Flight Controller Design and Autonomous Flight Tests of 60cm UAV

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Outline

- Background & Motivation
- Description of our UAV
- Flight Controller Design
  - Attitude Stability Augment System
  - Feedforward Filter
  - Guidance System
- Autonomous Flight Experiments

Background & Motivation

Small and light UAVs

- Advantages of portability and safety.
- Suitable for missions in urban area, or short-range missions.

Challenging issues

- The UAV is seriously affected by gusts of wind.
- The UAV should be able to avoid obstacles.

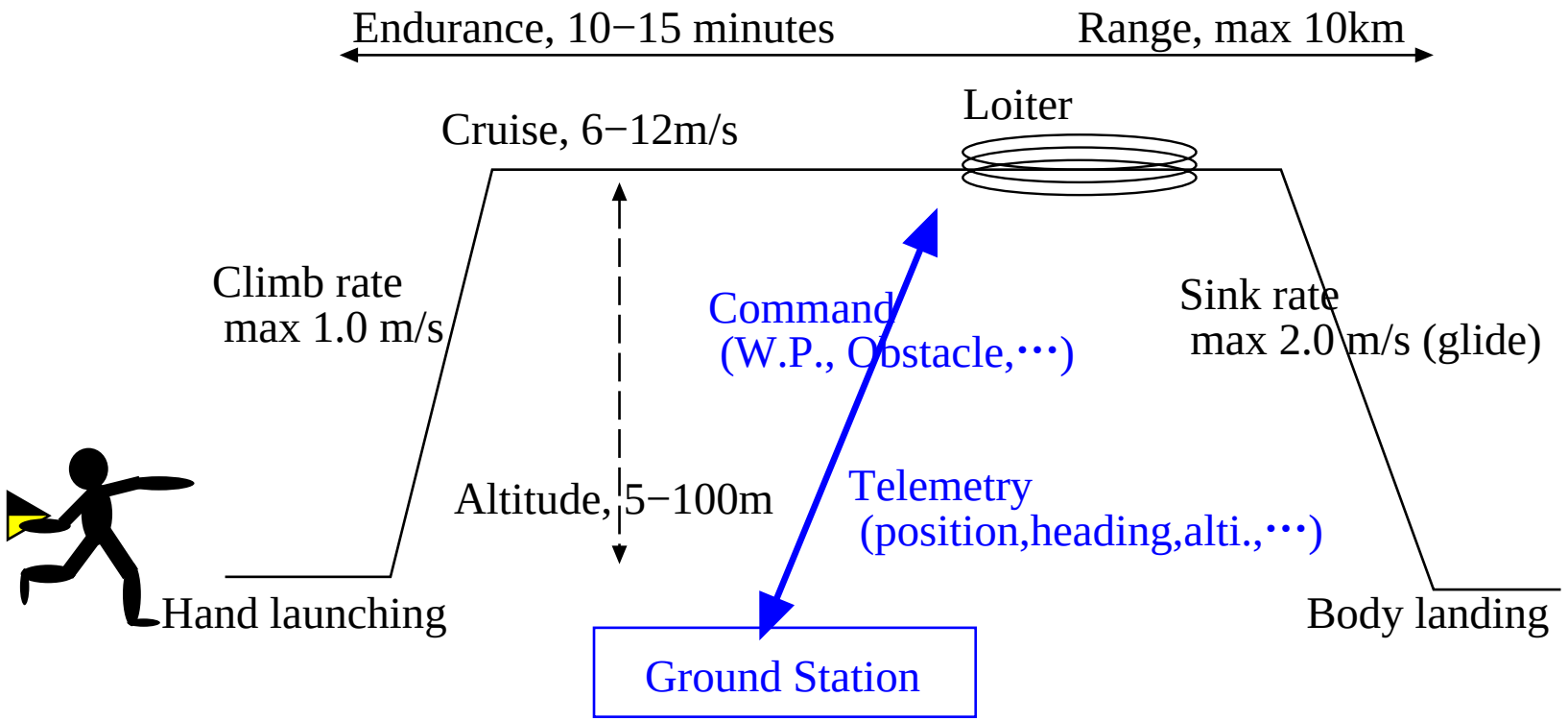
Key Points of this research

- Flight controller that ensure robust stabilities and performances
- Automatical flight experiments with avoiding a known obstacle

Description of the UAV

- Portability : Its span is 0.6m and the gross weight is 0.27kg.
- Safety : It is mainly made of styrene foam and can cruise at 6-12 m/s.
- Avionics : GPS antenna, rate gyros, flight computer, and so on.
- Control device : A set of elevons and a propeller.

