11

Matching Linear Stereoscopic Images

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11.1 Introduction

The stereoscopic sensor presented in the last chapter is different from other systems due to the use of linear CCDs. The main problem is to find matching techniques to obtain a 3D reconstruction of the observed scenes directly from two linear images.

This chapter presents matching methods used to give a 3D reconstruction of unknown scenes, the main purpose is to allow real-time reconstruction, we will start by analyzing the geometrical properties of the sensor then we will introduce two matching algorithms both based on dynamic programming. The first method uses pixels as a feature while the second is based on regions.

11.2 Geometrical Properties of the Panoramic Sensor

The elementary panoramic sensor is a linear CCD swiveling around a vertical axis that we will call Z. The focal distance is denoted f. We have shown that the projection is cylindrical, f represents the ray of the cylinder illustrated by Figure 11.1.

The image coordinates of a 3D point \( P = (x, y, z) \) on the cylinder are given by \( \theta, Z_p \), where \( \theta \) represents the angular position of the point \( P \), \( Z_p \) is the vertical distance between the image point and the plane containing the optical center \( O \), the projection on the cylinder is defined as follows:

\[
\theta = \arctan\left(\frac{y}{x}\right), \quad \theta \in \left(-\frac{\pi}{2}, \frac{\pi}{2}\right).
\]

\[
Z_p = \frac{z + f}{\sqrt{x^2 + y^2}}, \quad \theta \in \left(-\frac{\pi}{2}, \frac{3\pi}{2}\right), \quad \text{obtained by transforming:} \quad \theta \rightarrow \theta + \pi.
\]

A 3D line \( D \) observed in the scene has the following equation:

\[
D : \mathbf{x} = \begin{pmatrix} x_0 \\ y_0 \\ z_0 \end{pmatrix} + \begin{pmatrix} O \\ t \\ O \end{pmatrix} \mathbf{t}; \quad t \in (-\infty, +\infty)
\]

and it is projected on the cylinder as follows:

\[
Z_p = \cos(\theta) \cdot \left(\frac{f \cdot x_0}{z_0}\right); \quad x_0 > 0; \quad \theta \in \left(-\frac{\pi}{2}, \frac{\pi}{2}\right)
\]
The result shows that the vertical ridges of a wall in the scene are projected in the form of sinusoidal curves. The apex of these curves corresponds to the angular orientation of the sensor where the distance between the cameras and the wall is minimal, Figure 11.2 illustrates this principle.

Parallel lines of the form:

\[
D : x = \begin{pmatrix} c \cdot x_0 \\ y_0 \\ c \cdot z_0 \end{pmatrix} + \begin{pmatrix} O \\ t \\ O \end{pmatrix} ; t \in (-\infty, +\infty) ; c \in \mathbb{IN}
\]

have the same image on the cylinder, this shows that we can not retrieve any depth information from a single panoramic view, which is an expected result.