

# Real-Time 3D Model Acquisition

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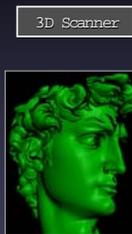
# 3D Scanning



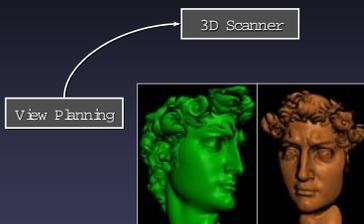
# Possible Research Goals

- Low noise
- Guaranteed high accuracy
- High speed
- Low cost
- Automatic operation
- No holes

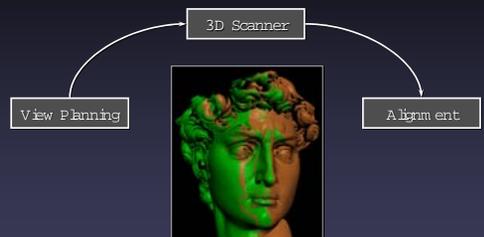
# 3D Model Acquisition Pipeline



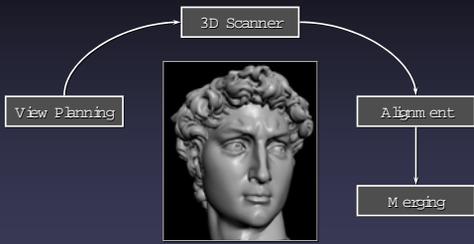
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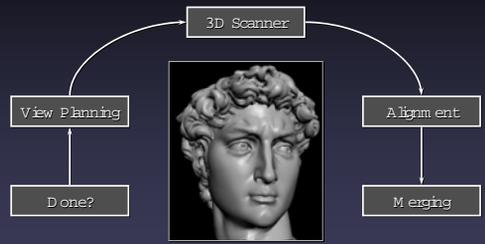
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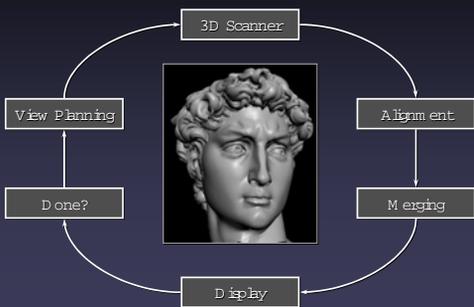
### 3D Model Acquisition Pipeline



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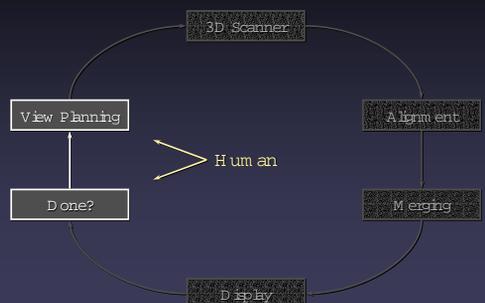
### 3D Model Acquisition Difficulties

- Much (often most) time spent on "last 20%"
- Pipeline not optimized for hole-filling
- Not sufficient just to speed up scanner - must design pipeline for fast feedback

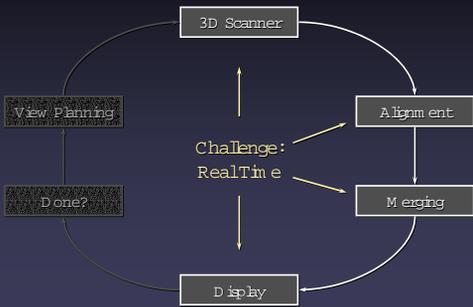
### Real-Time 3D Model Acquisition



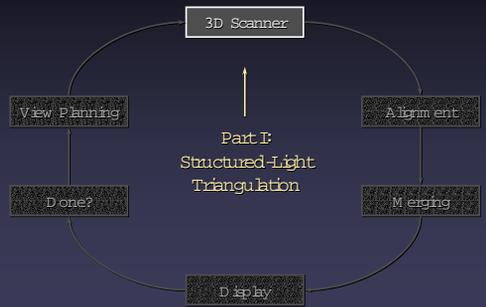
### Real-Time 3D Model Acquisition Pipeline



