Camera Calibration and Structure from Motion using NAO

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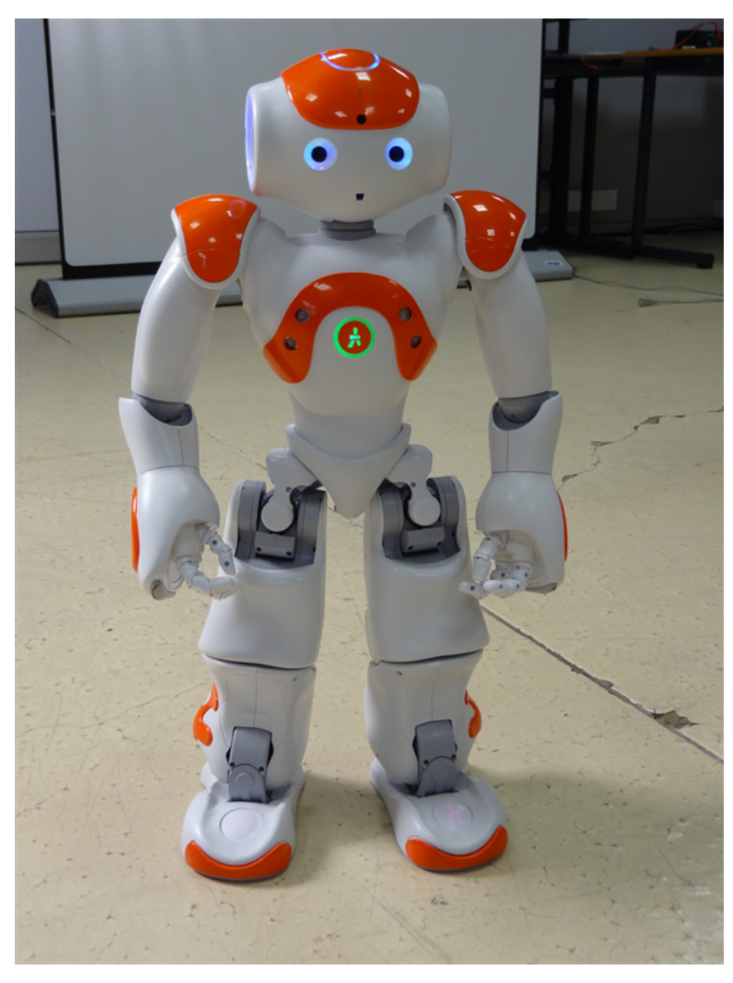
MOTIVATION

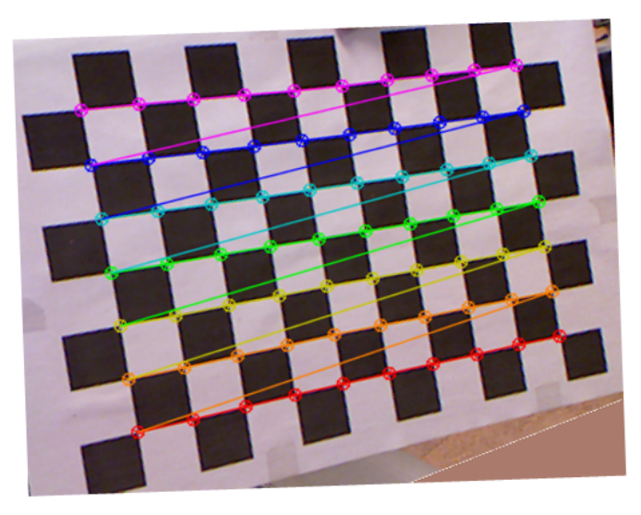
Nao is a 57 cm tall humanoid, with 27 degrees of freedom, produced by Aldebaran Robotics[1] for R&D purposes and it is one of the best of its league. The aim of humanoid robotics research is to gain better understanding of human body structure and behaviors and create a robot that reaches the capabilities of a human in terms of motion, perception, information interpretation and intelligence. Computer vision, a branch of artificial intelligence, is one of the major fieds that seeks solutions in order to satisfy the requirements of this challenging task. For most of the computer vision algorithms, such as structure from motion, it is assumed that the characteristics of the camera is known. Thus, first we present a camera calibration algorithm and it's application on Nao. Another challenging and popular problem in computer vision is the reconstruction of 3D world structure and motion estimation of the camera, from a sequence of 2D images. This problem is known as Structure from Motion. We present two algorithms and their application to humanoid Nao for Camera Calibration and Structure from Motion.



