in a LCD are good for 10 to 50 thousand hours of operation.
  - Native Resolution (Display Capabilities)
  - Dynamic Contrast Ratio (and True Contrast Ratio)
  - Response Time (Better LCD TVs operate at 120 MHz refresh rate for fast moving objects)

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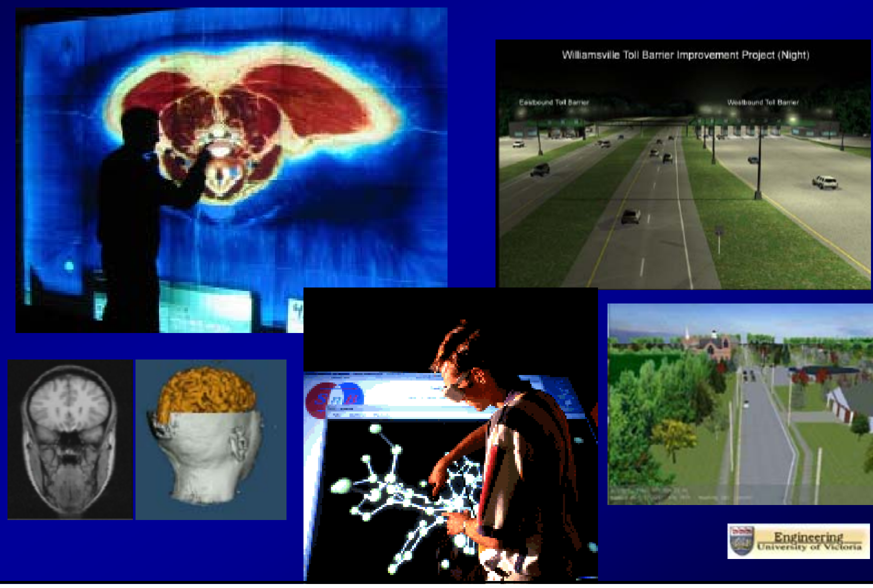
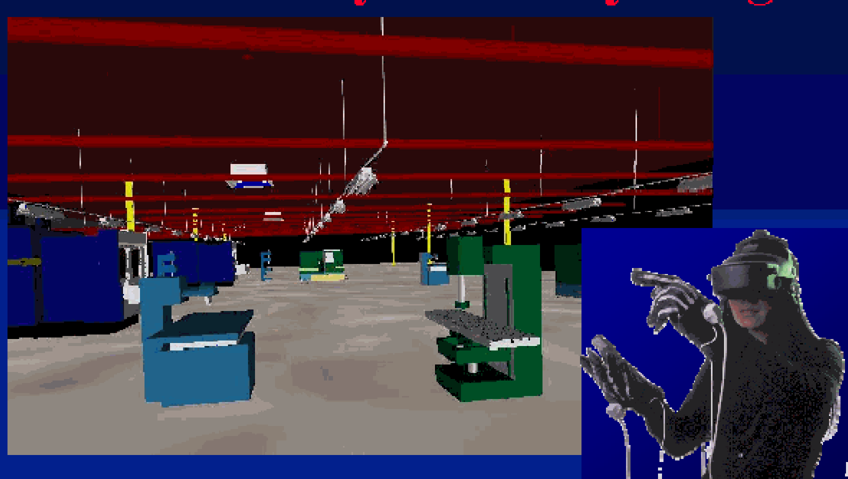
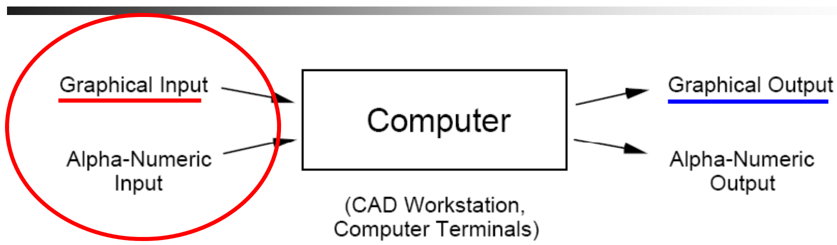
High-Performance Computing & High-End Visualization



Virtual Reality & Factory Design



Graphical Input Devices:



a) Keyboard

- Alphanumeric characters
- Graphical input by arrow keys

Pressing key sends an ASCII code to the computer. The software translates the ASCII code into a change in the cursor position. Return key enters location.

