Active stereo vision system for object position estimation

Lab Seminar

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Active Stereo Vision

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Introduction

Conventional Stereo Vision

Conventional Stereo Vision

Stereo vision is the extraction of 3D information from digital images, such as obtained by a CCD camera. By comparing information about a scene from two vantage points, 3D information can be extracted by examination of the relative positions of objects in the two panels. This is similar to the biological process stereopsis.
Active Stereo Vision

: The active stereo vision is a form of stereo vision which actively employs a light such as a laser or a structured light to simplify the stereo matching problem.

• Conventional structured-light vision (SLV)
  : employs a structured light or laser, and finds projector-camera correspondences

• Conventional active stereo vision (ASV)
  : employs a structured light or laser, however, the stereo matching is performed only for camera-camera correspondences, in the same way as the passive stereo vision.

• Structured-light stereo (SLS)
  : a hybrid technique, which utilizes both camera-camera and projector-camera correspondences.
Introduction

Active Stereo Vision

\[ Z = \frac{bf}{x_l - x_r} \]
Structured light

Structured light is the process of projecting a known pattern (often grids or horizontal bars) on to a scene. The way that these deform when striking surfaces allows vision systems to calculate the depth and surface information of the objects in the scene.
Active Stereo Vision
Structured light

**Binary Code**

\[ 2^n = X \]

- \( n \): the number of image
- \( X \): resolution

eg. 1024x768 : 10 images

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0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

\[ X_n = 2 \]

\( n \) : the number of image

eg. 1024x768 : 10 images

\[ X : \text{resolution} \]

\[ x1 \]

\[ x2 \]

\[ x4 \]

\[ x8 \]
Active Stereo Vision
Structured light

- Phase shifting method: using a relatively small number of images.
**Active Stereo Vision**

*Structured light*

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**Four step algorithm**

\[ I_1(x, y) = I'(x, y) + I''(x, y) \cos[\phi(x, y)] \]
\[ I_2(x, y) = I'(x, y) + I''(x, y) \cos[\phi(x, y) + \frac{\pi}{2}] \]
\[ I_3(x, y) = I'(x, y) + I''(x, y) \cos[\phi(x, y) + \pi] \]
\[ I_4(x, y) = I'(x, y) + I''(x, y) \cos[\phi(x, y) + \frac{3}{2} \pi] \]

Using simple trigonometric identity

\[ I_1(x, y) = I'(x, y) + I''(x, y) \cos[\phi(x, y)] \]
\[ I_2(x, y) = I'(x, y) - I''(x, y) \sin[\phi(x, y)] \]
\[ I_3(x, y) = I'(x, y) - I''(x, y) \cos[\phi(x, y)] \]
\[ I_4(x, y) = I'(x, y) + I''(x, y) \sin[\phi(x, y)] \]

\[ I_4 - I_2 = 2I''(x, y) \sin[\phi(x, y)] \]
\[ I_1 - I_3 = 2I''(x, y) \cos[\phi(x, y)] \]

\[ \frac{I_4 - I_2}{I_1 - I_3} = \frac{\sin[\phi(x, y)]}{\cos[\phi(x, y)]} = \tan[\phi(x, y)] \]

\[ \phi(x, y) = \tan^{-1}\left[ \frac{I_4 - I_2}{I_1 - I_3} \right] \]
Active Stereo Vision

Structured light

- **Three step algorithm**

\[ I_1(x, y) = I'(x, y) + I''(x, y) \cos[\phi(x, y) - \alpha] \]
\[ I_2(x, y) = I'(x, y) + I''(x, y) \cos[\phi(x, y)] \]
\[ I_3(x, y) = I'(x, y) + I''(x, y) \cos[\phi(x, y) + \alpha] \]

Using the trigonometric addition identities

\[ I_1(x, y) = I'(x, y) + I''(x, y) \{ \cos[\phi(x, y)] \cos(\alpha) + \sin[\phi(x, y) \sin(\alpha)] \} \]
\[ I_2(x, y) = I'(x, y) + I''(x, y) \cos[\phi(x, y)] \]
\[ I_3(x, y) = I'(x, y) + I''(x, y) \{ \cos[\phi(x, y)] \cos(\alpha) - \sin[\phi(x, y) \sin(\alpha)] \} \]
Three step algorithm

cf. Four step algorithm

\[ I_4 - I_2 = 2I'''(x, y) \sin[\phi(x, y)] \]
\[ I_1 - I_3 = 2I'''(x, y) \cos[\phi(x, y)] \]
\[ \frac{I_4 - I_2}{I_1 - I_3} = \frac{\sin[\phi(x, y)]}{\cos[\phi(x, y)]} = \tan[\phi(x, y)] \]

\[ I_1 - I_3 = 2I'''(x, y) \sin[\phi(x, y)] \sin(\alpha) \]
\[ I_2 - I_1 = I'''(x, y) \cos[\phi(x, y)] \{1 - \cos(\alpha)\} - I'''(x, y) \sin[\phi(x, y)] \sin(\alpha) \]
\[ I_2 - I_3 = I'''(x, y) \cos[\phi(x, y)] \{1 - \cos(\alpha)\} + I'''(x, y) \sin[\phi(x, y)] \sin(\alpha) \]
\[ 2I_2 - I_1 - I_3 = 2I'''(x, y) \cos[\phi(x, y)] \{1 - \cos(\alpha)\} \]
Active Stereo Vision

Structured light

- Three step algorithm

\[ I_1 - I_3 = 2I''(x, y) \sin[\phi(x, y)] \sin(\alpha) \]

\[ 2I_2 - I_1 - I_3 = 2I''(x, y) \cos[\phi(x, y)] \{1 - \cos(\alpha)\} \]

\[
\frac{I_1 - I_3}{2I_2 - I_1 - I_3} = \frac{2I''(x, y) \sin[\phi(x, y)] \sin(\alpha)}{2I''(x, y) \cos[\phi(x, y)] \{1 - \cos(\alpha)\}}
= \frac{\sin[\phi(x, y)] \sin(\alpha)}{\cos[\phi(x, y)] \{1 - \cos(\alpha)\}} = \frac{\sin(\alpha)}{1 - \cos(\alpha)} \tan(\phi(x, y))
\]

\[ \phi(x, y) = \tan^{-1} \left\{ \frac{1 - \cos(\alpha)}{\sin(\alpha)} \frac{I_1 - I_3}{2I_2 - I_1 - I_3} \right\} \]

when \( \alpha = \frac{3\pi}{2} \)

\[ \phi(x, y) = \tan^{-1} \left( \sqrt{3} \frac{I_1 - I_3}{2I_2 - I_1 - I_3} \right) \]
Active Stereo Vision

Structured light

Unwrapping

Before unwrapping (0~2\(\pi\))

After unwrapping

Phase Image
Active Stereo Vision

Experimental results

- Experimental results (Three step algorithm)
Q & A
Thank You!!!
\[ \frac{X}{Z} = \frac{x_i}{f} \quad \text{a} \]

\[ \frac{X - b}{Z} = \frac{x_r}{f} \quad \text{b} \]

from a \[ X = \frac{x_i}{f} Z \]

from b \[ X = \frac{x_r}{f} Z + b \]

\[ \frac{x_i}{f} Z = \frac{x_r}{f} Z + b, \quad \frac{x_i - x_r}{f} Z = b \]

\[ \therefore Z = \frac{bf}{x_i - x_r} \quad \text{We need to disparity information} \]