CAMERA CALIBRATION

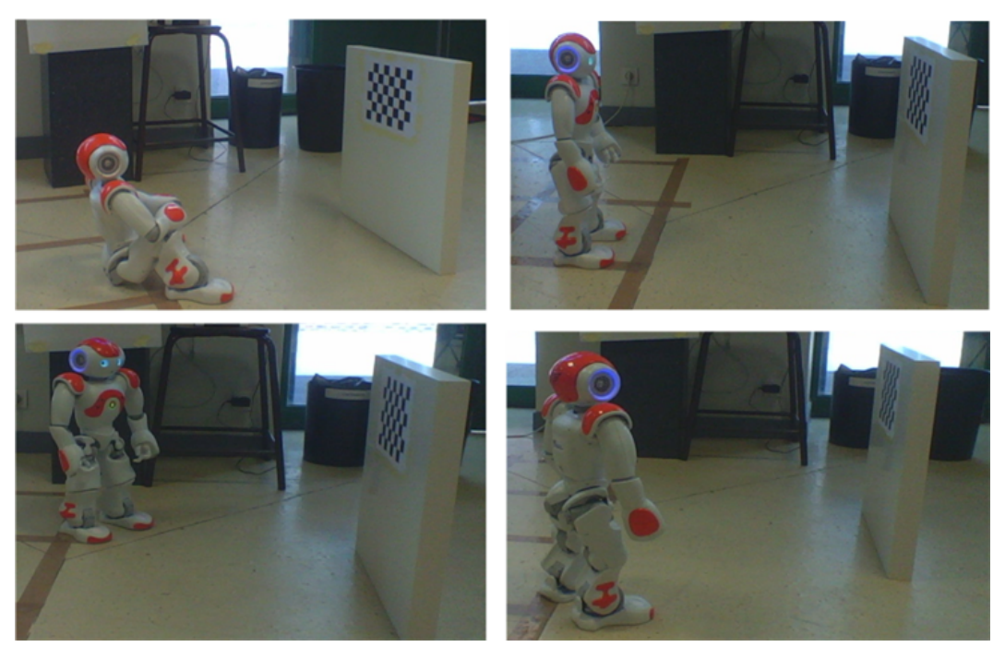
Camera Calibration is the problem of finding the inrinsic and extrinsic parameters of a camera. Z. Zhang's method[2] is applied to Nao and a fully-automatic camera calibration module is developed.

1



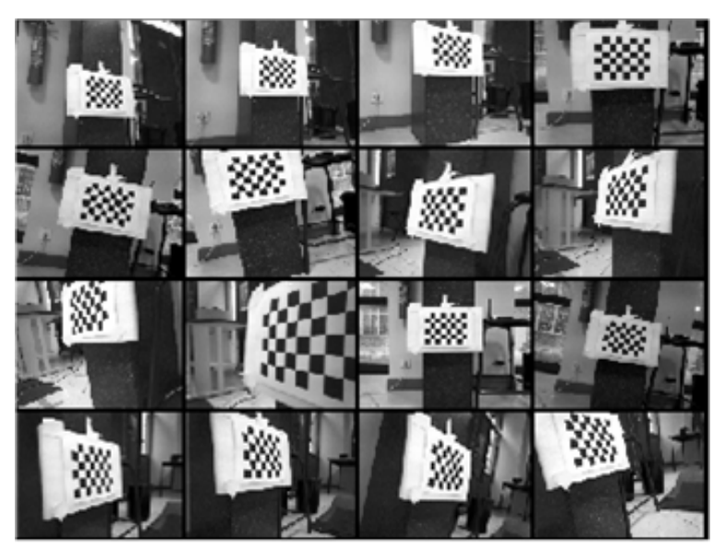
Before saving an image, Nao had to be sure that the chessboard pattern is in it's perspective. This we always try to detect before each image acquisation