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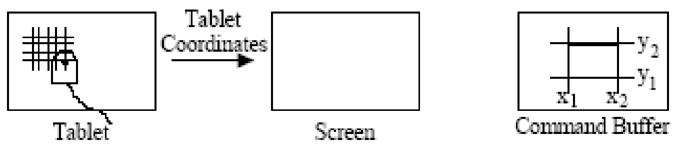
Graphical Input Devices:

b) Tablet

- Grid board



The embedded grid of wires in the tablet senses the electric field produced by the puck/pen and provides the software with puck/pen position. It can be used for

- updating the graphic cursor position
- digitizing a drawing on paper
- entering a system command

If $x_1 < x < x_2$ and $y_1 < y < y_2$, execute command "xxx"

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Graphical Input Devices:

New Thinkpad (Lenovo)
and Dell Mobile Workstations:

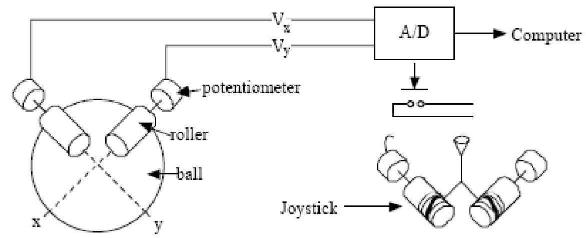
Thinkpad W – Series ThinkPad mobile workstations:

- Intel® Core™2 Duo technology (CPU)
- Advanced NVIDIA discrete graphics (card)
- OpenGL (Open Graphics Library) with dedicated video memory
- Build-in Palm-rest digitizer and pen
- Automatic Color Calibration
- 17" widescreen display

Graphical Input Devices:

c) Mouse

- Mechanical Mouse (and Joystick)



As the ball rolls on surface, rollers and potentiometers monitor changes in x, y coor. Button records position.

- Optical Mouse

LED illumination and grid interpreter

- Wireless Mouse

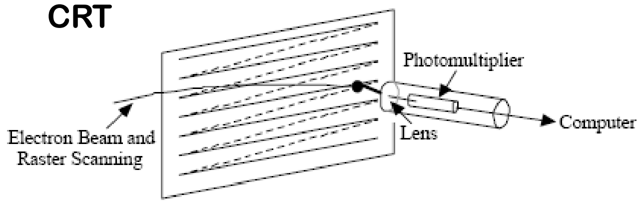
Infrared system and Bluetooth system: mouse (emitter) and USB connected receiver.

Graphical Input Devices:

d) Light Pen

The photomultiplier records the passage of the electron beam. Time lapse from the start of Raster determines the pen location.

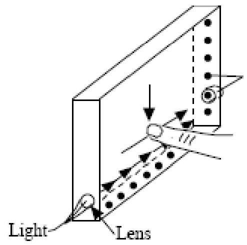
CRT



Graphical Input Devices:

(e) Touch Sensors

- Arrays of beams and detectors (old)



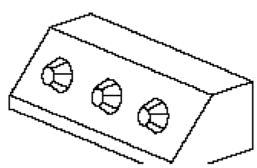
Arrays of infrared light sources and array of detectors are used to generate invisible light grids. A finger interrupts two light beams and provides x and y coordinates.

- Touch Screen (present)

  - Pressure sensible pad and film on top of graphical display (PDA and Tablet PC)

Graphical Input Devices:

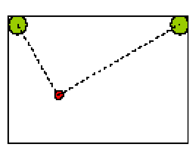
(f) Valuator



For CAD and Simulation Workstations

- Light sensor based

  - two sensors on each top corner of the "pad" with a special/regular pen.