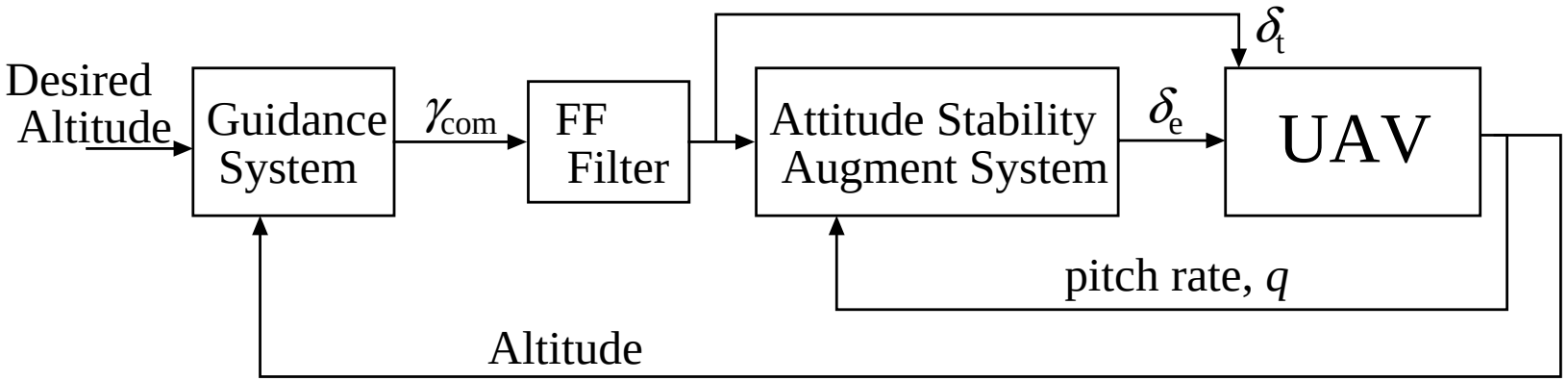
Description of the UAV



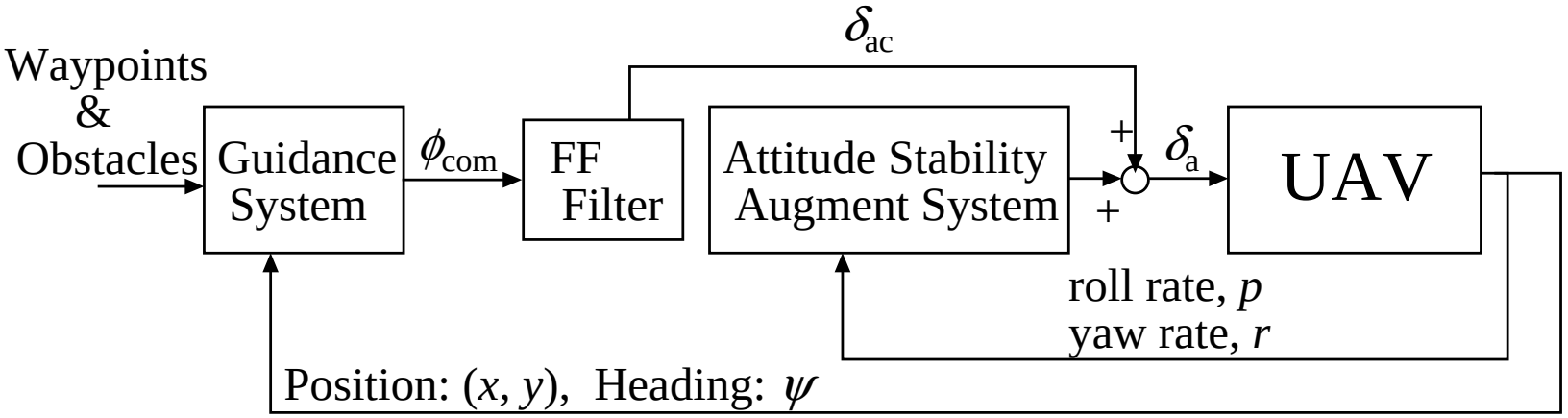
- Endurance : 10-15 min with 11.1V, 450mAh Li-Po battery
- Payload : A 50g camera can be equipped.
- Operation : Both autonomous flight and manual flight can be performed.