2

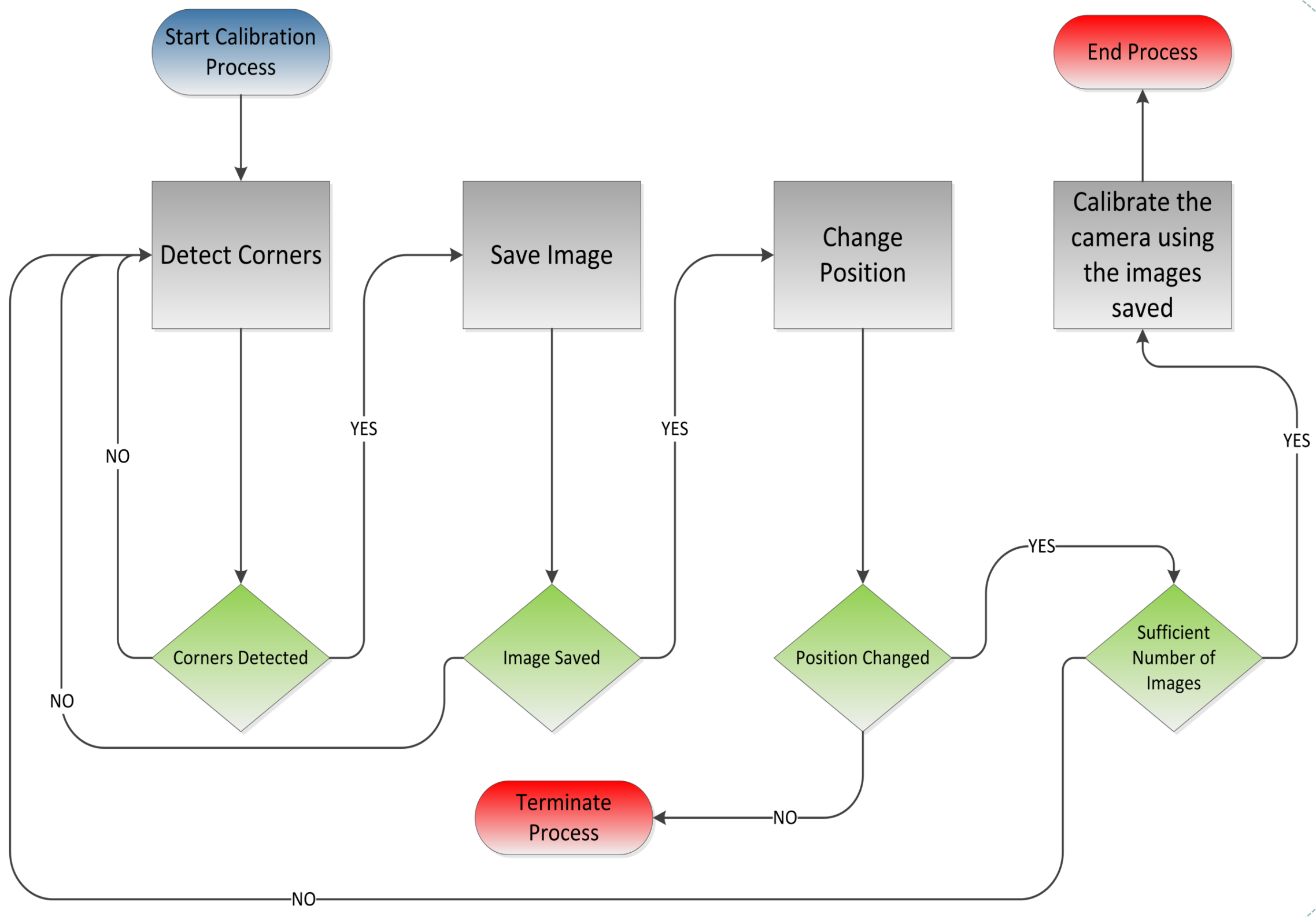


Since the method requires the planar chessboard images from different poses as input, the motion of Nao is in a circular fashion

