Thesis Proposal

Title of the working programme

Modular time-constrained algorithms for autonomous mobile robots vision systems

Scientific Domain

Informatic Engineering

Work programme starting date

12 September 2011

Duration

3 years

Place of work

Instituto de Engenharia Electrónica e Telemática de Aveiro -IEETA

Departamento de Electrónica, Telecomunicações e Informática -DETI

Abstract

Autonomous robotics is nowadays one of the most challenging research areas and with every year it becomes more approachable in the university environment. From the NAO soccer player robot developed by Aldebaran to Honda's ASIMO-the world's most advanced robot and to NASA's Robonaut2-the first robot prepared for entering Earth's orbit on a NASA space shuttle, all autonomous robots are designed for imitating basic human tasks such as reaching for things, picking things up, navigate along floors or climbing stairs. One of the most important things that these examples have in common is the fact that their main sensorial element is their vision system. This PhD pretends to study and develop modular algorithms that not only has to cope with the constraints of real-time processing but that could also be applied to a wide range of vision systems for autonomous robots, independently of their architecture. The vision algorithms will address all necessary aspects for creating an ideal representation of the surrounding world for any autonomous robot. From camera calibration to object detection, algorithms based on Scale-Invariant Feature Transform (SIFT) or Speeded-Up Robust Features (SURF) will be developed and tested on all the robotic platforms provided by the University or Aveiro. Moreover, the Distributed Video Coding paradigm will be studied with the purpose of simplifying and improving the video acquisition from wireless video devices which are commonly used in different robotic architectures.

Objectives

The aim of this PhD is to implement generic algorithms that could be used with a large number of autonomous robots, independently of their hardware architecture. Such algorithms could be used in robotic soccer, autonomous driving, domestic assistance and industrial automation.

The University of Aveiro currently holds four robotic projects on which the algorithms could be tested. Two humanoid platforms are available, the Robotis' Bioloid robot and the NAO robot, developed by Aldebaran and which is currently the standard robotic platform used in RoboCup Standard Platform League. In the case of these robotic soccer players, vision mostly relies on color segmentation for the objects of interest. Several approaches for object detection and localization based on color segmentation will be studied and tested [THESIS]. Another platform provided by the University of Aveiro are the Middle Size robots of the CAMBADA team. In this case, more advanced agorithms for object detection have to be implemented since the color restrictions are no longer valid. Thus, complex algorithms based on feature extraction and shape recognition will be studied, still keeping in mind the constraints of real-time processing [SIFT], [SURF], [MECHATRONICS]. For the autonomous driving agent, which is the third platform available, the implemented algorithms should be able to detect the path, pedestrians, road blocking agents and interpret road signs with base on the types of algorithms previously mentioned. An @Home robotic agent has to be capable of navigating inside domestic environments and recognize and classify objects of interest mostly based on their shape [LUL].

The final objective of this work is to provide robust algorithms for autonomous robots allowing them to acquire information about the surrounding environment even under challenging conditions while still performing in real-time.

Detailed description

Nowadays, many robotic applications make use of digital cameras as their main sensorial element. Worldwide robotic competitions such as *RoboCup* and *DARPA Urban Challenge* are two main events that foster research projects who incorporate robotic vision as one of their main element. From robots playing soccer, performing rescue operations or immitating basic daily human tasks to autonomous driving robotic agents, robotic vision is used to provide real-time information about the surrounding world. Also many industrial applications use vision systems to perform tasks such as object positioning, quality control and defective product check. Although different, such applications focused on robotic vision, share several important features such as: the image acquisition process, image processing algorithms, the necessity of performing a camera callibration and the realtime constraints.

For the image acquisition process, the paradigm of Distributed Video Coding will be studied [DVC]. Based on Wyner-Ziv coding, that is lossy compression with receiver side information, this

paradigm enables low-complexity video encoding where the bulk of the computation is shifted to the decoder. With the use of a super-computer on the decoder side, the image acquisition process for wireless cameras that are commonly used in robotic applications can be significantly improved.

The camera calibration process can be implemented in two ways. Either based on a static approach where all the calibration is done previously to the activation of the system or by implementing a dynamic system for self-calibration of the camera. The first approach is more common among robotics projects since the limitations of real-time processing do not always allow a continuously running process of calibration. One of the goals of this PhD is to implement a dynamic self-calibration module that could continuously run in real-time along with the other processes running on a robot. This would allow a better performance of the vision system, considering that it could be used in all kind of changing environments, this rising the degree of automatization of the process. In [[IBPRIA], [CUNHA], [VIP], [PETER], [ICIP]] are some examples of static and dynamic camera calibrations applied to the robotic soccer team CAMBADA (acronym of Cooperative Autonomous Mobile roBots with Advanced Distributed Architecture) for the *RoboCup Soccer* challenge.

Object detection algorithms tend to be specific to each application and usually involves several heuristics methods. Finding a common solution for implementing object detection algorithms for a wide range of robots is quite a challenge. For this reason, several algorithms will be studied and implemented. From more specific algorithms based on color segmentation and extraction of features from blobs of certain colors [THESIS], to algorithms based on edge detection and merging of contours (ex. Sobel, Canny) [MORPH] and finally to generic algorithms based on feature extraction and shape recognition such as SURF and SIFT [SURF], [SIFT], a wide range of image processing algorithms will be studied with the purpose of providing reliable algorithms for a large number of robotic applications.