Flight Controller Design

LONGITUDE

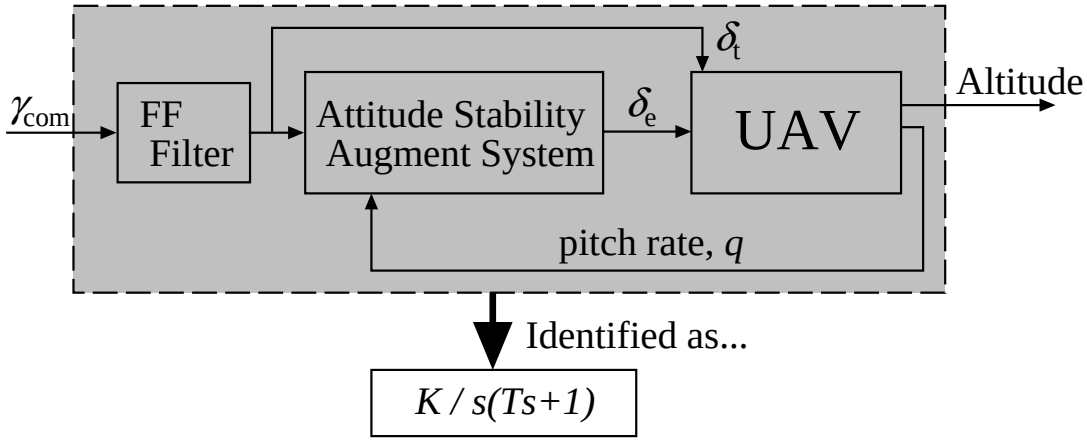


LATERAL-DIRECTION

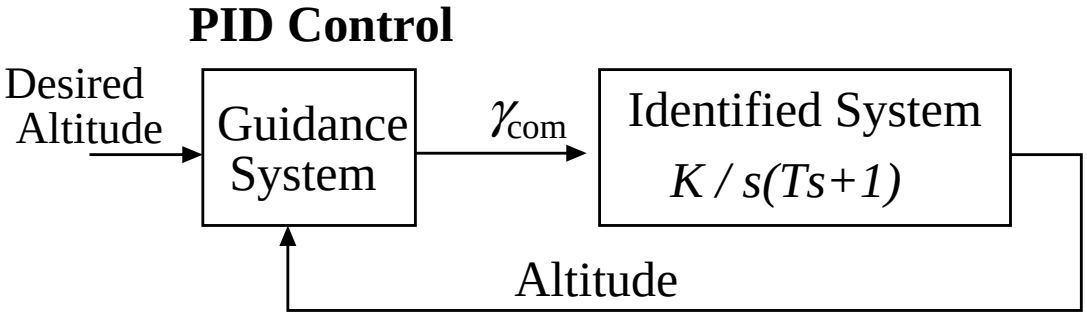


Longitudinal Guidance System

1. The closed-loop was identified as a first order lag system.



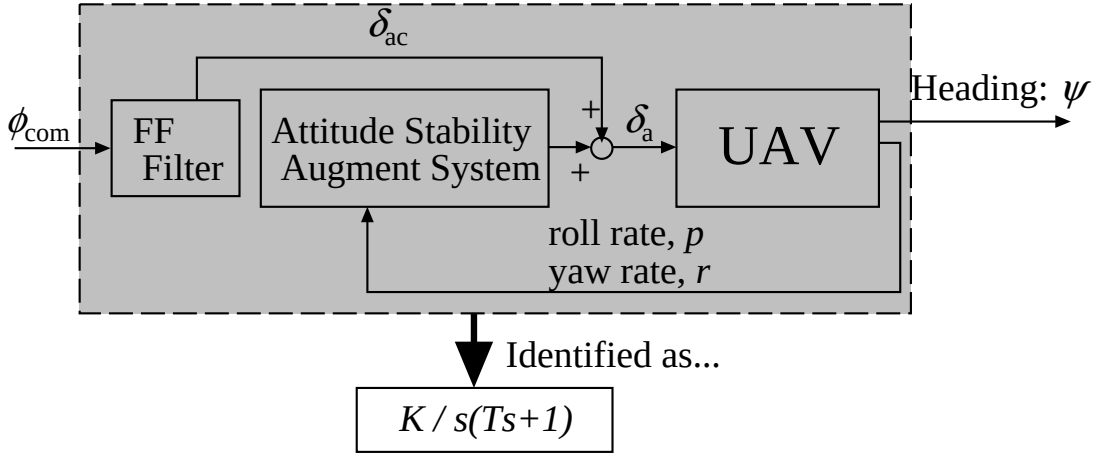
2. The longitudinal guidance system was designed with PID control manner.



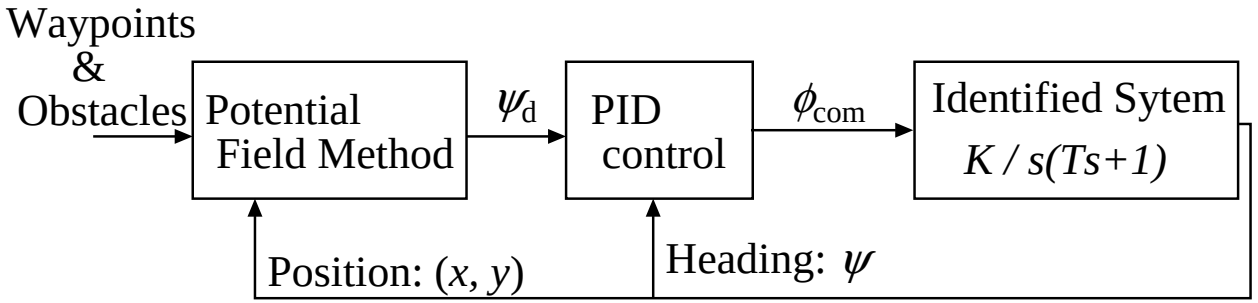
3. The PID gains were tuned in numerical simulations.

Lateral-Directional Guidance System

1. The closed-loop was identified as a first order lag system.



2. The lateral-directional guidance system was designed with PID control manner and artificial potential field method.



3. The PID gains were tuned in numerical simulations.

Artificial Potential Field Method

Using an artificial potential field, U_{art},

$$\psi_d = \tan^{-1}\left(\frac{\partial U_{\mathrm{art}}(\boldsymbol{r})/\partial x}{\partial U_{\mathrm{art}}(\boldsymbol{r})/\partial y}\right).$$