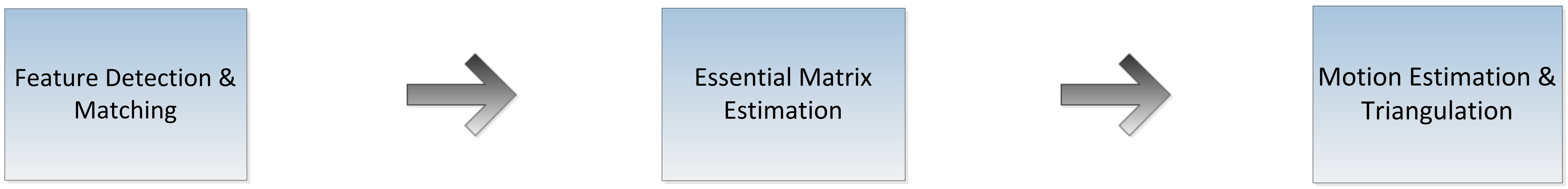
3



Once the first two steps are satisfied an image is acquired



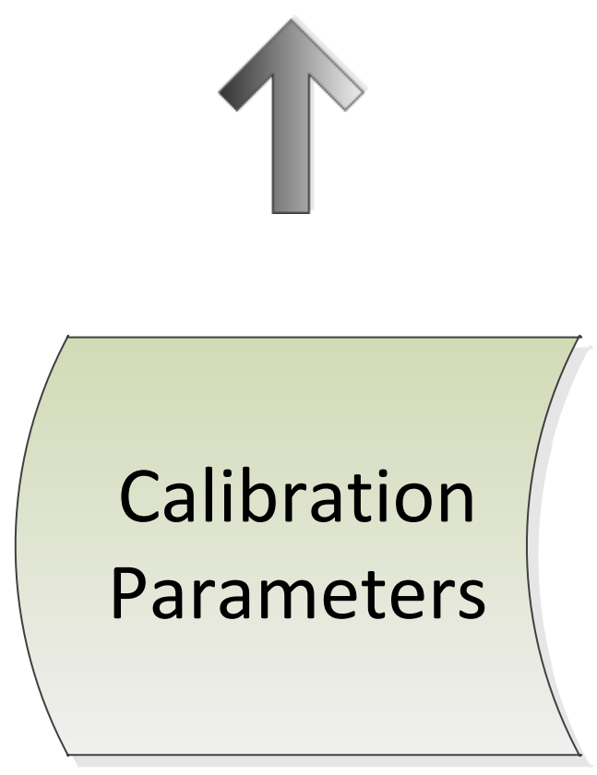
STRUCTURE FROM MOTION



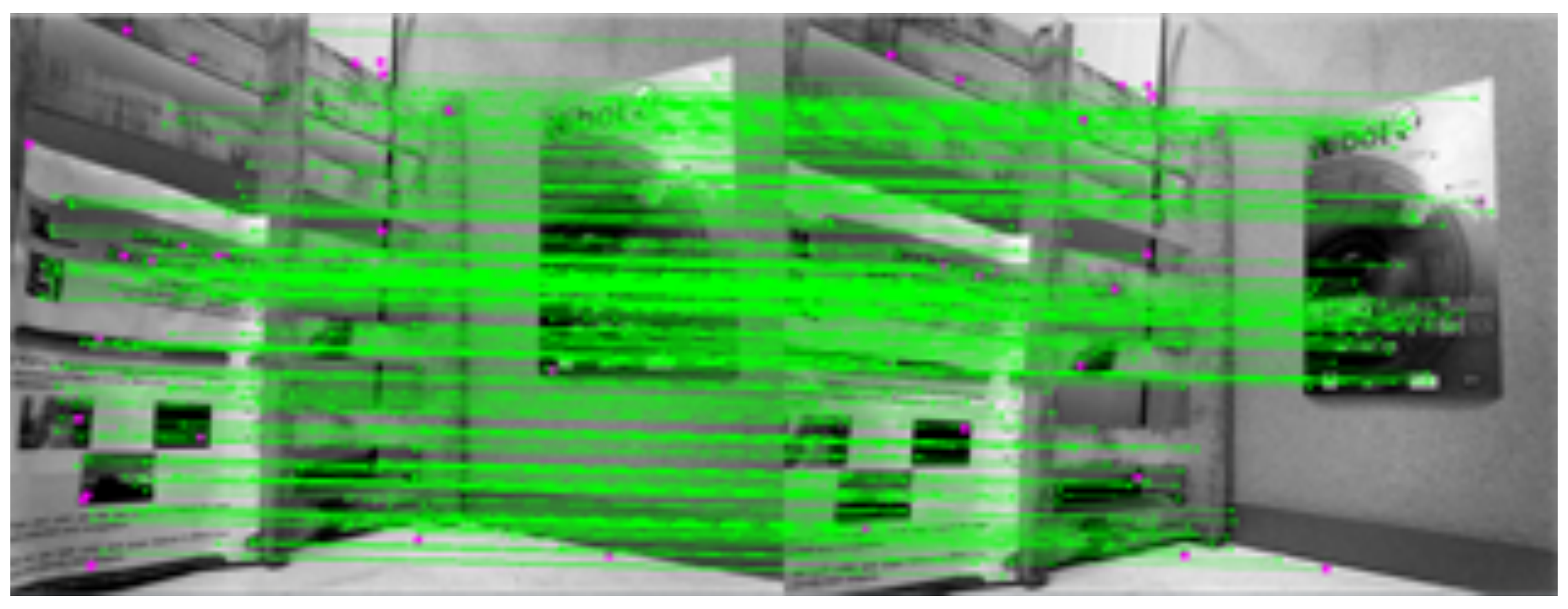
Feature Detection & Matching

Essential Matrix Estimation

Motion Estimation & Triangulation



Calibration Parameters



Feature detection and matching is employing SURF[4] descriptors. After applying SURF we also apply RANSAC[3] in order to eliminate the false positive results. Purple points represent the features detected but can not matched.

Normalized 8-point algorithm[5] is used to estimate essential matrix. In order to estimate the essential matrix

The pose of the second camera is obtained from essential matrix by triangulating one point. Then by triangulating all the points a 3D point cloud is created .

