Augmented Video: Final Report and Demonstration

Douglas Lanman

EN 292-13: Video Processing

8 May 2006

BROWN

Outline

- *Introduction to Scene Insertion*
- Building a Calibrated Video Player in VXL
- Initial Results using Manual Calibration
- Automatic Camera Tracking
- Conclusion

Motivation

General Problem

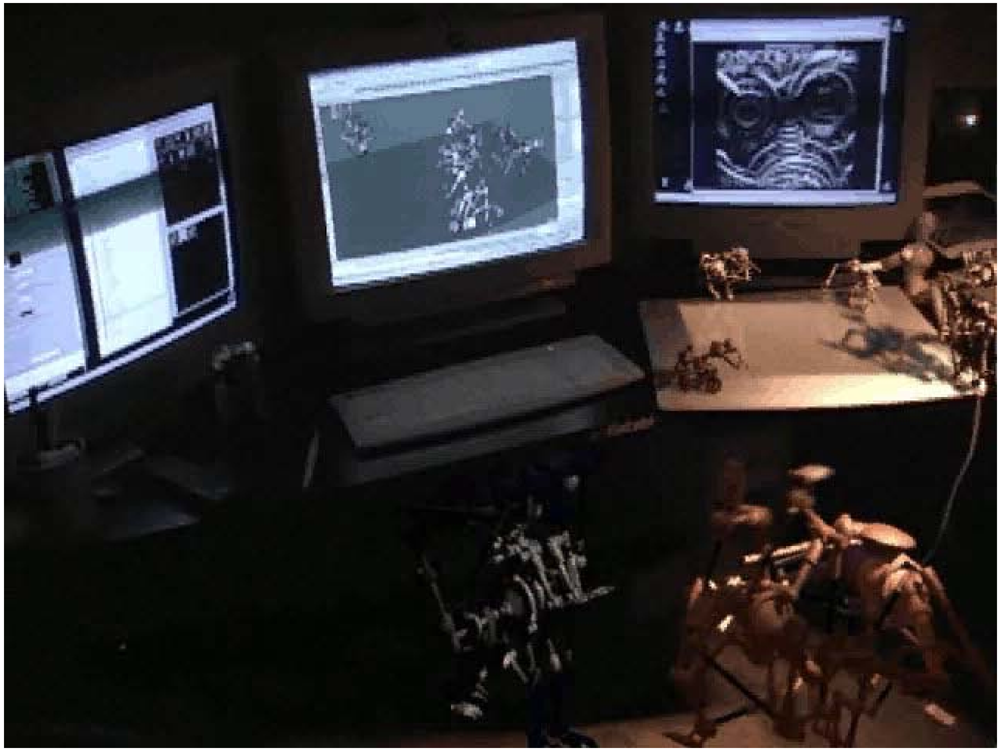
- Commonly called “matchmoving” or “camera tracking”
- Estimate the parameters of a general camera model for each frame of a video sequence

Challenges

- Unknown camera model
- Dynamic scenes
- Markerless calibration

Applications

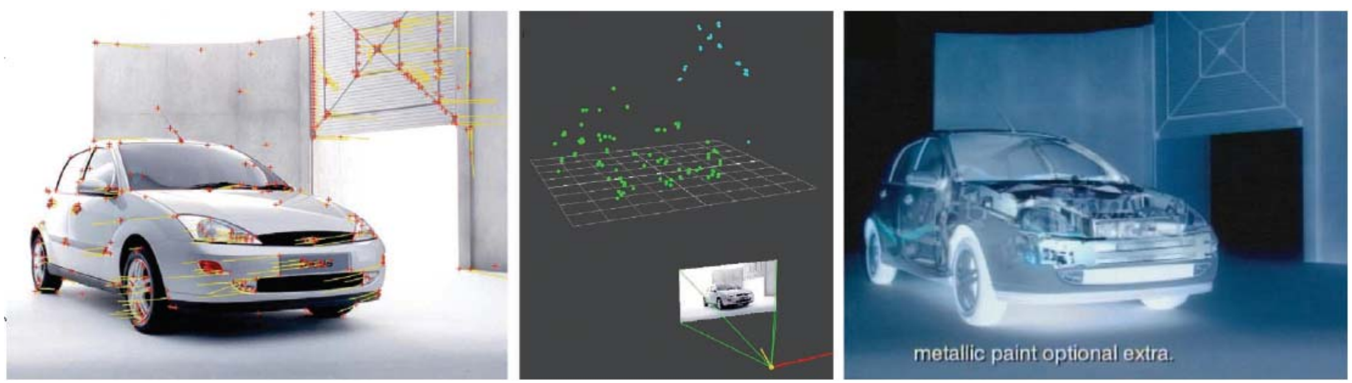
- Special effects industry
- Augmented virtual reality



