Table of Content

1 Introduction **1**
- 1.1 Motivation . . . 2
- 1.2 Problem definition . . . 3
- 1.3 Hypotheses . . . 5
- 1.4 Objectives . . . 5
  - 1.4.1 General objective . . . 5
  - 1.4.2 Specific objectives . . . 6
- 1.5 Contributions . . . 6
- 1.6 Thesis outline . . . 7

2 Literature review **8**
- 2.1 Fundamentals of attitude determination . . . 8
  - 2.1.1 Sensors for attitude determination . . . 9
  - 2.1.2 Attitude determination modes . . . 10
  - 2.1.3 Attitude representations . . . 10
  - 2.1.4 The rotation matrix . . . 14
  - 2.1.5 Reference frames . . . 15
  - 2.1.6 Transformations between frames . . . 16
  - 2.1.7 Attitude from the STT to other representations . . . 17
- 2.2 Algorithms for star identification . . . 17
- 2.3 Using *a priori* information . . . 18
  - 2.3.1 Using TLE information . . . 18
  - 2.3.2 Using Kalman filtering . . . 18
  - 2.3.3 Kalman filter description for attitude determination . . . 19
- 2.4 Software and hardware tools for STT development . . . 20
  - 2.4.1 Software . . . 20
  - 2.4.2 Hardware . . . 24
- 2.5 Developing Star Trackers for CubeSats . . . 25
- 2.6 Use of COTS in space projects . . . 25
  - 2.6.1 Use of COTS for STT development . . . 25
  - 2.6.2 Using Raspberry Pi . . . 25
- 2.7 Considerations about space environment . . . 26
  - 2.7.1 Environmental threats in LEO . . . 26
  - 2.7.2 Effects produced by space radiation . . . 27
  - 2.7.3 Study and mitigation of radiation effects . . . 30

3 Algorithm Development **32**
3.1 Description . . . 32
3.2 Tangent plane projection of the stellar catalog . . . 32
3.3 Attitude determination algorithm . . . 33
3.4 Adapting the algorithm for different field of view . . . 36

4 Evaluation **39**
4.1 Algorithm evaluation by using on-space images . . . 39
4.2 Platform evaluation . . . 40
4.2.1 Description . . . 40
4.2.2 Exposure Time . . . 41
4.2.3 Success rate, precision, catalog segmentation and processing time . . . 42
4.2.4 Vacuum chamber test . . . 44
4.2.5 Power consumption . . . 45
4.2.6 Discussion . . . 46
4.3 Radiation effects assessment . . . 49
4.3.1 Method description . . . 49
4.3.2 Results . . . 52

5 Star tracker integration and set up for on-flight evaluation **55**
5.1 Being part of a CubeSat project . . . 55
5.2 Payload integration with Flight Software (FS) . . . 55
5.3 Validation through on-flight experiments . . . 56

6 Conclusions and future work **62**

Bibliography **64**

Annex A Extended abstract **73**

Annex B Code links **75**