For wireless pen input, and electronic whiteboard

3D Range Data Acquisition and Its Applications

- **2D Image:** **(for each pixel: X and Y coordinates and light intensity). The intensity could be gray (8 bits: 0 – 255) or color RGB (24 bits).**
- **3D Range Image/Data from Range Sensing Devices and 3D Camera – data points defined by their X, Y, and Z coordinates (cloud point data) – added Depth.**
  - ***Mechanical probe (measurement and scanning)***
  - ***Laser scanning***
    - ***Triangulation-based*** range sensing devices
    - ***Time-of-flight based*** range sensing devices
  - Machine vision based CAD model generation for:
    - reverse engineering
    - machine vision and intelligent robot
    - vehicle size measurement and traffic monitoring
    - scanning of 3D object, human body, and art work

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Generation of CAD Model with Free-form Shape Automotive Design Example

Architecture Design & Scaled Clay Model

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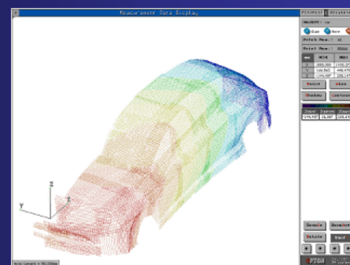
Automotive Design and CAD Model Generation

Scanning of Clay Model to Obtain Surface Data



Design Details Using CAD System

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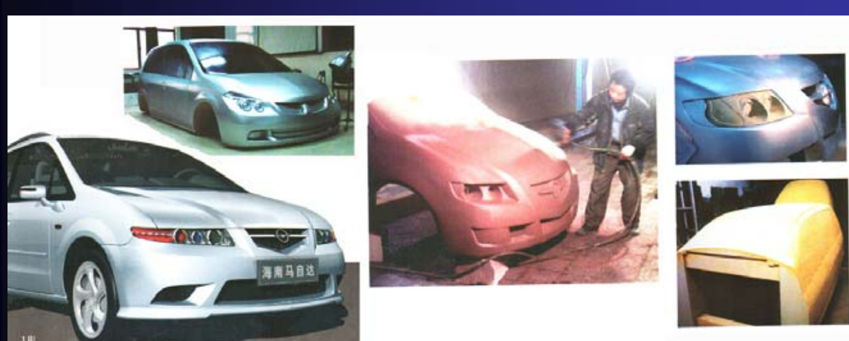
Full Size Foam Model Machined Using a 5-Axis CNC Mill from 3D CAD Model



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Full Size Foam Model Machined Using a 5-Axis CNC Mill from 3D CAD Model

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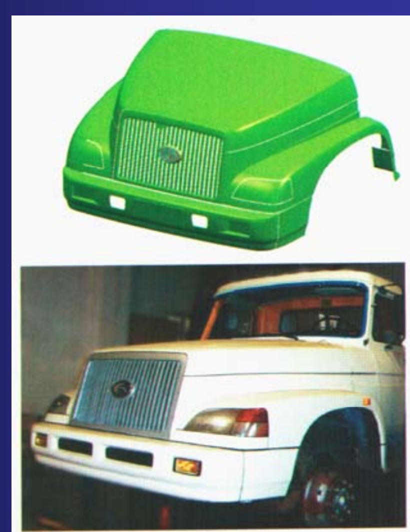
CAD Model Regenerated from 3D Scanning



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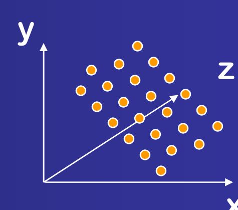
Scanners with Mechanical Probe

CAD Modeling Based on a 3-D Vision System

- 3D Range Sensors (3D Cameras): 3D Cloud Data Points
  - Triangulation-based: visible laser light, short range, accurate
  - Time-of-flight-based: laser light & micro wave, long range, less accurate



- Processing of 3D Range Data
  - 3D Cloud Data Points → Cross-section-based CAD Model
  - Generation of a Complete Model of Objects and Workspace – by Sensor Fusion
- Forming a Surface Model and Carrying out Reverse Engineering
  - Cross-section-based CAD Model → Surface Model → CNC Machining; RP; etc.