Augmented Video Examples

Product Placement

Education (e.g., Archeological Restoration)



Entertainment and the Special Effects Industry

Project Goals

Implement a "Calibrated" Video Player in VXL

- Extend existing video players and geometry display routines to support real-time scene insertion

Develop an Initial Dataset

- Manually estimate a set of cameras for a short video sequence for debugging

Estimate Camera Models Automatically

- Track features using the KLT tracker
- Use the */gel/mrc/vpgl* photogrammetry library to estimate a camera model for each frame

Outline

- Introduction to Scene Insertion
- *Building a Calibrated Video Player in VXL*
- Initial Results using Manual Calibration
- Automatic Camera Tracking
- Conclusion

Overview: VXL Libraries

Basic Video Player Functions

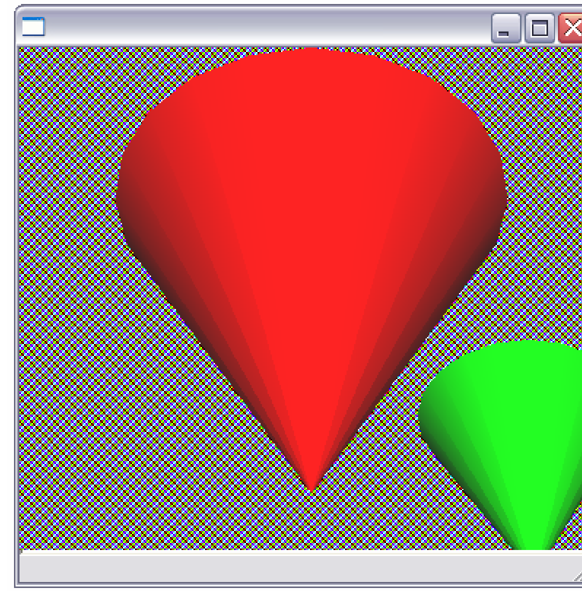
- Extended */vidl/examples/vidl_player*
- Added AVI output using */brl/vvid/vidfpl* (i.e., vgui_utils::colour_buffer_to_view())

3D Model Display Routines

- Used */basic/bgui3d* in LEMS-VXL
- Implements a general scene graph supporting VRML and Inventor models
- Wrapper for the Coin3D library