Real time constraints are highly important when implementing robotic vision algorithms. Such constraints can be met by combining image processing algorithms of low complexity with hardware capable of delivering realtime execution, such as DSPs (Digital Signal Processor) and GPU (Graphics Processing Unit) assisted [FPGAGPU].

This PhD will focus on attaining a qualitative image acquisition while still reducing the complexity of the acquisition process on the robotic side, on developing object algorithms for a wide range of autonomous robotic vision systems as well as on the development of a dynamic calibration of the camera system relying also on hardware capable to meet the real-time restrictions.

With this work we intend to develop robust algorithms for the current robotic projects associated to our research departments IEETA (acronym of Instituto de Engenharia Electrónica e Telemática de Aveiro) and DETI (acronym of Departamento de Electrónica, Telecomunicações e Informática) from Universidade de Aveiro such as: the CAMBADA robotic agents, the humanoid platforms NAO by Aldebaran and Bioloid by Robotis as well as an autonomous driving robotic agent and the @Home agent. While still focusing on the modularity of the algorithms, specific features required by all these

robotic platforms will be taken into consideration and implemented.

Main aimed conferences and journals

- IS&T SPIE Electronic Imaging and SPIE Journal of Electronic Imaging
- European Signal Processing Conference - EUSIPCO
- IEEE/RSJ International Conference on Intelligent Robots and Systems - IROS
- International Conference on Image Analysis and Recognition - ICIAR
- IEEE Conference on Computer Vision and Patter Recognition - CCVPR
- International Conference on Computer Vision - ICCV
- IEEE International Conference on Robotics and Automation - ICRA
- IEEE Transactions on Robotics
- IEEE Transactions on Image Processing
- IEEE Robot Automation Magazine
- Elsevier Mechatronics
- Springer International Journal of Computer Vision

Bibliographical references

[$CUNHA$] Cunha, B., Azevedo, J.L., Lau, N., Almeida, L.: Obtaining the inverse distance map from a nonSVP hyperbolic catadioptric robotic vision system. In: Proc. of the RoboCup 2007, Atlanta, USA (2007)

[VIP] Martins, D.A., Neves, A.J., Pinho, A.J.: Obtaining the distance map for perspective vision systems. In: Proc. of the 2nd ECCOMAS Thematic Conference on Computational Vision and Medical Image Processing, VipIMAGE 2009.

[$IBPRIA$] Neves, A.J.R., B. Cunha, A.J.P., Pinheiro, I.: Autonomous configuration of parameters in robotic digital cameras. In: Proc. of the 4th Iberian Conference on Pattern Recognition and Image Analysis, ibPRIA 2009, P´ voa de Varzim, Portugal

[$ICIP$] Neves, A.J.R., Martins, D.A., Pinho, A.J.: Arbitrary ball detection for soccer robots based on the circular hough transform. In: Proc. of the 2009 IEEE International Conference on Image Processing, ICIP2009, Cairo, Egypt

[$MORPH$] Lu, H., Zhang, H., Zheng, Z.: Arbitrary ball recognition based on omnidirectional vision for soccer robots. In: Proc. of RoboCup 2008. (2008)

[$FPGAGPU$] Chase, J.; Nelson, B.; Bodily, J.; Zhaoyi Wei; DahJye Lee, "RealTime Optical Flow Calculations on FPGA and GPU Architectures: A Comparison Study," FieldProgrammable Custom Computing Machines, 2008. FCCM '08. 16th International Symposium on , vol., no., pp.173182, 1415

[$THESIS$] Trifan, A.L.: Developing a vision system for humanoid robots. Master's thesis, Universidade de Aveiro (2011).

[$PETER$] Khandelwal, P.; Hausknecht, M.; Lee, J.; Tian, A.; Stone, P. , "Vision Calibration and Processing on a Humanoid Soccer Robot", The Fifth Workshop on Humanoid Soccer Robots at Humanoids 2010

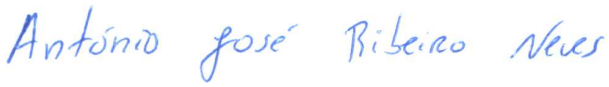
[DVC] Girod, B.; Aaron, A.; Rane, S.; Rebollo-Monedero, D., "Distributed Video Coding", IEEE Invited Paper, 2005

[$SURF$] Juan, L.; Gwun, O., "A Comparison of SIFT, PCA-SIFT and SURF", International Journal of Image Processing (IJIP) Volume(3), Issue(4), 2009

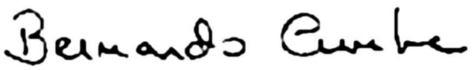
[$SIFT$ Bay, H.; Tuytelaars, T., Van Gool, L. ; "Object recognition from local scale invariant features", European Conference on Computer Vision, 2006

[$MECHATRONICS$] Neves, A.J.R. ; Pinho, A. ; Martins, D.; Cunha, B.; "An efficient omnidirectional vision system for soccer robots: from calibration to object detection", Mechatronics, Volume 21, Number 2, p. 399-410, 2011

Aveiro, 2nd of March, 2012



Prof. Doutor António José Ribeiro Neves (supervisor)



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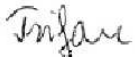

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