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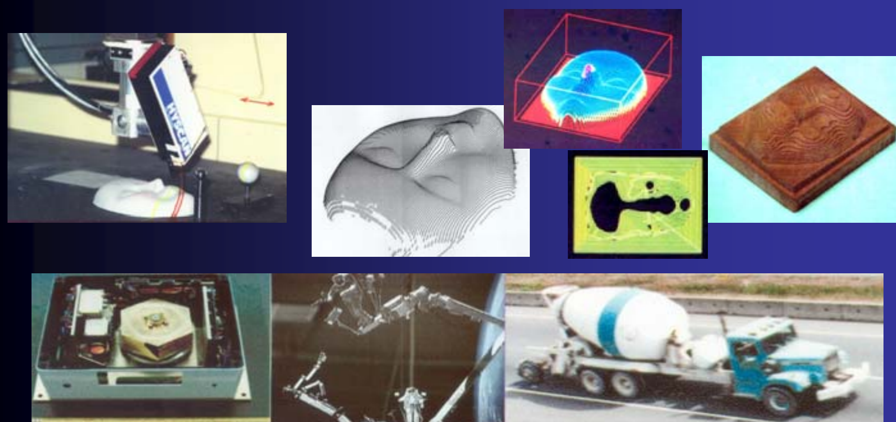
Our Past Researches on Three Dimensional Range Sensing and Object/Workspace Modeling from Multiple Range Images



Obtaining 3D Cloud Data Points Using 3D Range Sensors (3D Cameras)

Two Alternatives:

- Triangulation-based: visible laser light, short range, accurate
- Time-of-flight-based: laser light & micro wave, long range, less accurate

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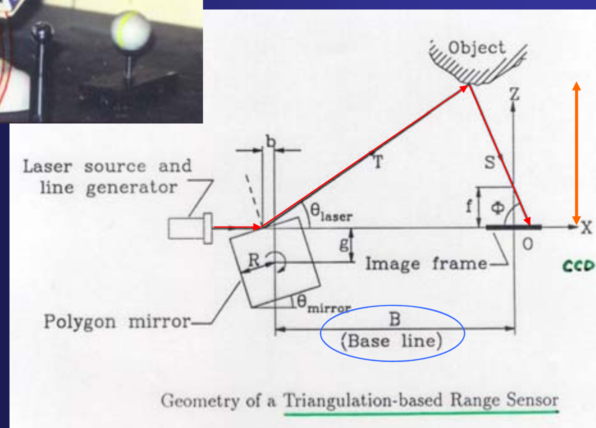
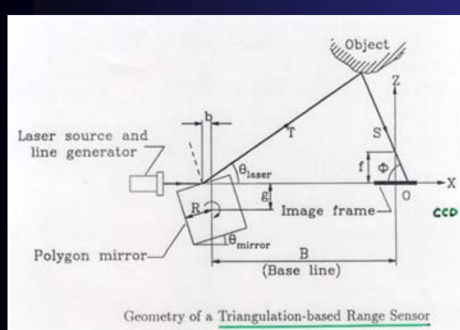
Triangulation-based Range Sensor