Camera Models and Optimization

- Used */gel/mrc/vpgl* photogrammetry library and the */gel/vgel* KLT tracker

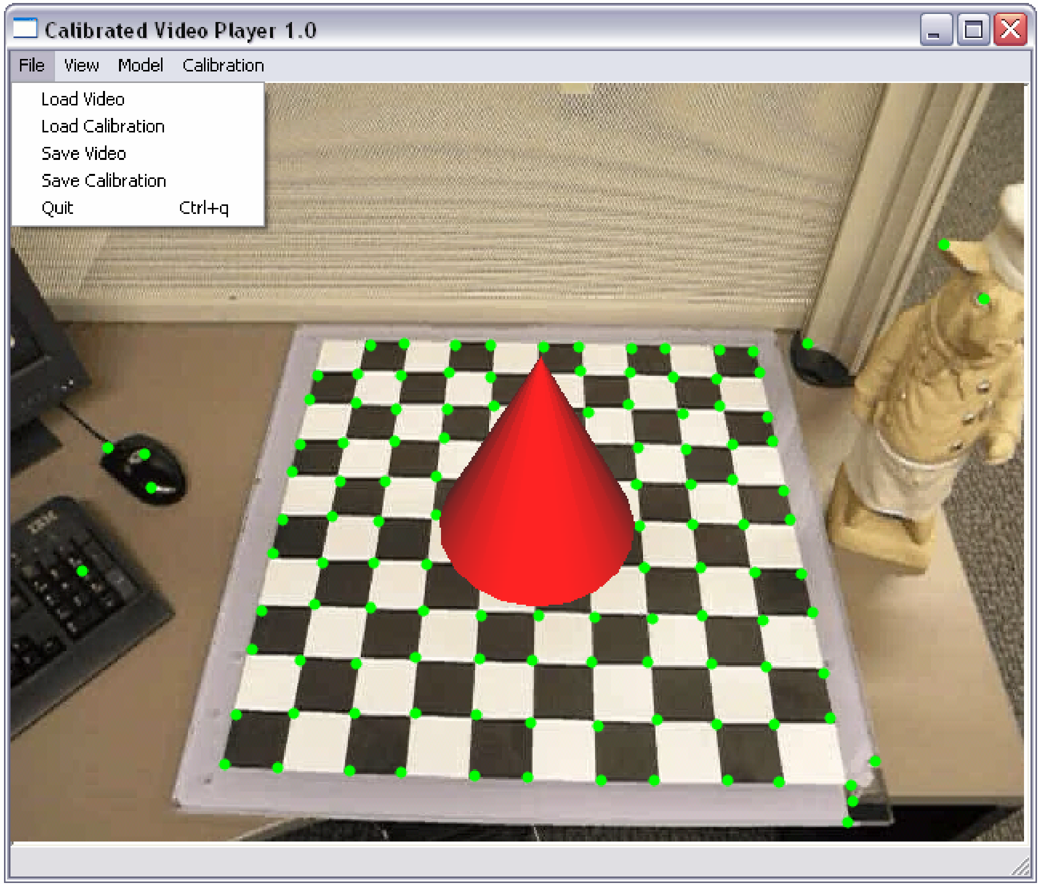


bgui3d_example_project2d

Coin3D Accelerate your 3D development

VXL

Initial Application: *CVP*



Calibrated Video Player 1.0

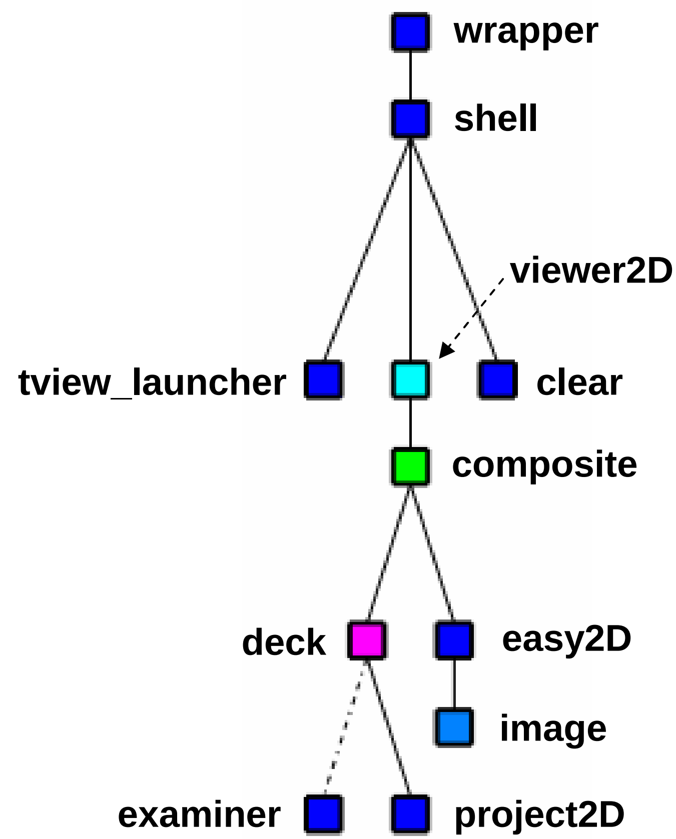


Tableau Hierarchy

Outline

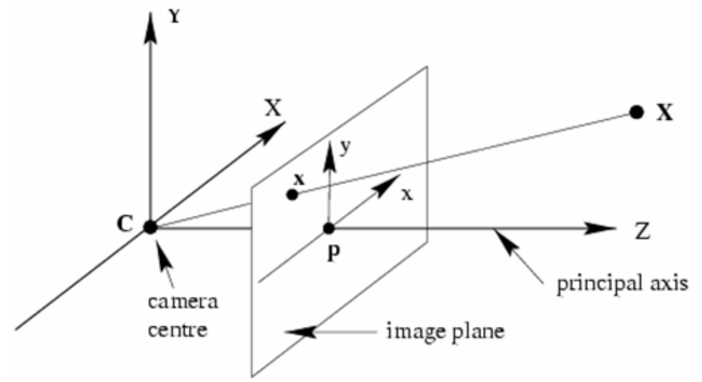
- Introduction to Scene Insertion
- Building a Calibrated Video Player in VXL
- *Initial Results using Manual Calibration*