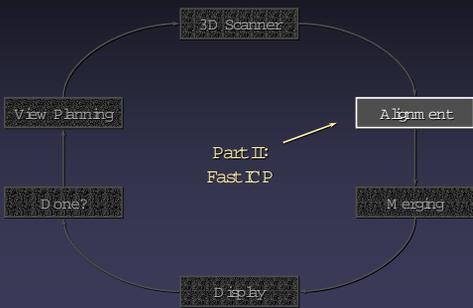
# Real-Time 3D Model Acquisition Pipeline



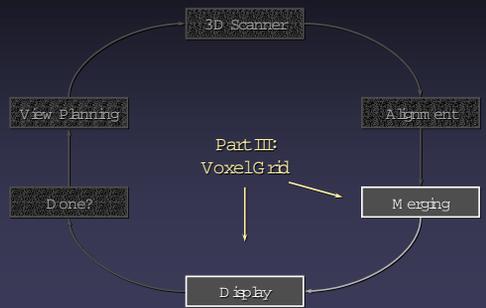
# Real-Time 3D Model Acquisition Pipeline



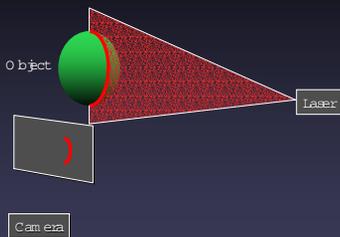
# Real-Time 3D Model Acquisition Pipeline



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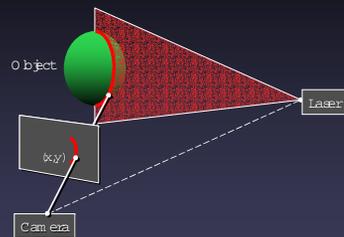


## Triangulation



- Project laser stripe onto object

## Triangulation

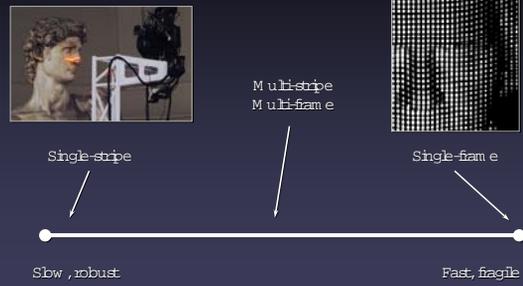


- Depth from ray-plane triangulation

## Triangulation

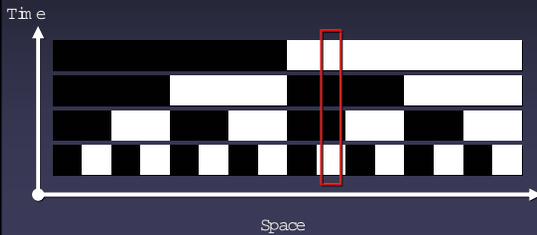
- Faster acquisition: project multiple stripes
- Correspondence problem: which stripe is which?

## Continuum of Triangulation Methods



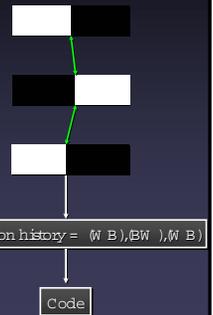
## Time-Coded Light Patterns

- Assign each stripe a unique illumination code over time [Poslaner82]



## Codes for Moving Scenes

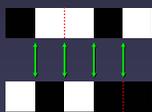
- Assign time codes to stripe boundaries
- Perform frame-to-frame tracking of corresponding boundaries
  - Propagate illumination history



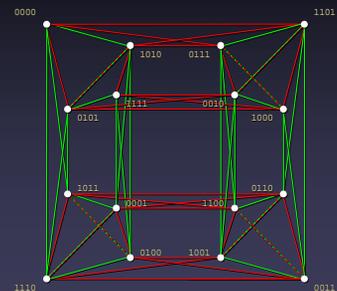
[Hall et al. & Rushkewitz, ICCV 2001]

## Designing a Code

- Want many "features" to track: lots of black/white edges at each frame
- Try to minimize ghosts - WW or BB "boundaries" that can't be seen directly



## Designing a Code



[Hall et al. & Rushkewitz, ICCV 2001]

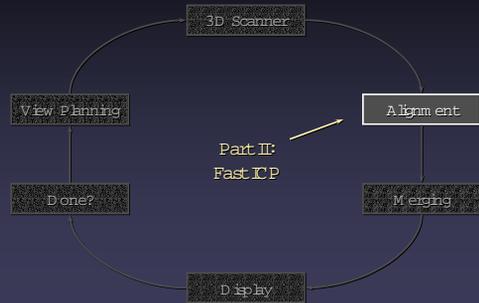
## Implementation

- Pipeline:



- DLP projector illuminates scene @ 60 Hz.
- Synchronized NTSC camera captures video
- Pipeline returns range images @ 60 Hz.

