Televiewing (Thrust 3)

Brett Hall, Koshia Huang

Computer Vision and Robotics Research Laboratory
University of California at San Diego
Real-Time System for Integrated Omni-Directional and Rectilinear Image-based Virtual Walkthroughs

- Software enables powerful visualization of traffic scenes
- Integrates high resolution images seamlessly in the visualization
- Uses a series of Omni-directional images snapshots to create a virtual walkthrough
- This software was created by Rick Capella of the CVRR

For more information, please contact Mohan Trivedi, UCSD (619-822-0075) trivedi@ece.ucsd.edu http://swiftlet.ucsd.edu/
A mobile EZ-GO cart with attached acquisition hardware enables us to take images of traffic scenes.

- A good view of a traffic scene is achieved using a high perspective with an omni-directional lens.
- Capture setup is quick to deploy to new locations and acquire images using a mobile PC.
New infrastructure enables us to perform these televiewing operations outdoors

- Currently software is being tested on indoor equipment with new mirror shape

- Development is in progress of outdoor televiewing application
The Omni-directional image is transformed into a perspective view for real time visualization.

- A 360° view is taken with the omni-directional camera.
- A high resolution detail view is taken with a rectilinear camera.
A high resolution image is smoothly integrated to observe detail in the scene.
- The objective is to locally “boost” the resolution of the view, such that items of interest can be viewed in detail.

- High-resolution overlay images are placed in the perspective views and aligned with items of interest.

- As panning and tilting take place, the overlay is moved and warped to stay aligned with underlying item.
Warping & stretching the hi-res image creates a registration vector for proper integration.

- Image registration is defined by 4 points.
- OpenGL texture mapping is used to distort the overlay.
- Registration coordinates are stored in Vector form.
ODVS network in the Aviary demonstrates televiewing software enhancements

Quad ODVS Image

Perspective View

Panoramic View
Hyperboloid optical imaging parameters

Hyperboloid Equation:
\[ \frac{Z^2}{a^2} - \frac{R^2}{b^2} = 1 \]
and \( c^2 = a^2 + b^2 \)

Formulation 1

\[ r_i = \frac{f R_M}{Z_M + c} \]

where
\[ Z_M = m R_M + c \]
\[ R_M = \frac{mc + a\sqrt{1+m^2}}{\left(\frac{a^2}{b^2} - m^2\right)} \]
\[ m = \frac{Z_o - c}{R_o} \quad , \quad |m| < \frac{a}{b} \]

Formulation 2

\[ r_i = \frac{f (a^2 - c^2)}{(a^2 + c^2)(Z_o - c) - 2ac\sqrt{R_o^2 + (Z_o - c)^2}} R_o \]
Coordinate System Rotation:

\[
R = \begin{bmatrix}
\cos \theta \cos \phi & -\sin \theta & -\cos \theta \sin \phi \\
\sin \theta \cos \phi & \cos \theta & -\sin \theta \sin \phi \\
\sin \phi & 0 & \cos \phi
\end{bmatrix}
\]

Perspective View Unit Vectors:

\[
\mathbf{n} = R \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix}
\cos \theta \cos \phi \\
\sin \theta \cos \phi \\
\sin \phi
\end{bmatrix}, \quad \mathbf{u} = -R \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix}
\sin \theta \\
-\cos \theta \\
0
\end{bmatrix}, \quad \mathbf{v} = R \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix}
-\cos \theta \sin \phi \\
-\sin \theta \sin \phi \\
\cos \phi
\end{bmatrix}
\]

Perspective View World Coordinates:

\[
\begin{bmatrix} x \\ y \\ z \end{bmatrix} = u_p \mathbf{u} + v_p \mathbf{v} + FL \mathbf{n} = R \begin{bmatrix} FL \\ -u_p \\ v_p \end{bmatrix}
\]

Then transform the perspective view world coordinates to CCD image coordinates.
Actual views from the original and full-resolution unwarped ODVS images

Perspective Views from Quad Rectilinear Image

Perspective Views from Quad ODVS Image

Perspective View from Hi-Resolution ODVS Image
The improved ODVS de-warping software improves the image quality

• Several improvements have been made to the algorithm:
  
  • The software can utilize:
    • 4 ODVS at low-res
    • 1 ODVS with better resolution

  • High Pass filtering removes some noise

• Next steps:
  
  • Finish outdoor ODVS pan/tilt/zoom interface

  • Utilize the outdoor PTZ cameras to fuse high-resolution video onto the ODVS scene