- Automatic Camera Tracking
- Conclusion

Review of Camera Projection

Intrinsic Calibration

- Maps points to a normalized image plane
  (*focal length, skew and distortion effects*)
- Typically done off-line

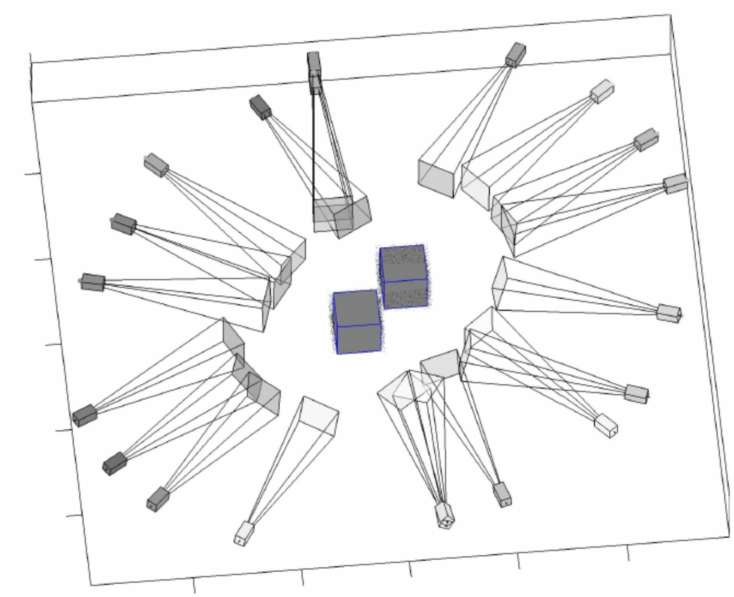
$$K = \begin{bmatrix} \alpha_x & s & x_0 \\ & \alpha_y & y_0 \\ & & 1 \end{bmatrix}$$



Extrinsic Calibration

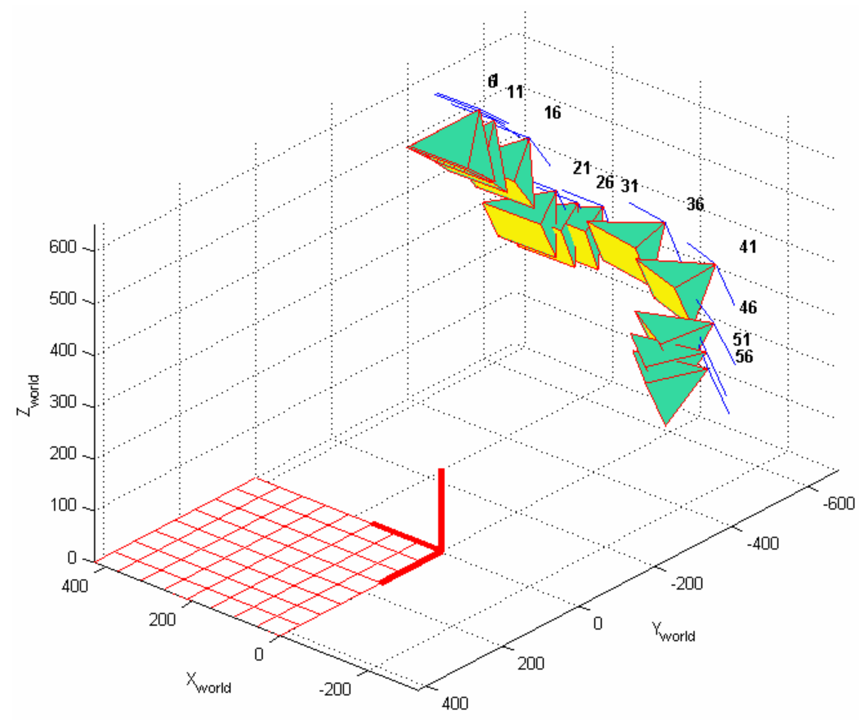
- Pose of camera relative to a fixed world coordinate system (*translation and rotation*)
- Updated continuously