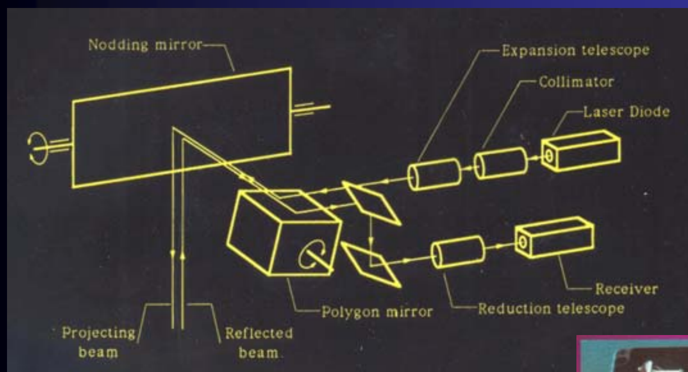


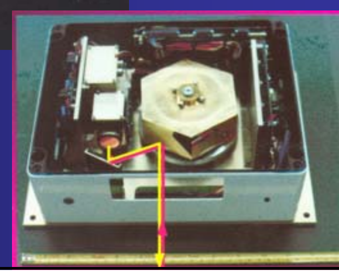
Triangulation-based Range Sensor

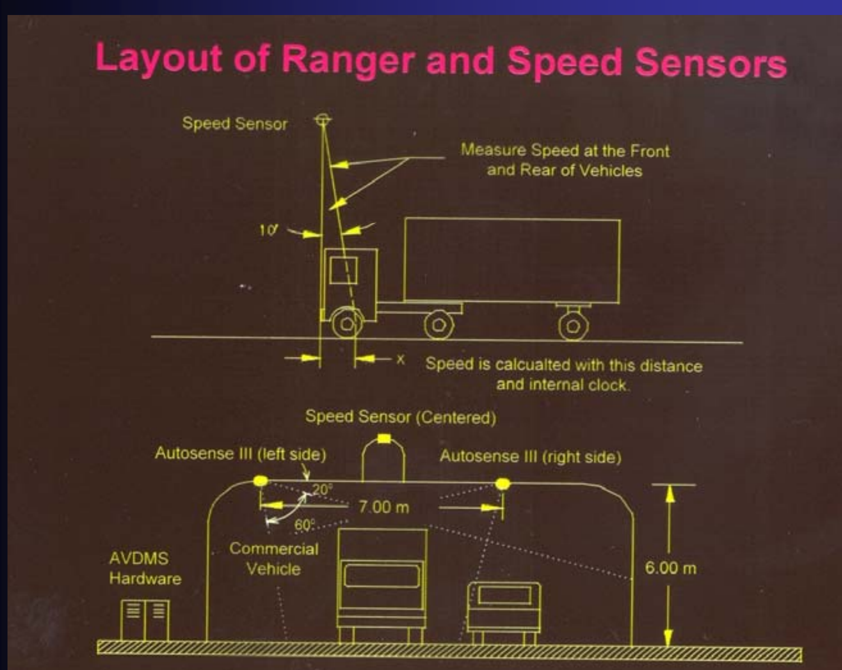


calibration

Time of Flight Based Range Sensor







Processing 3D Range Data to Get 3D CAD Models for Reverse Engineering

- Processing of 3D Range Data
  - 3D Cloud Data Points → Cross-section-based CAD Model
  - Generation of a Complete Description for Objects and Workspace by Sensor Fusion
- Forming a Surface Model and Carrying out Reverse Engineering
  - Cross-section-based CAD Model → Surface Model
    → CNC Machining; RP; etc.