$$U_{\mathrm{art}} = U_{\mathrm{wp}} + U_{\mathrm{obs}}$$

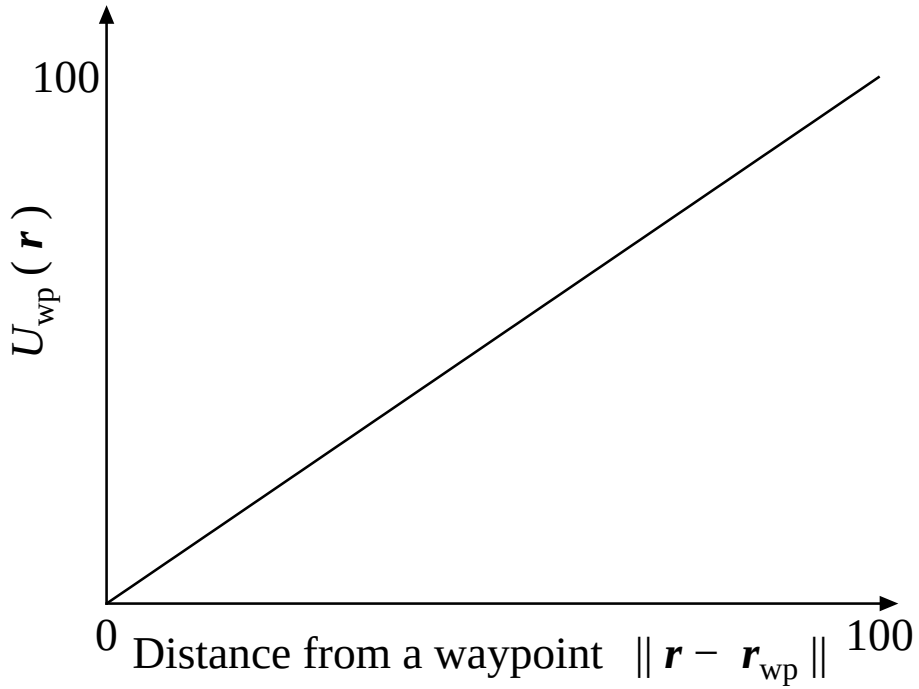
The potential functions were selected from the following point of view.

- Implementation is as easy as possible.
- Computational load is as low as possible.

Artificial Potential Field Method

Potential Field for Waypoints, $U_{\mathrm{wp}}(\boldsymbol{r})$

$$U_{\mathrm{wp}}(\boldsymbol{r}) = \|\boldsymbol{r} - \boldsymbol{r}_{\mathrm{wp}}\| = \sqrt{(x - x_{\mathrm{wp}})^2 + (y - y_{\mathrm{wp}})^2}$$