$$P = K\left[I \quad | \quad 0\right]\begin{bmatrix} R & t \\ 0^t & 1 \end{bmatrix}$$



Matlab Calibration Toolbox

“Debugging” Video Sequence



Manual Extrinsic Calibration

- Camera: 8 MP 640x480 15 fps
- Lens: Fixed wide-angle setting
- Sequence length: 58 frames

```
K_Olympus =
  519.8034         0  318.2800
         0  553.4801  307.8282
         0         0    1.0000
```

Manual Intrinsic Calibration

Manual Scene Insertion Results

"Al" Sequence
(Simple VRML Model)

"Getty" Sequence
(Texture and Transparency)

Outline

- Introduction to Scene Insertion
- Building a Calibrated Video Player in VXL
- Initial Results using Manual Calibration
- *Automatic Camera Tracking*
- Conclusion

Feature Tracking

Methodology

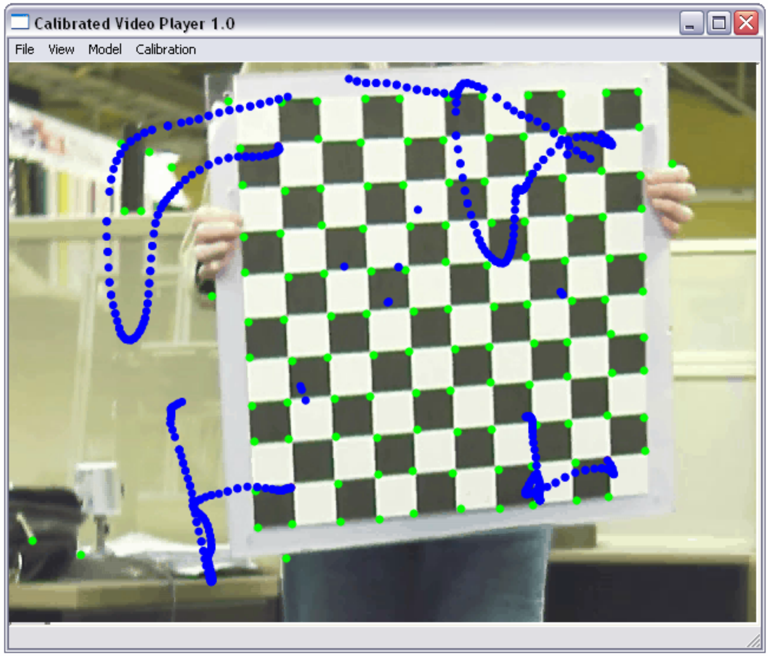
- Estimate camera model given a set of image-to-world correspondences
- Track a small number of known world points (e.g. doors, corners, etc.)
- From an initial guess of the camera position, refine and track over time