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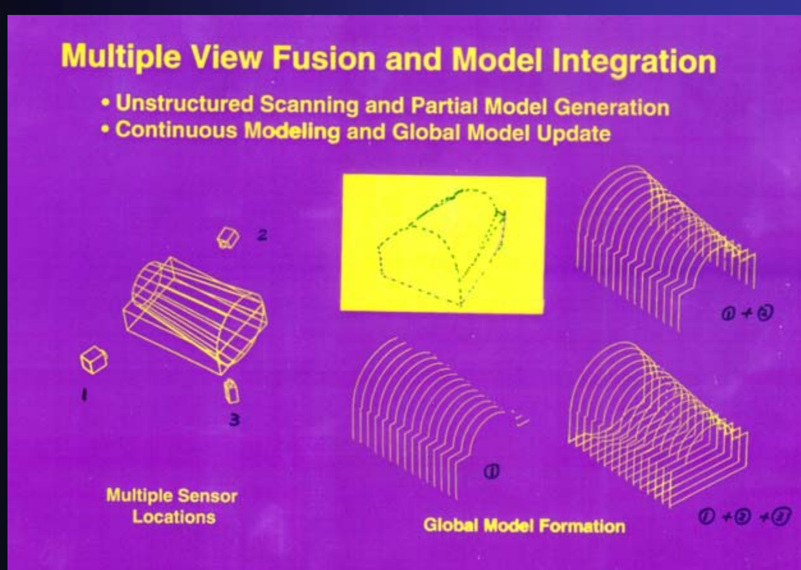
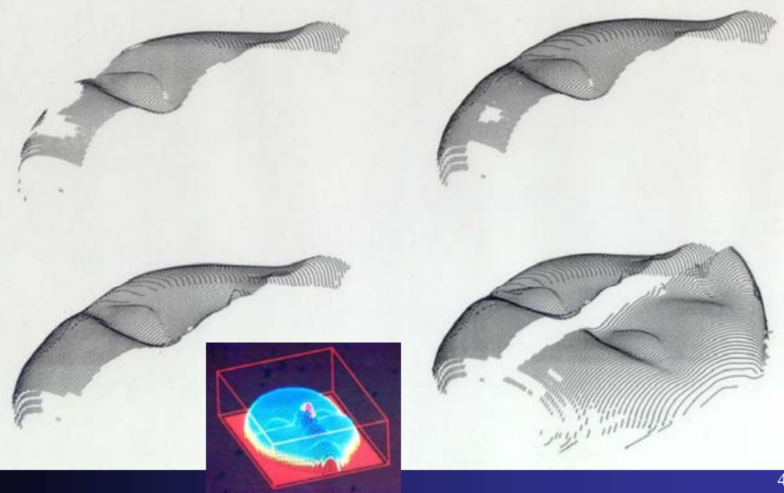
Multiple View Fusion and Model Integration



Global Model Generation with Multiple View Fusion

An Approach to Generate Geometric Models from Multiple Range Images

Cross-section Model



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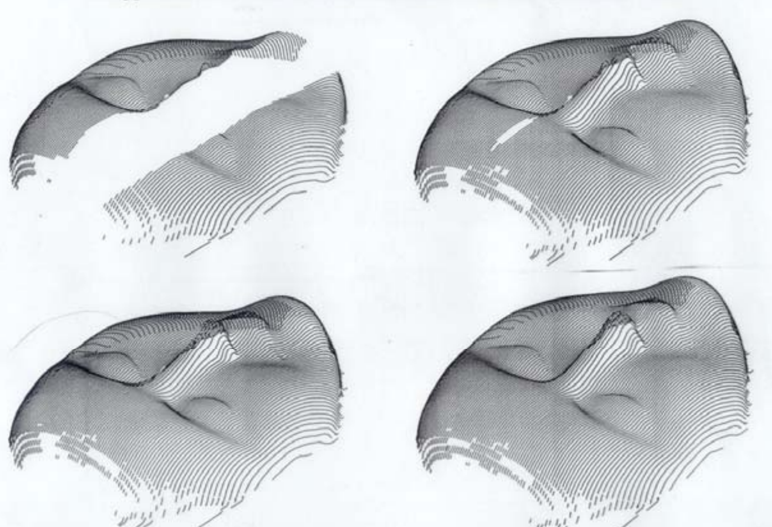
Global Model Generation with Multiple View Fusion

An Approach to Generate Geometric Models from Multiple Range Images



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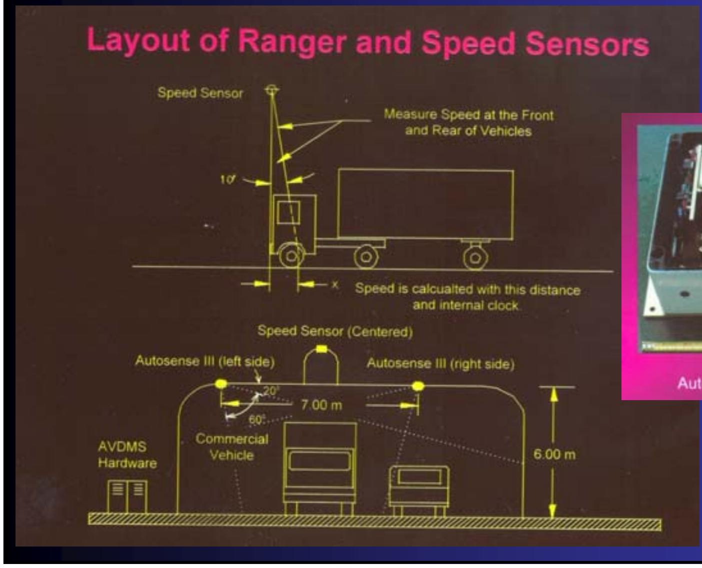
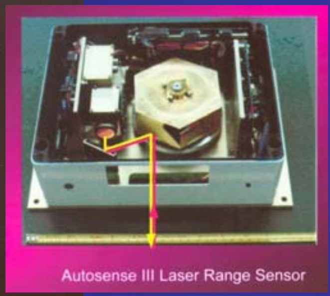
Automated Real-time Dimension Measurement of Moving Vehicles Using Infrared Laser Rangefinders

