Refined Attitude Estimation of Ships in Photographs via Matching Images Rendered from 3D Models

Hongxiang WANG and Xiaojian XU
School of Electronics and Information Engineering, Beihang University, Beijing, China
Contact email: hongxiangwang@buaa.edu.cn

Introduction

In model based target recognition from synthetic aperture radar (SAR) images, three-dimensional (3D) models of objects are used for electromagnetic calculation, SAR imaging and matching. An inaccurate model has severe impacts on the electromagnetic calculation as well as the fidelity of calculated SAR images. To refine the 3D models, the first step is to estimate the attitude of objects in photographs, so an iterative procedure for refined attitude estimation of objects is proposed.

Attitude Estimation of Objects

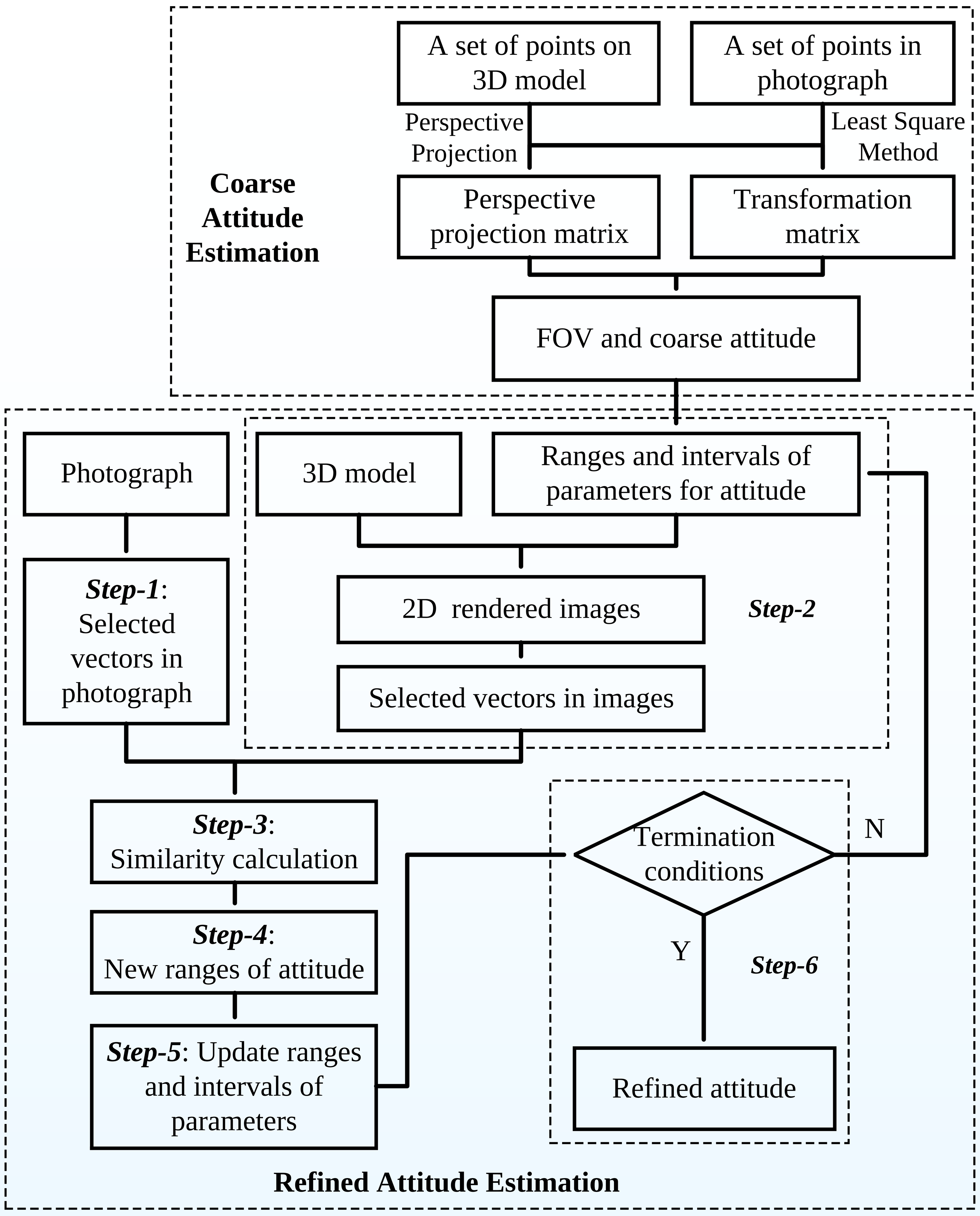
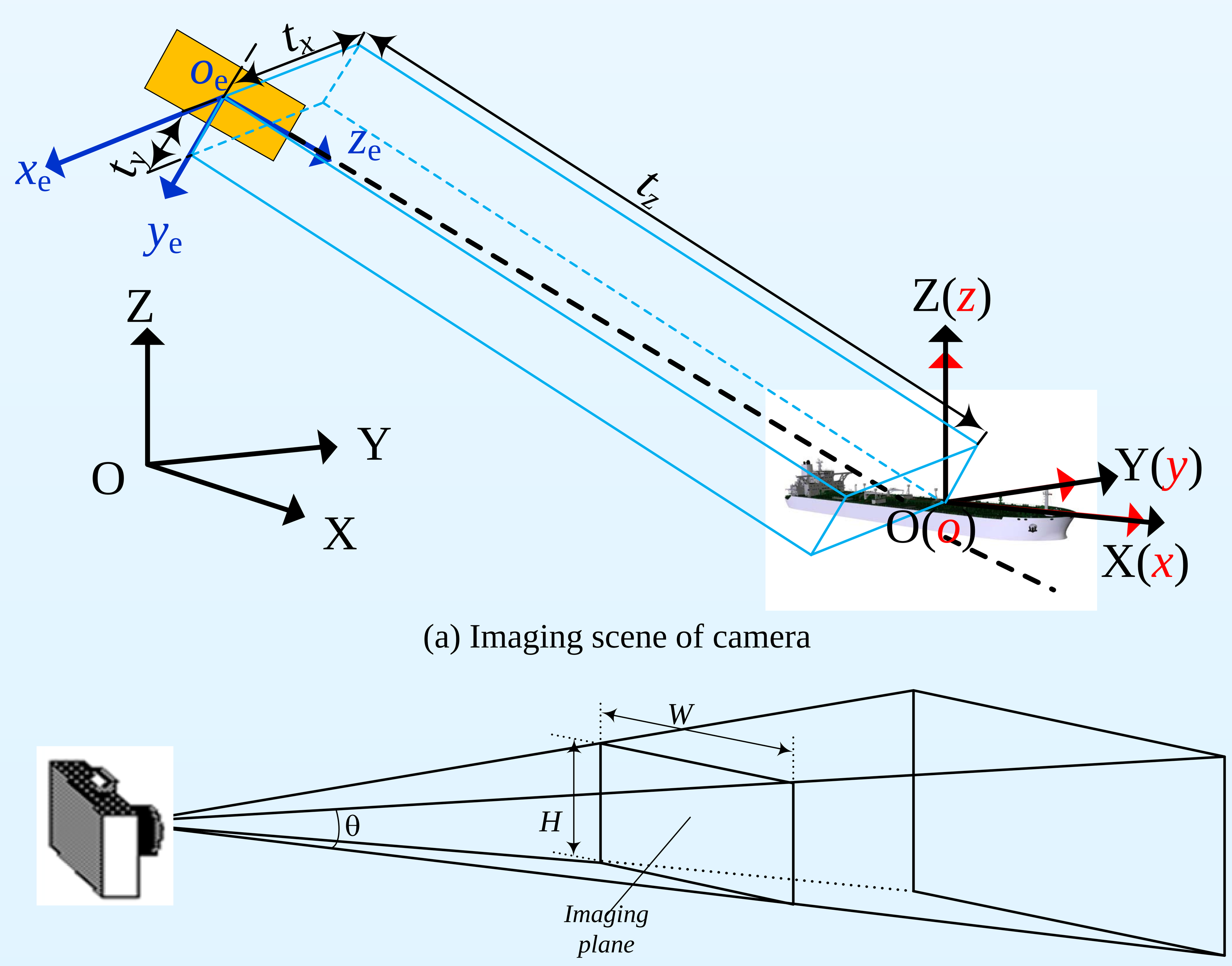


Fig 1. Flow chart of attitude estimation of ships

A. Coarse Attitude Estimation

The imaging scene of camera and camera model are shown in Fig. 2.