## Real-Time 3D Model Acquisition Pipeline

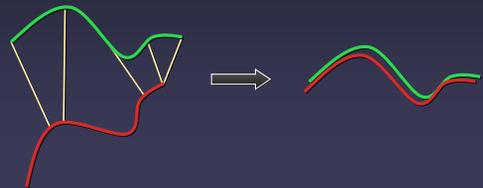


## Aligning 3D Data

- This range scanner can be used for any moving objects
- For rigid objects, range images can be aligned to each other as object moves

## Aligning 3D Data

- ICP (Iterative Closest Points): for each point on one scan, minimize distance to closest point on other scan...



## Aligning 3D Data

- ... and iterate to find alignment
  - Iterative Closest Points (ICP) [Besl & McKay 92]

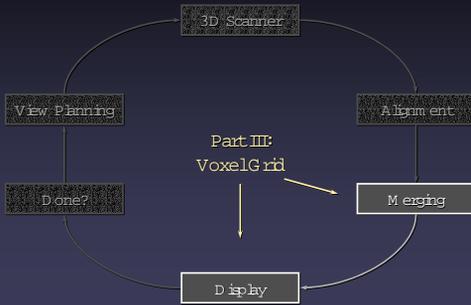


## ICP in the Real-Time Pipeline

- Potential problem with ICP: local minima
  - In this pipeline, scans close together
  - Very likely to converge to correct (global) minimum
- Basic ICP algorithm too slow (~ seconds)
  - Point-to-plane minimization
  - Projection-based matching
  - With these tweaks, running time ~ milliseconds

[Rushkiewicz & Levoy, 3D IM 2001]

## Real-Time 3D Model Acquisition Pipeline



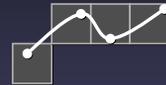
## Merging and Rendering

- Goal: visualize the model well enough to be able to see holes
- Cannot display all the scanned data - accumulates linearly with time
- Standard high-quality merging methods: processing time  $\sim$  1 minute per scan

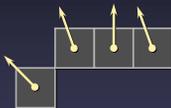
## Merging and Rendering



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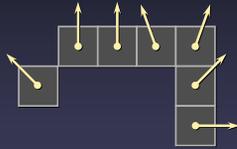


## Merging and Rendering



## Merging and Rendering

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- Point rendering, using accumulated normals for lighting

## Example: Photograph

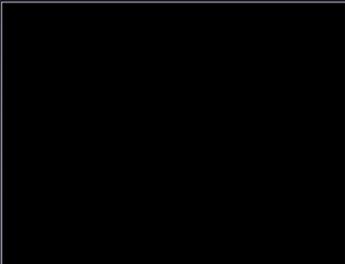
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18 cm .

## Result

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## Postprocessing

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- Real-time display
  - Quality/speed tradeoff
  - Goal: let user evaluate coverage, fill holes
- Offline postprocessing for high-quality models
  - Global registration
  - High-quality merging (e.g., using VRIP [Curless 96])

## Postprocessed Model

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## Recapturing Alignment

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## Summary

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- 3D model acquisition pipeline optimized for obtaining complete, hole-free models
- Use human's time most efficiently
- Pieces of pipeline selected for real-time use:
  - Structured-light scanner for moving objects
  - Fast ICP variant
  - Simple grid-based merging, point rendering

## Limitations

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- Prototype noisier than commercial systems
  - Could be made equivalent with careful engineering
  - Ultimate limitations on quality: focus, texture
- Scan-to-scan ICP not perfect  $\Rightarrow$  alignment drift
  - Due to noise, misalignment, degenerate geometry
  - Reduced, but not eliminated, by "anchor scans"
  - Possibly combine ICP with separate trackers

## Future Work

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- Faster scanning
  - Better stripe boundary tracking
  - Multiple cameras, projectors
  - High-speed cameras, projectors
- Application in different contexts
  - Cart- or shoulder-mounted for digitizing rooms
  - Infrared for imperceptibility

## Acknowledgments

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  - Liwei He
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  - Intel
  - Intel