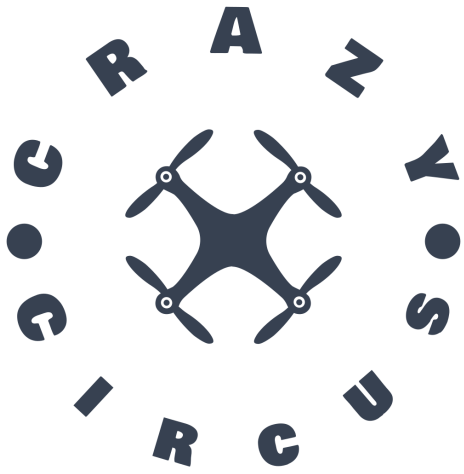
Requirement Specification

CrazyCircus-Group

December 13, 2023

Version 1.1



Status

Reviewed		
Approved		

Project Identity

Group E-mail: ellge955@student.liu.se

Homepage: http://www.liu.se/

Orderer: Anton Kullberg, Reglerteknik/LiU
Phone: -
E-mail: anton.kullberg@liu.se

Customer: Daniel Axehill, Reglerteknik/LiU
Phone: +46 13 28 40 42
E-mail: daniel.axehill@liu.se

Supervisor: Joel Nilsson, Reglerteknik/LiU
Phone: -
E-mail: joel.nilsson@liu.se

Course Responsible: Daniel Axehill, Reglerteknik/LiU
Phone: +46 13 28 40 42
E-mail: daniel.axehill@liu.se

Project participants

Name	**Responsibility**	**E-mail**
Elliot Gestrin	Project manager (PM)	ellge955@student.liu.se
Martin Agebjär	Control technology (CT)	marag492@student.liu.se
Hugo Asplund	Hardware (HW)	hugas433@student.liu.se
Marcus Filipsson	Simulation (SIM)	marfi245@student.liu.se
Alvin Gustavsson Vester	Design (DES)	alvgu648@student.liu.se
Albin Helsing	Testing (TEST)	albhe896@student.liu.se
Tomas Röjder	Software (SW)	tomro614@student.liu.se
Adam Simon	GUI/Information (GUI/I)	adasi503@student.liu.se
Axel Stockhaus	Documentation (DOC)	axest416@student.liu.se

CONTENTS

CrazyCircus-Group
ellge955@student.liu.se

DOCUMENT HISTORY

Version	Date	Changes made	Made by	Reviewed
0.1	2023-09-14	First version	CrazyCircus-Group	Elliot Gestrin
0.2	2023-09-18	Second version	CrazyCircus-Group	Axel Stockhaus
1.0	2023-09-18	Version 1.0	CrazyCircus-Group	Axel Stockhaus
1.1	2023-12-06	After renegotiation of requirements	CrazyCircus-Group	Axel Stockhaus

1 INTRODUCTION

In this document all the requirements for the project are specified.

1.1 Purpose and goal

The long-term purpose of this project is to create an infrastructure that can be used in research and education within UAVs. The goal is to design a cool and robust visual demonstration of a flying drone in Visionen. This demonstration includes acrobatic maneuvers with the drone.

1.2 Use

This project will be reused by future projects. If the project is successful it can be used in both research and education, as well as advertisement for LIU.

1.2.1 *Concept descriptions*

Table 1: Definition of terms

Concept	**Description**
Crazyflie	Crazyflie 2.1 drone developed by Bitzcraze. [1]
Crazyradio	CrazyRadio PA developed by Bitzcraze. [2]
GUI	Grafical User Interface to interact with the electronics easily.
IMU	Inertial Measurement Unit, combination of accelerometers, gyroscopes.
ROS	Robot Operating System used to build robot applications.
Visionen	Robotics lab at Linköpings universitet.
Qualisys Camera System	A motion capture system inside Visionen, used for positioning of drones [3].
Waypoint	A specific location or point in space that is used in navigation.
Path	A route or course taken by the drone from one waypoint to another.
Trajectory	A predefined path with information of coordinates and angles for the drone to follow.
Flip	Spinning 360 degrees around its own roll and/or pitch axis in mid air.
Loop	Making a 360 degree turn with a given velocity, except it is in the vertical plane instead of the horizontal. Like a flip but in a circular motion.
Acrobatic trick	An acrobatic trick is a visually interesting motion performed by the drone, for example a loop or a flip.
Acrobatic sequence	An acrobatic sequence is a sequence of one or more movements and tricks performed by the drone.