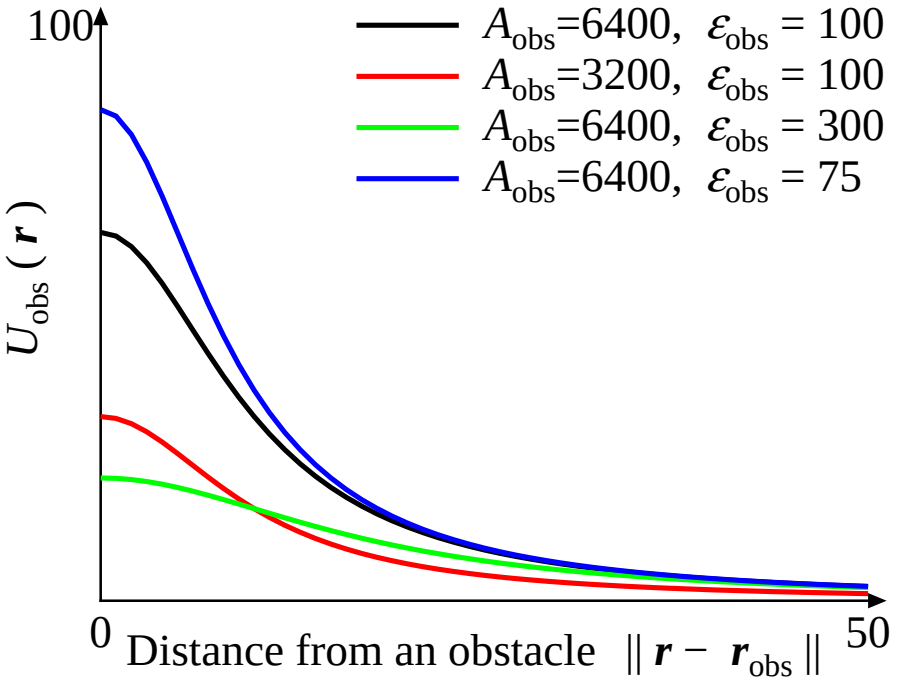


Artificial Potential Field Method

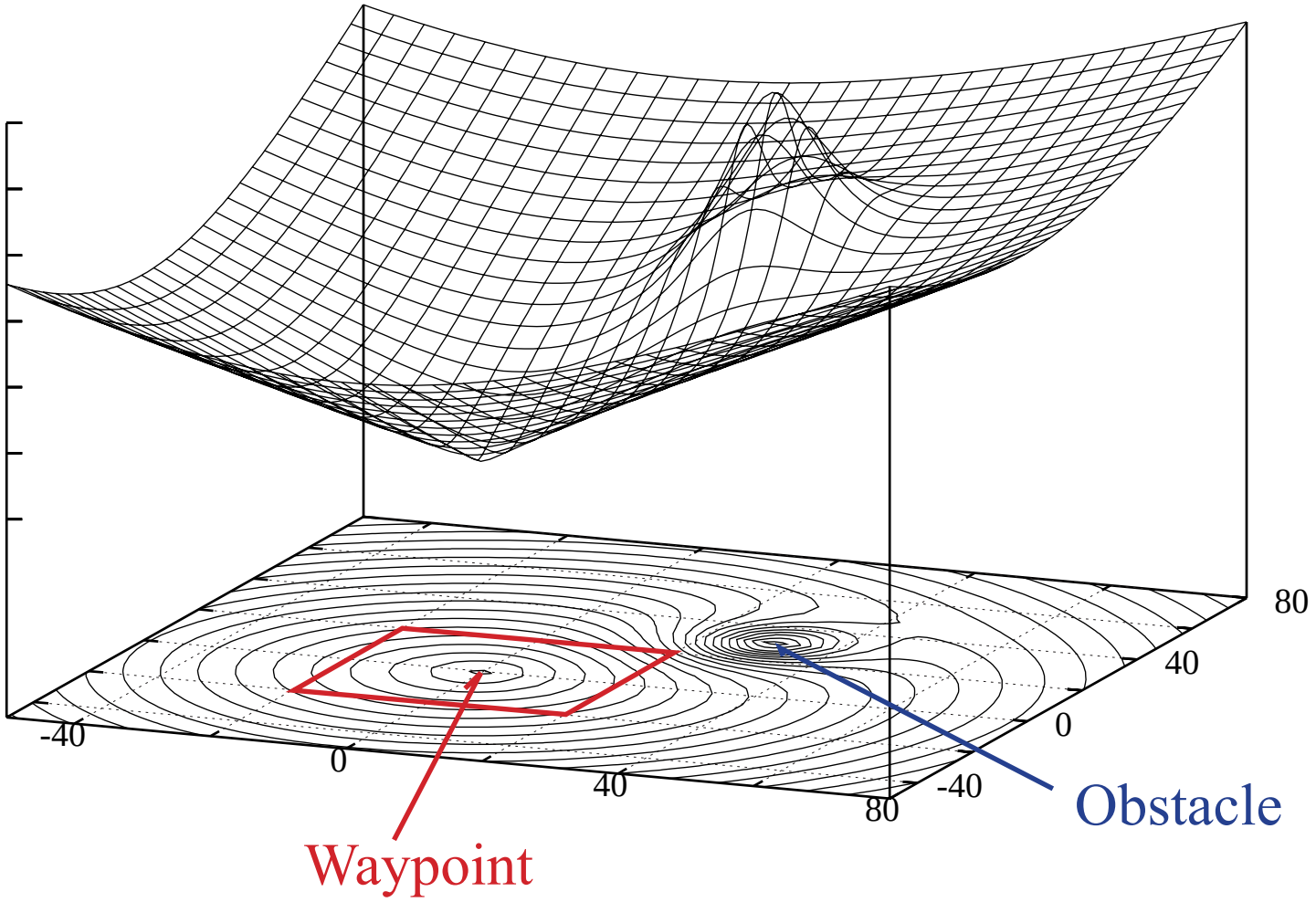
Potential Field for Obstacles, $U_{\text{obs}}(\boldsymbol{r})$

$$U_{\text{obs}}(\boldsymbol{r}) = \frac{A_{\text{obs}}}{\|\boldsymbol{r} - \boldsymbol{r}_{\text{obs}}\|^2 + \varepsilon_{\text{obs}}} = \frac{A_{\text{obs}}}{(x - x_{\text{obs}})^2 + (y - y_{\text{obs}})^2 + \varepsilon_{\text{obs}}}$$

- The A_{obs} and ε_{obs} are designing parameters.
- The non-zero ε_{obs} plays the role of avoiding "division by zero".



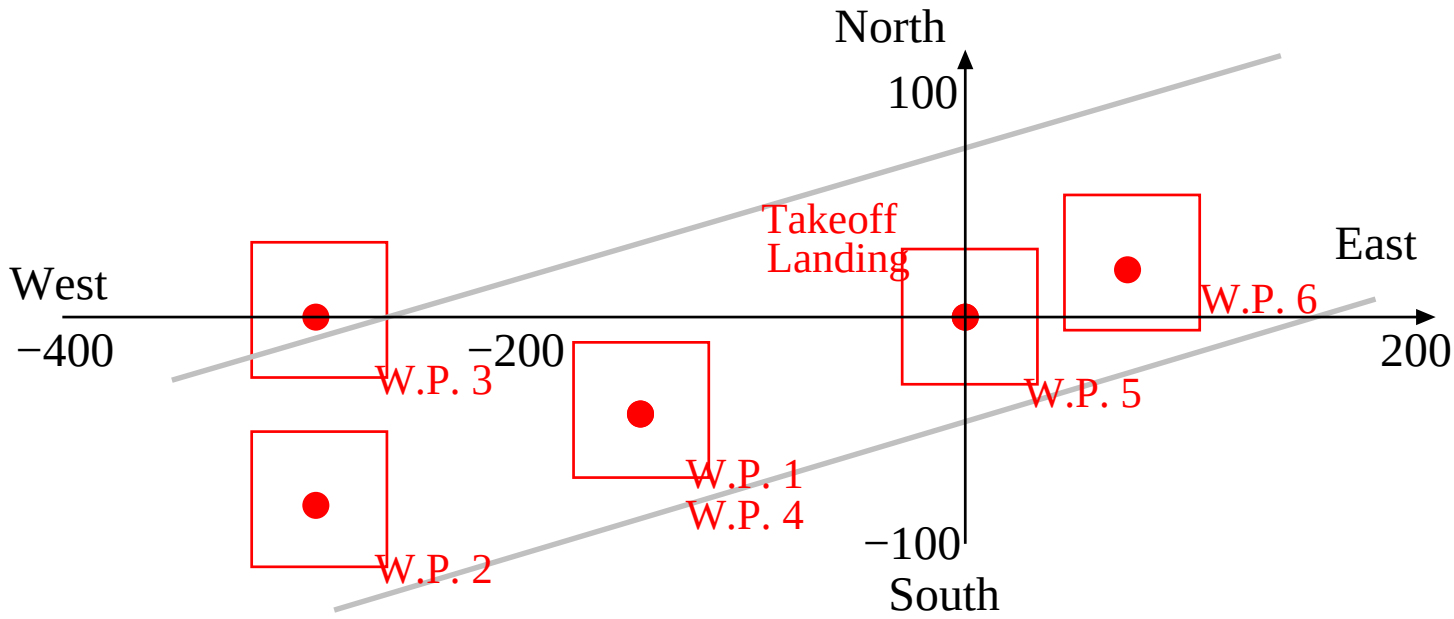
3-D image of the artificial potential field