Automated Vehicle Dimension Measurement System for Commercial and Oversize Vehicles

- Implemented at BC Ferries Terminal
- Real-time Vehicle Dimension Measurement
- Complex Vehicle Shapes
- Dimensions Measured at Speeds up to 120 km/hr
- Adverse Weather Conditions
- Height and Width Accuracy: 15 cm
- Length Accuracy: 30 cm

Automated Real-time Dimension Measurement of Moving Vehicles Using Infrared Laser Rangefinders





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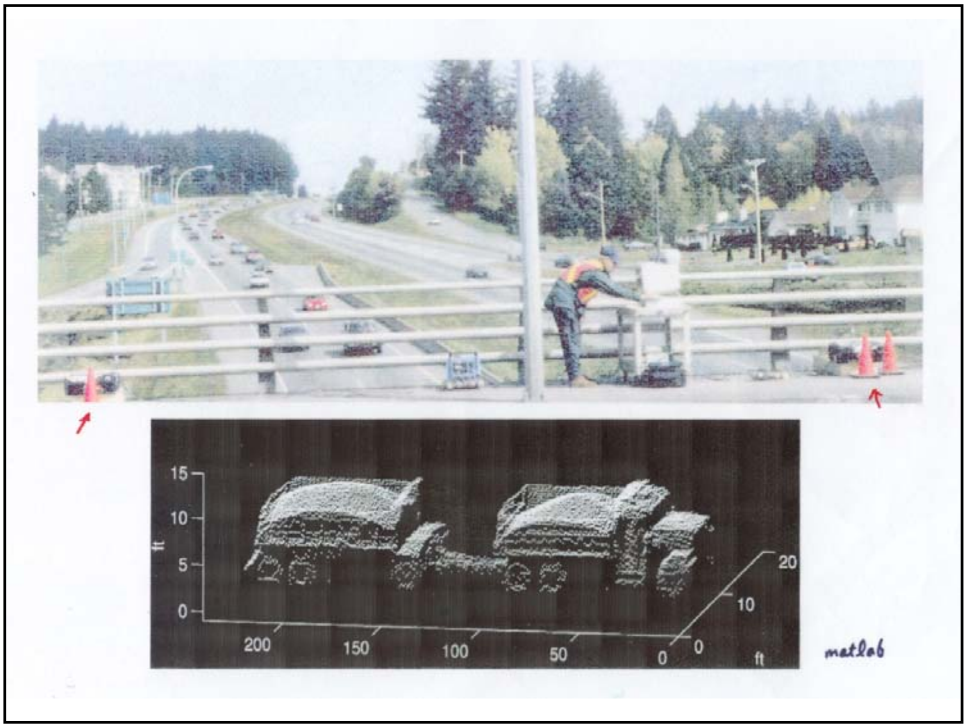
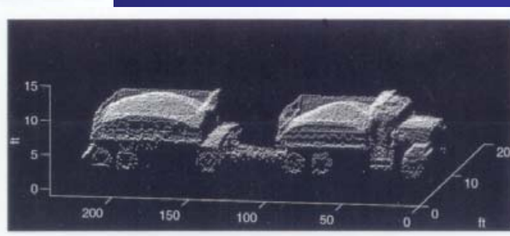
Road Test Site