RESULTS

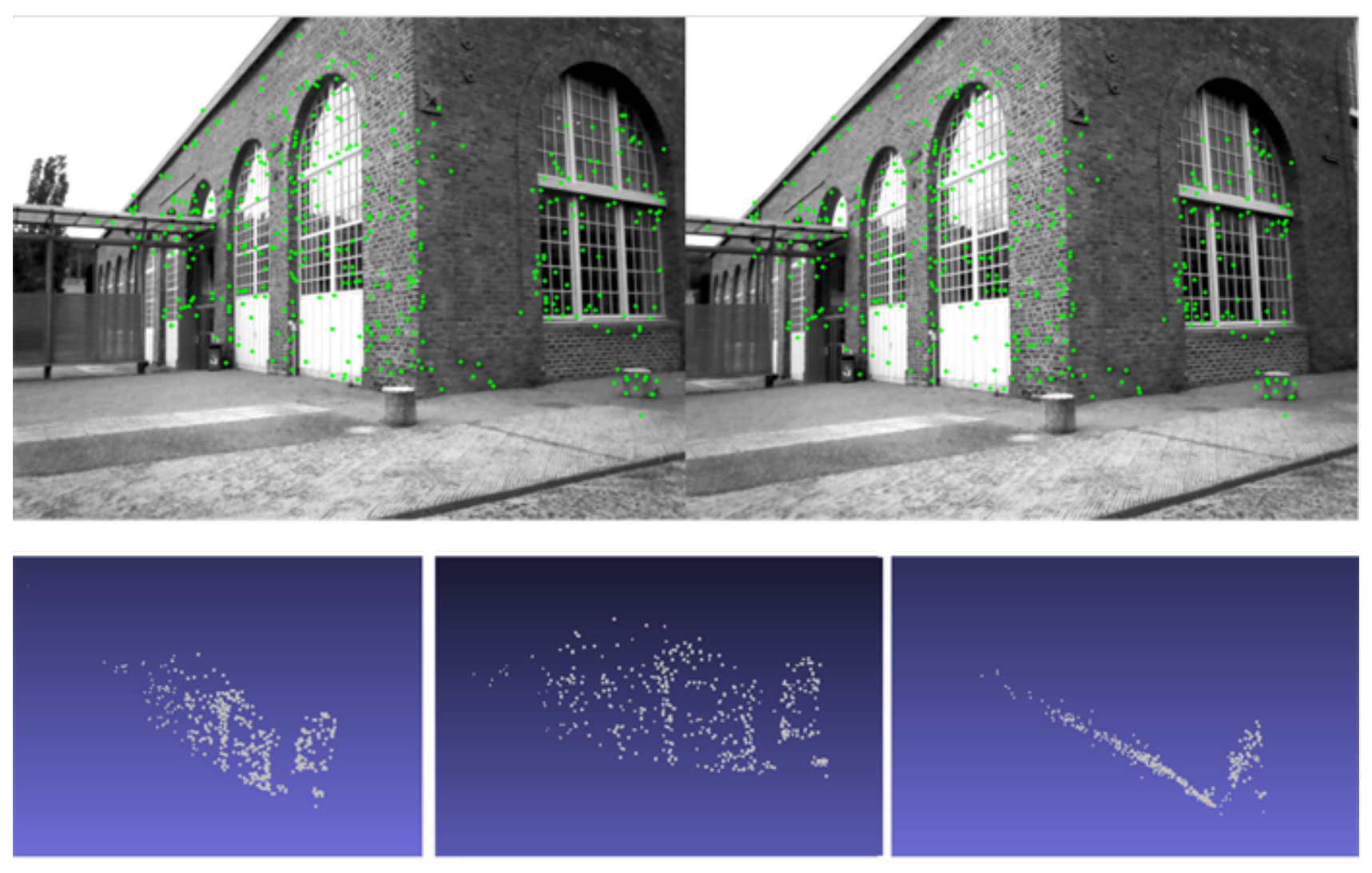
Camera calibration results are tested using Bouguet Toolbox. Also the SfM results are verifying the reliability of calibration module. The results of SfM procedure is also demonstrated.