1.3 Definitions

Requirements are defined as follows:

- Requirement number.

- Requirement type:
  - O: Requirements that were present throughout the course of the project.
  - R: Requirements that have been renegotiated in consultation with the orderer after an approved specification. The date of renegotiation is stated.
  - A: Requirements that have been added after an approved requirement specification and after negotiation with the client. The date when the requirement was added is shown.
- Description of requirement.
- Priority:
  - 1 : All these requirements **must** be met for the project to be considered complete.
  - 2 : All these requirements **should** be met during the project, or otherwise be renegotiated.
  - 3 : All these requirements **can** be met if time allows, and would be valuable to the project.

2 OVERVIEW OF THE SYSTEM

The goal of the project is to create a cool and robust visual demonstration of a Crazyflie doing acrobatics in a controlled environment inside Visionen. To accomplish this demonstration the Crazyflie needs to be able to do tricks like flips and loops. This will be the main focus of the project.

2.1 Description of the system

Multiple subsystems will be implemented in the project. The subsystems included in the project are:

- Graphical User Interface, see Section 5.
- Simulation Environment, see Section 6.
- Motion Planning System, see Section 7.
- Control System, see Section 8.
- Communication System, see Section 9.
- Sensor System, see Section 10.

2.2 Product components

The system is made up of the following components:

- 4 Crazyflie 2.1
- 1 Crazyradio 2.0
- Qualisys motion capture system
- Portable computer running Ubuntu and ROS

3 GENERAL REQUIREMENTS

General requirements can be found below.

Table 2: General requirements

Requirement	Version	Description	Priority
1	O	The same control software is used for simulation and real life testing.	2

4 ACROBATICS

The following requirements state what motions/acrobatics the drone should be able to perform.

Table 3: Acrobatics requirements

Requirement	Version	Description	Priority
2	O	The drone should be able to spin 360 degrees around its own roll and/or pitch axis mid air (do a flip) and then return to a stable mid-air hover.	1
3	O	The drone should be able to fly in a vertical circle with a specified radius in roll and pitch axis (do a loop) and then return to a stable mid-air hover.	2
4	O	The drone should be able to spin 360 degrees around its own yaw axis and then return to a stable mid-air hover.	1
5	R	The drone should be able to do a throwing start, meaning that the drone is thrown out in the room and from there on the drone should take control and stabilize itself.	3
6	O	The drone should be able to spin 720 degrees around its own roll and pitch axis and then return to a stable mid-air hover.	3

Table 4: Acrobatics requirements in simulation

Requirement	Version	Description	Priority
7	R	The drone in simulation should be able to spin 360 degrees around its own roll and/or pitch axis mid air (do a flip) and then return to a stable mid-air hover.	3
8	R	The drone in simulation should be able to fly in a vertical circle with a specified radius in roll and pitch axis (do a loop) and then return to a stable mid-air hover.	3
9	R	The drone in simulation should be able to spin 360 degrees around its own yaw axis and then return to a stable mid-air hover.	3
10	R	The drone in simulation should be able to do a throwing start, meaning that the drone is thrown out in the room and from there on the drone should take control and stabilize itself.	3
11	R	The drone in simulation should be able to spin 720 degrees around its own roll and pitch axis and then return to a stable mid-air hover. .	3

4.1 Acrobatic sequence

The requirements below describe that it should be possible to save and load sequences of tricks/acrobatics, and how multiple drones should be able to cooperate.

Table 5: Acrobatic sequence requirements

Requirement	Version	Description	Priority
12	O	It should be possible to save built up sequences.	2
13	O	It should be possible to load and run previously saved sequences of tricks/acrobatics.	2
14	R	Multiple drones should be able to perform acrobatic sequences at the same time.	3
15	O	Multiple drones should be able to do syncronized acrobatic sequences.	3

5 GRAPHICAL USER INTERFACE

The following requirements states what the GUI should contain and its functionality.