The desired heading angle, ψ_d, is determined by the gradient of the artificial potential field.

Autonomous Flight Test 1

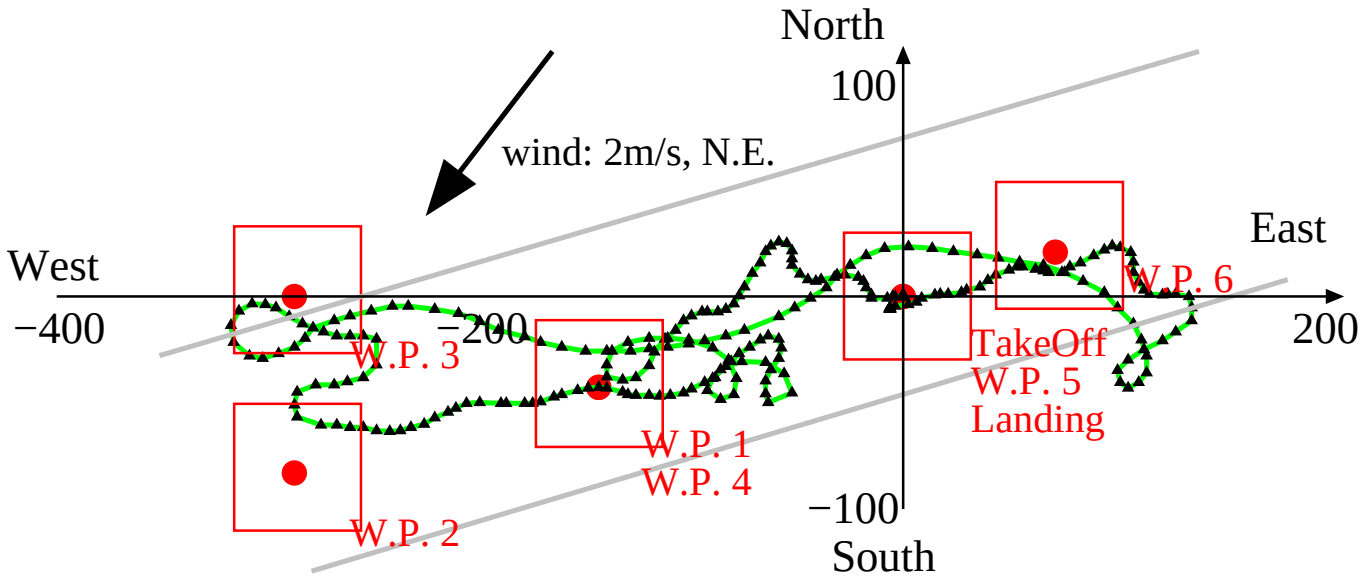
Flight area, Waypoint, and prescribed altitude



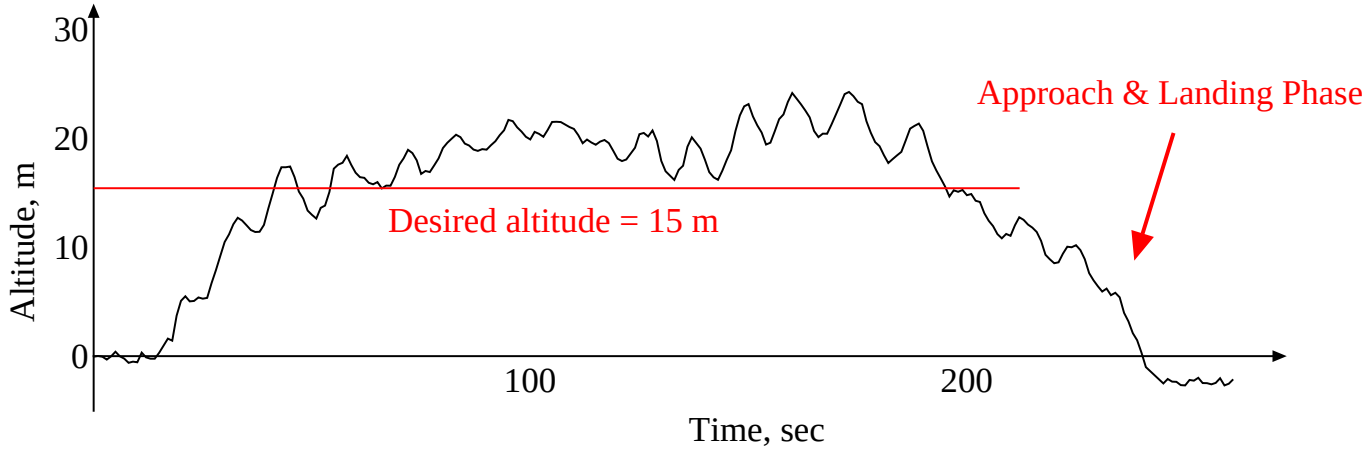
The UAV was required to fly over the 60-meter square zone of each waypoint, and to fly at an altitude of 15 meter.
No obstacle was given.