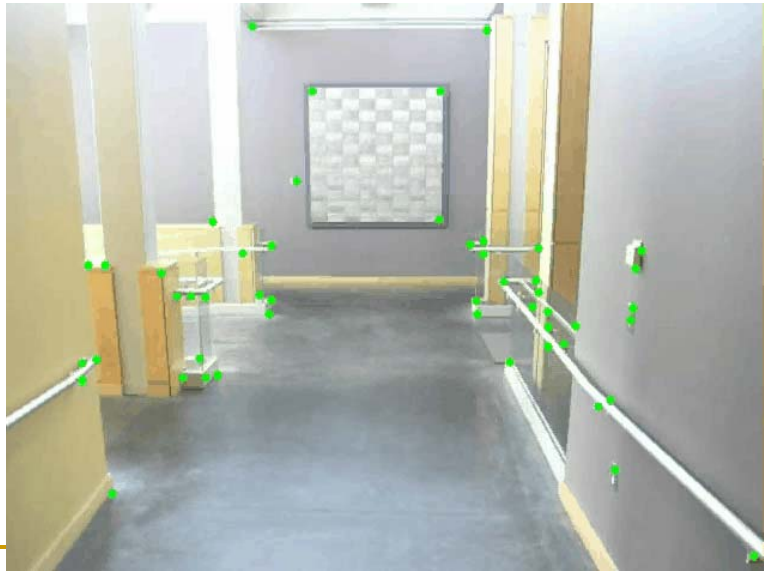
Implementation

- The */gel/vgel* KLT tracker was selected (reasons: well-supported in VXL and works for short sequences)

Alternatives

- *Boujou v3* by *2d3* tracks an arbitrary set of features without known image-world correspondences…