Table 6: Graphical User Interface requirements

Requirement	Version	Description	Priority
16	O	There should exist a GUI.	1
17	O	There should exist an emergency stop button that shuts the drone off immediately.	1
18	R	There should exist an emergency land button that makes the drone stabilize and land immediately.	3
19	O	From the GUI it should be possible to start an acrobatic sequence.	1
20	O	From the GUI it should be possible to start different acrobatic sequences.	2
21	O	From the GUI it should be possible to design and save a new acrobatic sequence.	3
22	R	There should exist a button that starts a drone mission.	1
23	O	The GUI should allow for manual control of the drone.	1
24	O	The GUI should be able to load acrobatic sequences.	2
25	R	The GUI should be able to control multiple drones.	3
26	O	The GUI should display the current drone state.	1
27	O	The GUI should be able to display the actual trajectory the drone is flying.	1
28	O	The GUI should display the planned trajectory that the drone is supposed to follow.	1

6 SIMULATION ENVIRONMENT

The requirements for the simulation environment can be found below.

Table 7: Simulation Environment requirements

Requirement	Version	Description	Priority
29	O	The simulation environment should include a dynamic model of the Crazyflie.	1
30	R	The dynamic model should be validated by data.	3
31	O	A 3D model of the Crazyflie should be used in the simulation.	3

7 MOTION PLANNING SYSTEM

The motion planning system requirements can be found below.

Table 8: Motion Planning System requirements

Requirement	Version	Description	Priority
32	O	With waypoints as input from the GUI the planner should plan a trajectory for the drone to follow.	1
33	O	With an acrobatic sequence as input from the GUI the planner should plan a trajectory for the drone to follow.	1

8 CONTROL SYSTEM

The requirements for the control system are described below. The control system takes the planned trajectories and the estimated positions as input and computes the control signals, which are then passed to the drones. The controller's purpose is to keep the drone on the planned trajectories regardless of reasonable disturbances.

8.1 General

The general requirements for the control system are presented below.

Table 9: Control general

Requirement	Version	Description	Priority
34	O	One drone should be able to fly autonomously.	1
35	O	One drone should be able to fly manually controlled.	1
36	O	The drone should be able to move in the global x-, y- and z-axis.	1
37	O	The drone should be able to rotate relative to the drone's z-axis (yaw angle).	1
38	O	The drone should be able to move in the global x-, y- and z-axis independent of the yaw angle.	1
39	R	Multiple drones should be able to fly autonomously and synchronised.	3

8.2 Design

The design requirements for the control system are presented below.

Table 10: Control design

Requirement	Version	Description	Priority
40	O	It should be possible to change parameters for the controller.	1

8.3 Trajectory Following

The requirements regarding the ability to follow a trajectory are presented below.

Table 11: Control trajectory

Requirement	Version	Description	Priority
41	O	The drone should follow a given trajectory with a maximal deviation of 10 cm without respect to the yaw, pitch and roll when not performing an acrobatic trick.	1
42	O	The drone should follow a given trajectory with a maximal deviation of 20 cm without respect to the yaw, pitch and roll when performing an acrobatic trick.	2
43	O	The drone should follow a given trajectory with a maximal deviation of 10 degrees with respect to the yaw, pitch and roll of the drone when not performing an acrobatic trick.	1
44	O	The drone should follow a given trajectory with a maximal deviation of 30 degrees with respect to the yaw, pitch and roll of the drone when performing an acrobatic trick.	2
45	O	The drone should hover in a specified position with a maximum deviation of 10 cm.	1
46	O	When multiple drones are used there should be synchronization between them.	3

Table 12: Control trajectory for simulation

Requirement	Version	Description	Priority
47	R	The drone should follow a given trajectory with a maximal deviation of 10 cm without respect to the yaw, pitch and roll when not performing an acrobatic trick in the simulation.	3
48	R	The drone should follow a given trajectory with a maximal deviation of 20 cm without respect to the yaw, pitch and roll when performing an acrobatic trick in the simulation.	3
49	R	The drone should follow a given trajectory with a maximal deviation of 10 degrees with respect to the yaw, pitch and roll of the drone when not performing an acrobatic trick in the simulation.	3
50	R	The drone should follow a given trajectory with a maximal deviation of 30 degrees with respect to the yaw, pitch and roll of the drone when performing an acrobatic trick in simulation.	3
51	R	The drone should hover in a specified position with a maximum deviation of 10 cm in simulation.	3

9 COMMUNICATION SYSTEM

The communication system requirements can be found below.