(a) Imaging scene of camera

(b) Diagram of camera model

Fig.2 Imaging scene and camera model

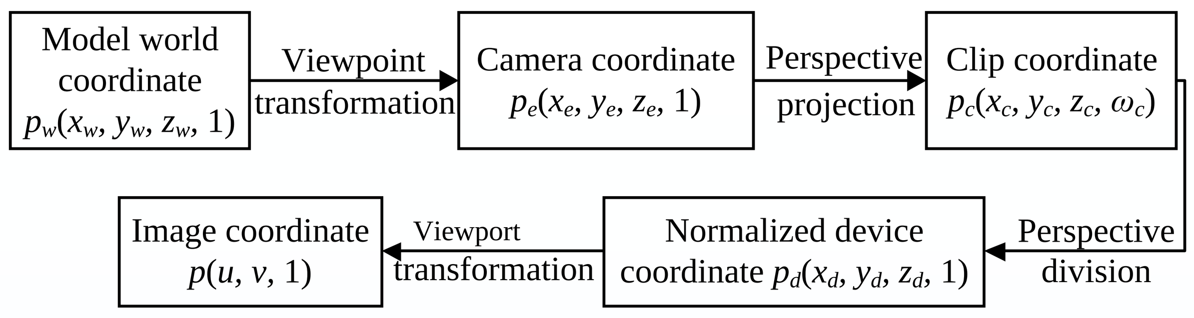


Fig.3 Imaging process in computer graphics

The transformation from 3D world coordinates to 2D image coordinates can be represented as (1).

$$\omega_c \cdot \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \mathbf{P} \cdot \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} = \begin{bmatrix} \mathbf{P}_1 & P_{14} \\ \mathbf{P}_2 & P_{24} \\ \mathbf{P}_3 & P_{34} \end{bmatrix} \cdot \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} \tag{1}$$

After selecting a set of matching points from models and photographs, respectively, the transformation (1) can be rewritten as

$$\omega_{ci} \cdot \begin{bmatrix} u_i \\ v_i \\ 1 \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} & m_{14} \\ m_{21} & m_{22} & m_{23} & m_{24} \\ m_{31} & m_{32} & m_{33} & m_{34} \end{bmatrix} \cdot \begin{bmatrix} x_{wi} \\ y_{wi} \\ z_{wi} \\ 1 \end{bmatrix} = \mathbf{M} \cdot \begin{bmatrix} x_{wi} \\ y_{wi} \\ z_{wi} \\ 1 \end{bmatrix} \tag{2}$$

Comparing (1) and (2), the coarse parameters of attitude can be calculated.

B. Iterative Procedure for Refined Attitude Estimation

The process of iterative procedure is shown in Fig.1 and the implementation steps are as follows.

- ***Step-1***: Four 2D points on the deck are manually selected from the photograph.
- ***Step-2***: Four 3D points are selected on the model, the corresponding 2D points in the rendered images are obtained.
- ***Step-3***: The similarities are calculated.
- ***Step-4***: The new ranges of attitude are determined.
- ***Step-5***: Ranges are updated and intervals are halved.
- ***Step-6***: Three termination conditions are checked.

Experiment Results

The detailed experimental results are shown in Table.1 and Fig.4.

TABLE.1 THE CORSE AND REFINED ESTIMATION RESULTS OF TANKER ATTITUDE

No.	Attitude	FOV	Three Euler Angles			Three Translation			Corr.
		θ (°)	α (°)	β (°)	γ (°)	t_x (cm)	t_y (cm)	t_z (cm)	r_0
1	Coarse	4.2	-116	-83.5	27.5	500	1500	-110000	0.8917
	Refined	4.2	-115.7	-83.6	25.8	500	1500	-109819	0.8982
2	Coarse	8.3	-14	-70	-71	-1100	1100	-85000	0.8968
	Refined	8.3	-14.1	-70.1	-70.7	-1300	1200	-85150	0.9022
3	Coarse	15	-90	-77	1	0	2200	-50000	0.9134
	Refined	15	-90.2	-78.1	0.2	0	2150	-49050	0.9435

Fig.4 Photographs (upper) and rendered images (lower) of the oil tanker

Summary

An iterative procedure for refined attitude estimation of ships in photographs is proposed in this paper, mainly including coarse attitude estimation and refined attitude estimation. Experimental results illustrate that after refined processing, the average correlation coefficient between the photographs and the images of tanker rendered using refined attitude is above 0.915, demonstrating the usefulness of the proposed procedure.