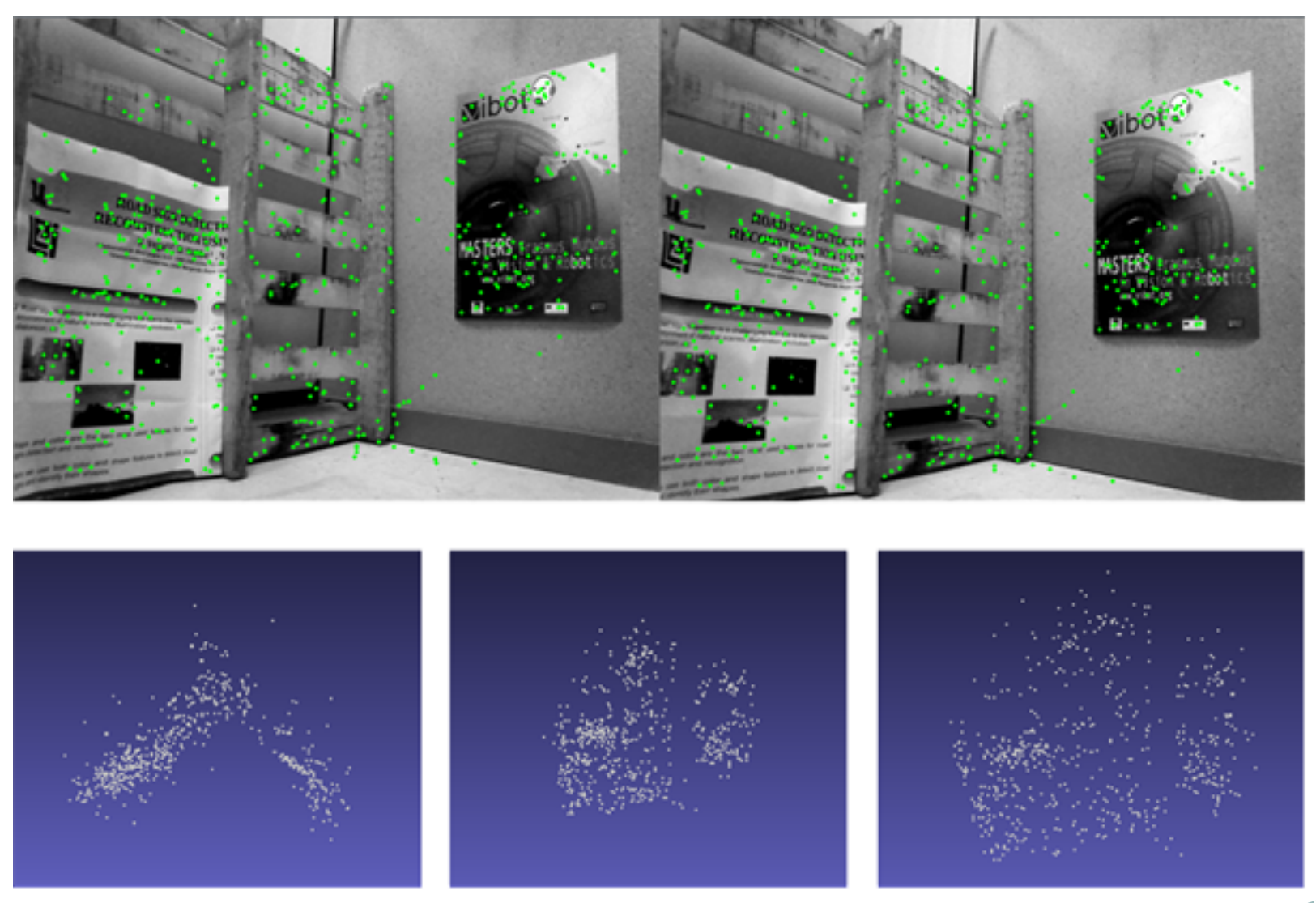
Camera calibraiton results using our application;

$$K = \begin{bmatrix} 557.473 & 0.0 & 329.959 \\ 0.0 & 558.239 & 232.031 \\ 0.0 & 0.0 & 1.0 \end{bmatrix}$$

Camera calibraiton results using Bouget Toolbox;

$$K = \begin{bmatrix} 556.686 & 0.0 & 328.683 \\ & 557.590 & 231.765 \\ 0.0 & 0.0 & 1.0 \end{bmatrix}$$





CONCLUSIONS

- A Camera Calibration Module is developed for humanoid Nao.
- A SfM prototype is developed and applied to the images acquired by Nao.

References

[1] Aldebaran Robotics.
[2] Zhengyou Zhang. A flexible new technique for camera calibration. *IEEE Trans. Pattern Anal. Mach. Intell*., 22(11):1330–1334, November 2000.
[3]Martin A. Fischler and Robert C. Bolles. Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography. Commun. ACM, 24(6):381–395, June 1981.
[4]Herbert Bay, Andreas Ess, Tinne Tuytelaars, and Luc Van Gool. Speeded-up robust features (surf). *Comput. Vis. Image Underst*., 110(3):346–359, June 2008.
[5]Richard I. Hartley. In defense of the eight-point algorithm. *IEEE Trans. Pattern Anal. Mach. Intell*., 19(6):580–593, June 1997..