Table 13: Communication System requirements

Requirement	Version	Description	Priority
52	O	The system runs ROS2.	1

10 SENSOR SYSTEM

The requirements for the sensor system can be found below. The sensor system includes the Qualisys Camera system, the IMU in the Crazyflies and the onboard filter which takes the measurements and produces a position estimate.

Table 14: Sensor System requirements

Requirement	Version	Description	Priority
53	O	The system should be able to receive data from the Qualisys Camera system.	1
54	O	The system should be able to fuse data from the Qualisys Camera system and the drones IMU to estimate the drones current state (position and velocity).	1

11 INFORMATION

Below the requirements for the information of the project are stated.

Table 15: Information requirements

Requirement	Version	Description	Priority
55	O	There should exist a website.	1
56	O	All the public documentation of the project should be available on the website.	1
57	O	There should exist a demonstrative film of the drone where some of the results of the project are shown.	1
58	O	The project film should be available on the website.	1
59	O	There should exist a poster for the project.	1

12 PROJECT QUALITY REQUIREMENTS

The requirements for the quality of the project can be found below.

Table 16: Quality requirements

Requirement	Version	Description	Priority
60	O	The project shall follow Google's coding standard and Lips document standards.	1
61	O	All documents and code should be version managed.	1
62	O	A record of each internal weekly meeting should be written.	1

13 ECONOMY

Economic requirements of the project are stated below.

Table 17: Economic requirements

Requirement	Version	Description	Priority
63	O	The time spent on the project by each group member should be 240 hours.	1

14 SECURITY REQUIREMENTS

The following requirements regard the safety and security aspects of the project.

Table 18: Security requirements

Requirement	Version	Description	Priority
64	R	The drone should be able to do an emergency landing, canceling all future actions and shutting down.	3
65	O	The drone should be able to do an emergency shutdown, turning off all motors at any stage. Kill power.	1
66	R	The drone should emergency land when battery is low.	3
67	R	The drone should emergency land when connection to computer is lost.	3
68	R	The drone should be able to land safely if it is outside the Qualisys positioning system range.	3

15 DELIVERY REQUIREMENTS

The projects requirements regarding deliveries are stated below.

Table 19: Deliveries

#	**Name**	**Receiver**	**Date for first version**	**Date for final version**
1	Requirement Specification	Orderer	2023-09-14	2023-09-20
2	Project Plan	Orderer	2023-09-14	2023-09-20
3	Time Plan	Orderer	2023-09-18	2023-09-20
4	Design Specification	Supervisor	2023-09-18	2023-10-04
5	Test Plan	Supervisor	-	2023-10-04
6	Acrobatics using simulation environment	Orderer	-	2023-11-15
7	Test Protocol	Orderer	-	2023-12-06
8	User manual	Orderer	-	2023-12-06
9	All functionality related to priority 1 and most of priority 2	Orderer	-	2023-12-06
10	Presentation of functionality	Orderer	-	2023-12-06
11	Technical report	Supervisor	2023-12-04	2023-12-11
12	After study	Orderer	-	2023-12-11
13	Poster presentation	Orderer	-	2023-12-12
14	Website	Orderer	-	2023-12-14
15	Demo film of project	Orderer	-	2023-12-18

Table 20: Delivery requirements

Requirement	Version	Description	Priority
69	O	Deliveries should be according to Table 19.	1

16 DOCUMENTATION

A table of all documents to be produced exists in in the "Project Plan" documentation [4], see Table 2 in Section 4.

Table 21: Documentation requirements

Requirement	Version	Description	Priority
70	O	All documents should be based on Lips templates.	1
71	O	Documentation should be delivered according to Table 2 in Project plan [4].	1

REFERENCES

[1] Bitcraze, "Crazyflie 2.1," https://www.bitcraze.io/products/crazyflie-2-1/, 2023, [Online; accessed September 12, 2023].

[2] ——, "Crazyradio pa," https://www.bitcraze.io/products/crazyradio-pa/, 2023, [Online; accessed September 12, 2023].

[3] Qualisys, "Motion capture camera for mri scanners," https://www.qualisys.com/cameras/oqus-mri/, 2023, [Online; accessed September 20, 2023].

[4] E. Gestrin, M. Agebjär, H. Asplund, M. Filipsson, A. Gustafsson-Wester, A. Helsing, T. Röjder, A. Simon, and A. Stockhaus, "Project plan," 2023.