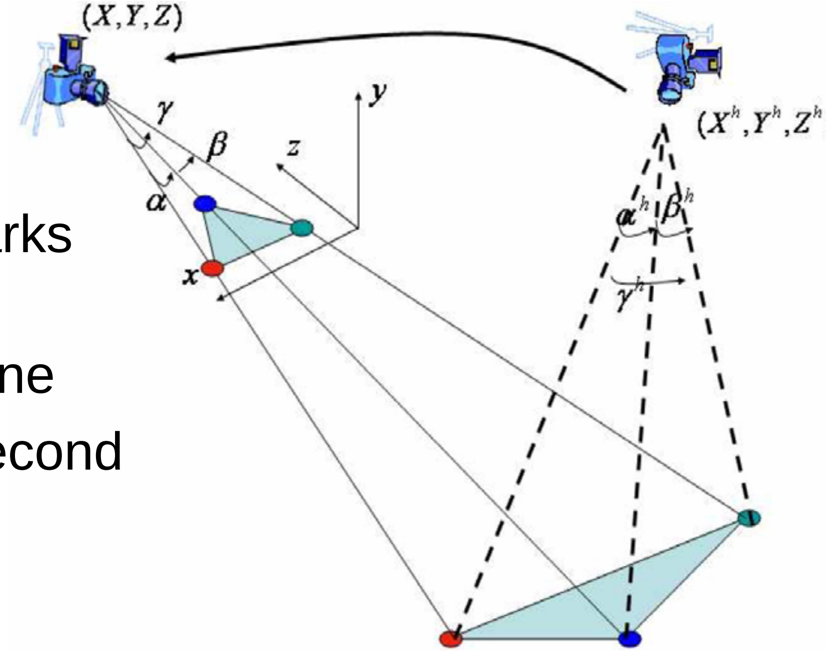
Non-linear Camera Calibration

Extrinsic Calibration Procedure

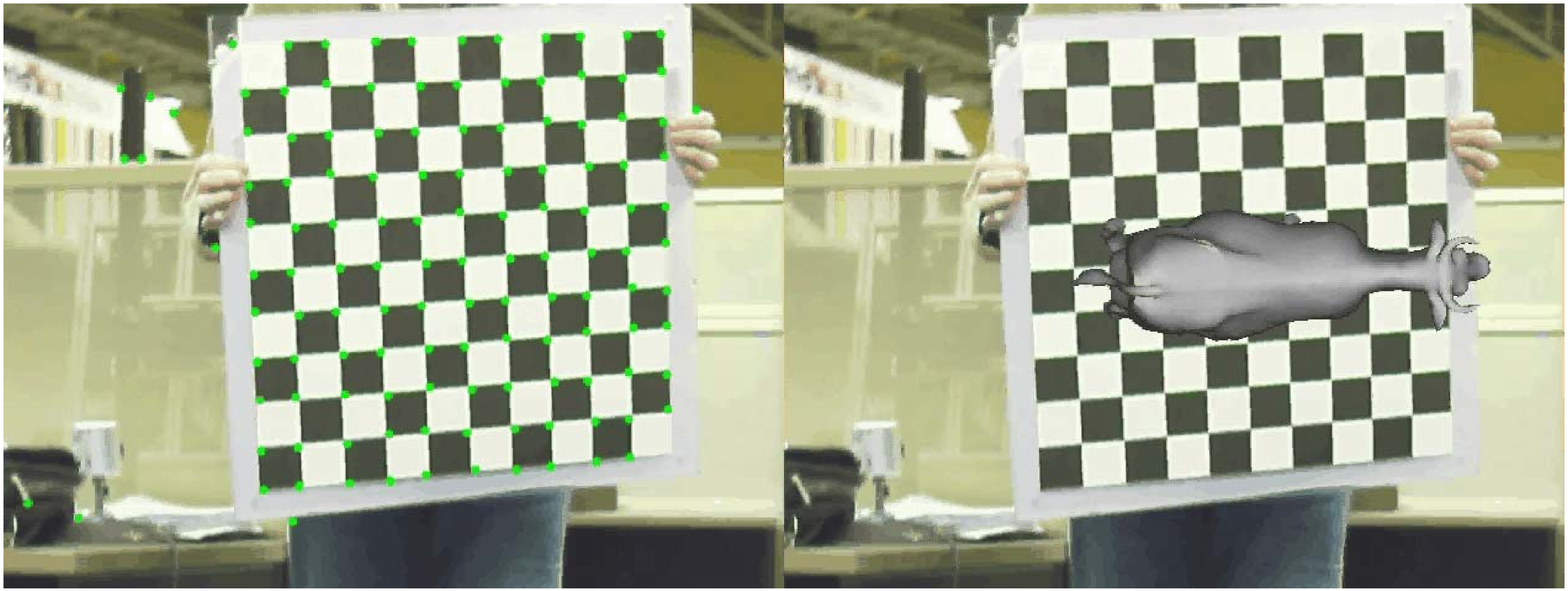
- Each camera must observe and fixed number of landmarks
- Guess an initial camera center and orientation
- Refine initial estimate using Levenberg-Marquardt method (implemented by */gel/mrc/vpgl/vpgl_optimize_camera*)

Church's Algorithm

- Pose estimation with three landmarks
- Face angles in spatial coordinates equal face angles in the image plane
- Thousands of pose updates per second
- Invented by Earl Church for aerial photogrammetry (1945)