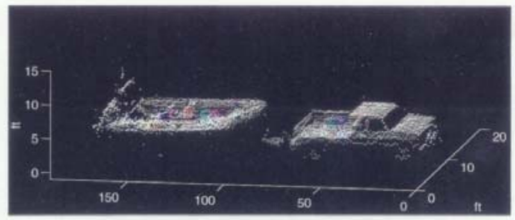


(a) Photograph of the Vehicle

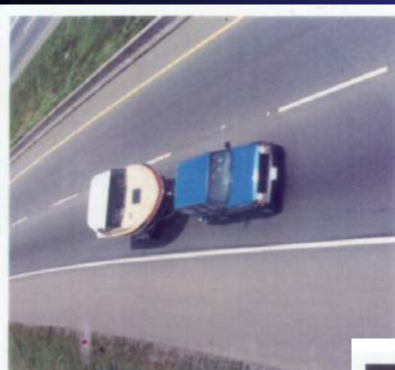


(b) Acquired Range Data of the Vehicle

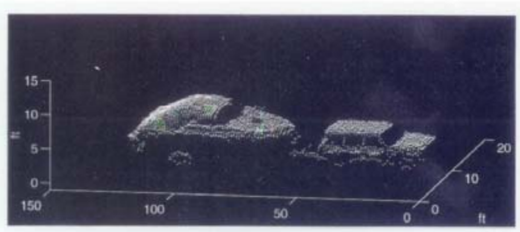
(a) Photograph of the Vehicle



(b) Acquired Range Data of the Vehicle



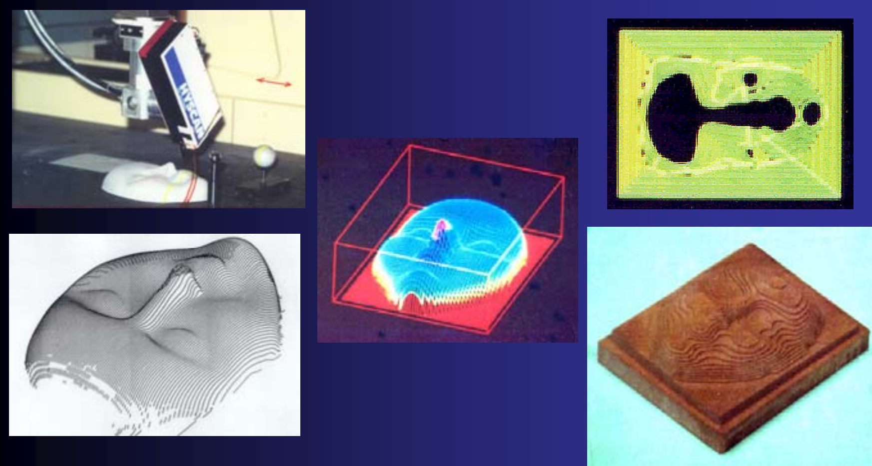
(a) Photograph of the Vehicle



(b) Acquired Range Data of the Vehicle

Reverse Engineering and Automated CNC Tool Path Generation for Efficient and High Quality Sculptured Part Machining

(To Be Discussed in Details Later on)



Geometric Modeling Based on 3D Scanning

- **Challenges:**
  - Accuracy/Lighting/Range (Selecting Right 3D Sensing Tech)
  - Occlusion (Obstruction)/Multiple View Fusion
  - Multiple Level Modeling:
    Cloud Data Points → Cross-sections → Surfaces → Solid
- **Applications:**
  - Reverse Engineering (e.g. Face Mask)
  - Size Measurement (e.g. Moving Vehicle)
  - Object Recognition (e.g. Moving Vehicle)
  - 3D Log CAD Model Generation
  - 3D Sculpture Documentation
  - Shoe Making
  - Character Modeling in Movies/Computer Games
- **Assignments:**
  Read on 3D Range Sensing (Reading Materials on Web:
  Technical References on 3D Scanning and Computer Model Generation)

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