Autonomous Flight Test 1: Result

Flight Trajectory

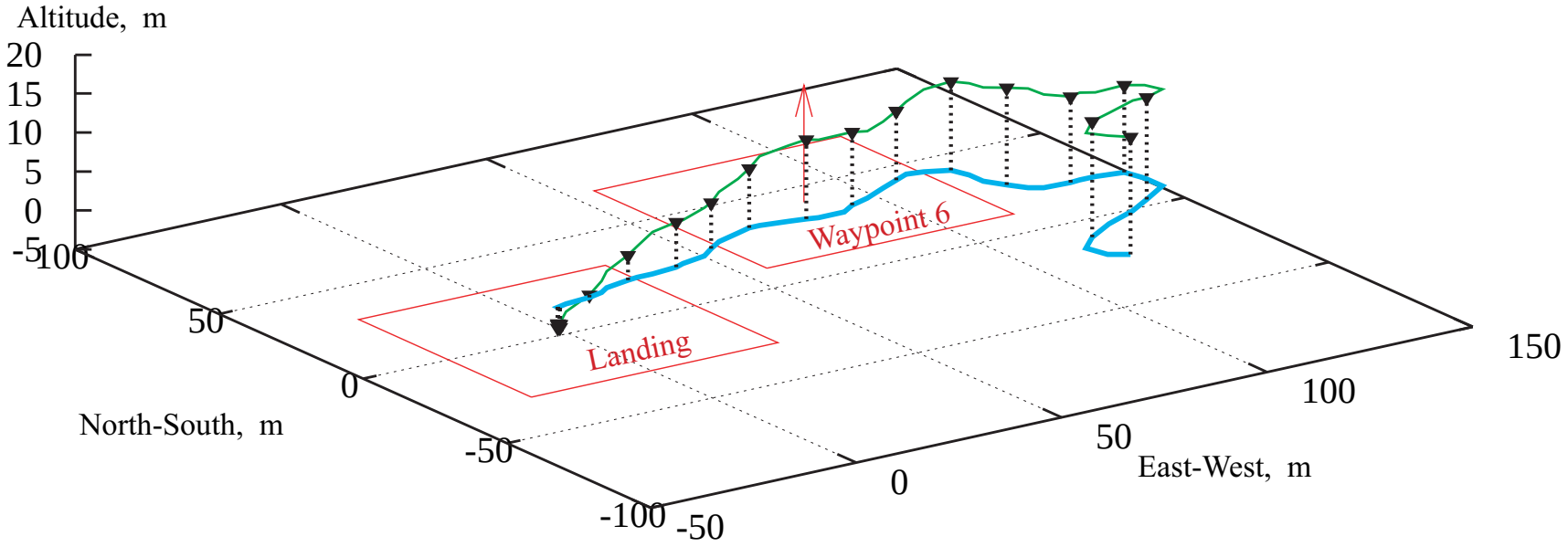


Altitude Time History



Autonomous Flight Test 1: Result

Approach & Landing Phase

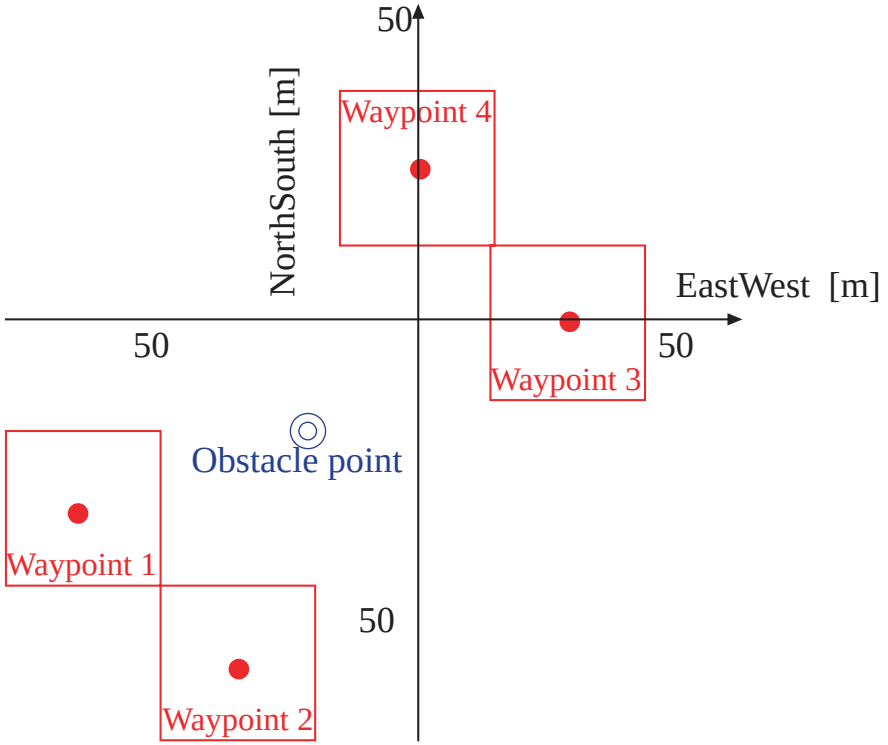


It is found that...

- the UAV's position and altitude were controlled appropriately.
- the UAV was able to land at the prescribed landing point.

Autonomous Flight Test 2

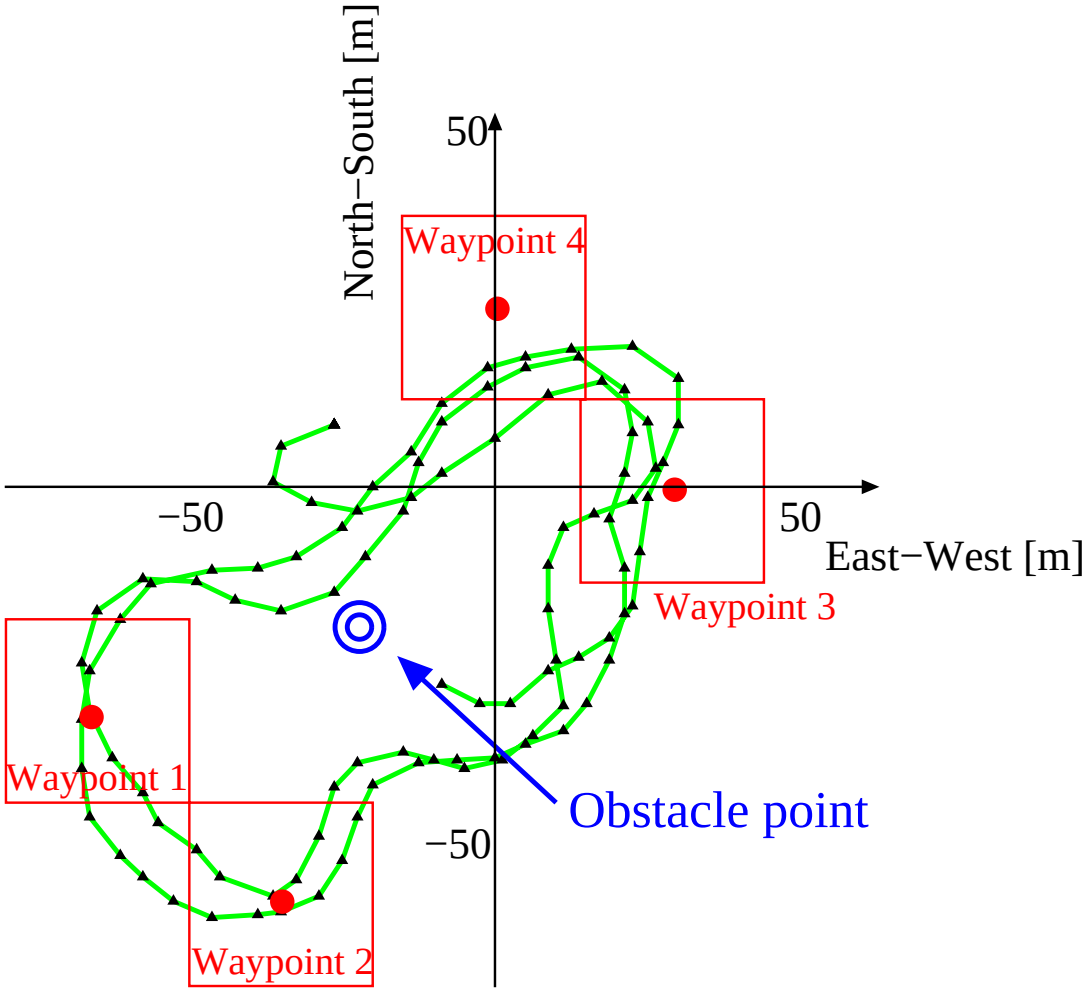
Predefined Waypoints and Obstacle point



Waypoint No.	x, m	y, m
1	-65	-35
2	-35	-65
3	30	0
4	0	30
Obstacle point	-20	-20

The UAV was required to fly over the 30-meter square zone of each waypoint with avoiding the obstacle.

Autonomous Flight Test 2: Result



It can be seen in the flight trajectory that...

- the UAV could avoid the obstacle.
- the UAV successfully flew over the four waypoints.

Summary

- The small size UAV (0.6 meter of its span and 0.27 kg of its weight) has been developed.
- The flight controller, which is composed of the attitude stability augment system, feedforward filter, and guidance system, has been developed.
- The predefined waypoints tracking and the known obstacle avoindace were successfully carried out.