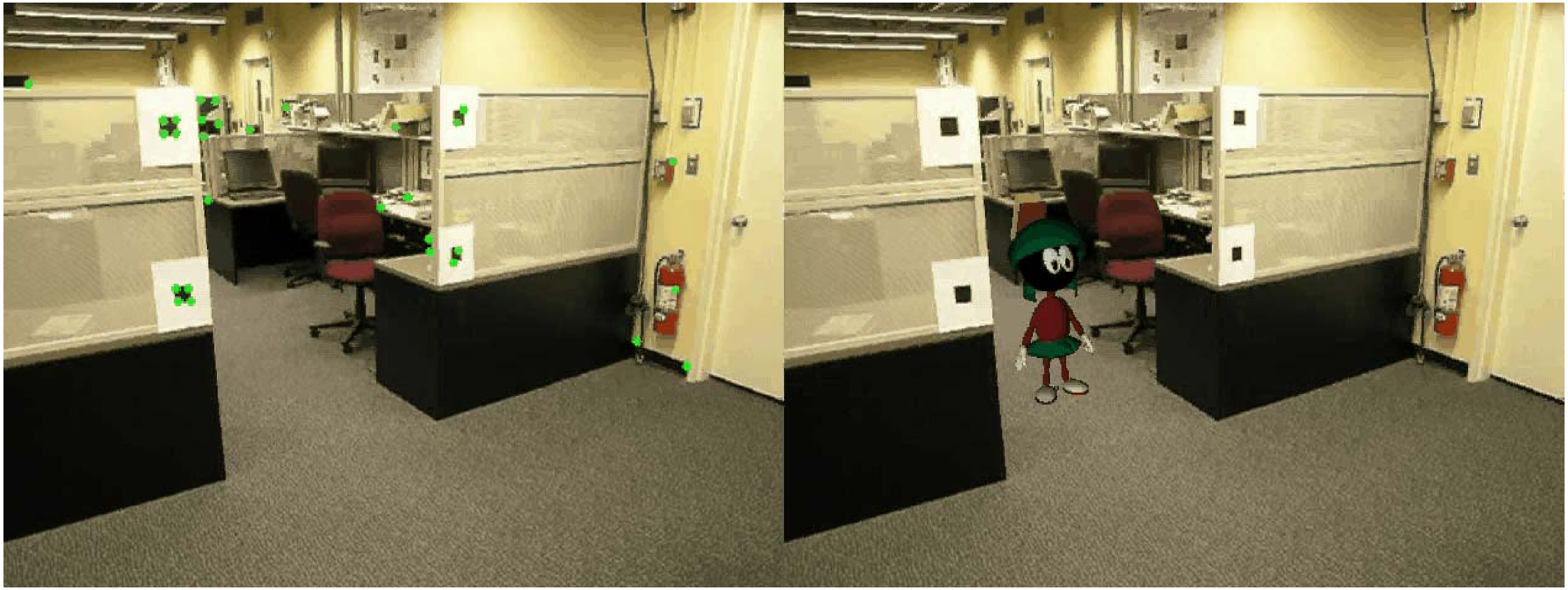


Automated Scene Insertion (I)



“Cow” Sequence

Automated Scene Insertion (II)



"Marvin" Sequence

Outline

- Introduction to Scene Insertion
- Building a Calibrated Video Player in VXL
- Initial Results using Manual Calibration
- Automatic Camera Tracking
- *Conclusion*

Conclusion

Main Accomplishments

- Implemented a "calibrated" video player
- Produced a ground truth "debugging" dataset
- Demonstrated automatic camera tracking using KLT and photogrammetry libraries

Limitations

- Requires world-image correspondences
- Only supports a limited-sense of "markerless" tracking over relatively short sequences

Future Work

- Eliminate need for correspondences
  (e.g. using structure-from-motion)
- Capture occlusion and lighting effects to simplify model insertion process
  (i.e., eliminate animators)

References

1. Richard Hartley and Andrew Zisserman, *Multiple View Geometry in Computer Vision*, Cambridge University Press, March 2004. http://www.robots.ox.ac.uk:5000/~vgg/hzbook/index.html
2. *The VXL Book,* The TargetJr Consortium, 2003. http://paine.wiau.man.ac.uk/pub/doc_vxl/books/core/book.html
3. Joseph Mundy, "VXL and Writing a Video Player", EN 292-13: Video Processing Class Notes, Spring 2006. http://webct.brown.edu/SCRIPT/Spring06/EN0292 S13/scripts/serve home
4. Kurt Cornelis, "From Uncalibrated Video to Augmented Reality", Ph.D. Thesis, Katholieke Universiteit Leuven, November 2004.
5. 2d3 Limited, Online. http://www.2d3.com/
6. Meats Meier, Portfolio, Online. http://www.3dartspace.com/animation/animation.html
7. Joseph Mundy, "Lecture9: Camera Projection", EN 292-13: Video Processing Class Notes, Spring 2006. http://webct.brown.edu/SCRIPT/Spring06/EN0292 S13/scripts/serve home
8. M. Pollefeys, "3D Photography: Camera Model and Calibration," On-line, http://www.unc.edu/courses/2004fall/comp/290/089/, 2004.
9. D. Devarajan and R. Radke., "Distributed Metric Calibration for Large-Scale Camera Networks," First Workshop on Broadband Advanced Sensor Networks 2004, San Jose, CA, 2004.
10. Jean-Yves Bouguet, *Camera Calibration Toolbox for Matlab*, Online. http://www.vision.caltech.edu/bouguetj/calib_doc/
11. Kostas Terzidis, On-line Real-time Virtual Reality. http://oldcda.design.ucla.edu/CAAD/worlds.html
12. L. Jiao, G. Wu, E. Chang, and Y-F. Wang, "The Anatomy of a Multi-Camera Video Surveillance System," ACM Multimedia System Journal, 2004.