RIFNOM: 3D Rotation-Invariant Features on Normal Maps

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1. Introduction

In this paper, we propose a method called 3D rotation-invariant features on normal maps: RIFNOM. It is difficult to robustly extract image features from textureless objects with conventional methods. RIFNOM features are based on surface normals obtained with photometric stereo, so it can be applied to textureless objects. Furthermore, deformation of a non-rigid object can be obtained by estimating 3D rotation for each pair of corresponding interest points.

2. Related work

One of the normal-map-based approaches, PHENOM, succeeded in extracting features from textureless objects [1]. However, it cannot deal with continuous 3D rotation, and the rigid body assumption is needed to estimate object motion. We address these problems by assigning a local coordinate system (CS) to each interest point.

[1] R. Sabzevari, E. Alak and D. Scaramuzza: PHENOM: Interest Points on Photometric Normal Maps. In EG 2015 - Posters (2015).

3. RIFNOM features

Definition of local CS Σ_L

Local z axis: $\vec{n}_c$

Local x axis: $\vec{m}' = 1/N \sum_{i=1}^{N} (\vec{n}_i - (\vec{n}_c \cdot \vec{n}_i)\vec{n}_c)$

$\vec{n}_c$: Normal of a pixel $\qquad \vec{n}_i$: Neighbor normals

Interest point detection

Repeatability $\qquad\qquad$ Uniqueness

$\|\vec{m}'\|^2 > t_{mean} \qquad 1/N \sum_{i=1}^{N} \|\vec{n}_i' - \vec{m}'\|^2 > t_{var}$
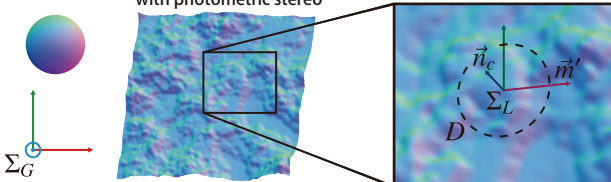
Feature description

RIFNOM features are obtained by extracting local x and y components of the normals at the polar grid points on D. The feature vector length is $2N_r N_\theta$.

Interest point matching and rotation estimation

The mean of squared error is used to define similarity between features. We use ratio test to find unique matches. By comparing local CSs between corresponding interest points, 3D rotation is estimated for each pair of interest points.

Input: normal map obtained with photometric stereo

4. Results

Mountain $\qquad$ Stanford bunny $\qquad$ Happy Buddha

$R = 10\,\mathrm{px} \quad t_{mean} = 0.15$
$N_\theta = 20 \qquad t_{var} = 0.15$
$N_r = 10 \qquad t_{diff} = 0.2$
$\qquad\qquad t_{ratio} = 0.7$

Interest points $\quad$ Matching $\qquad$ Rotation angle $\qquad$ Rotation axis