Introduction to the Crazyflie

Lecture at Aerial Robotics Course (EPFL)

Kimberly McGuire

31th of March 2020

Introduction to Bitcraze AB

- Who are we?
  - Crazyflie
  - Hardware Development
- Where are we?
  - Malmö, Sweden
- All the team members?
  - Tobias
  - Marcus
  - Kristoffer
  - Arnaud
  - Barbara
  - Kimberly

History of Bitcraze

- Hobby project
- Company in 2009
- Crazyflie 1.0
- Crazyflie 2.X

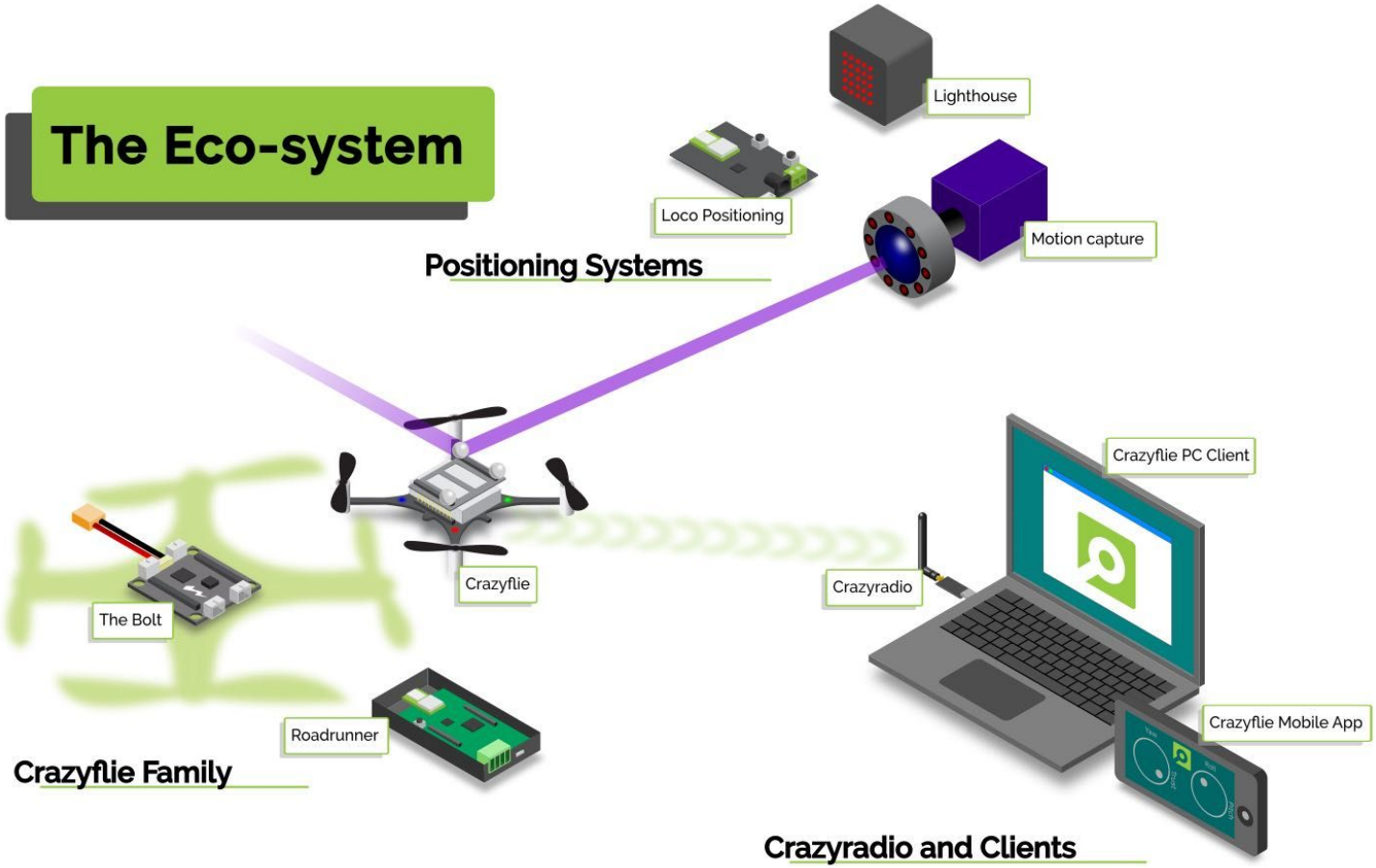
Who uses the Crazyflie?

- Hobbyists
- Researchers
- Educators
- Shows designers

Ted-Talk

Raffaello d'Andrea: https://www.ted.com/talks/raffaello_d_andrea_meet_the_dazzling_flying_machines_of_the_future

The Eco-system

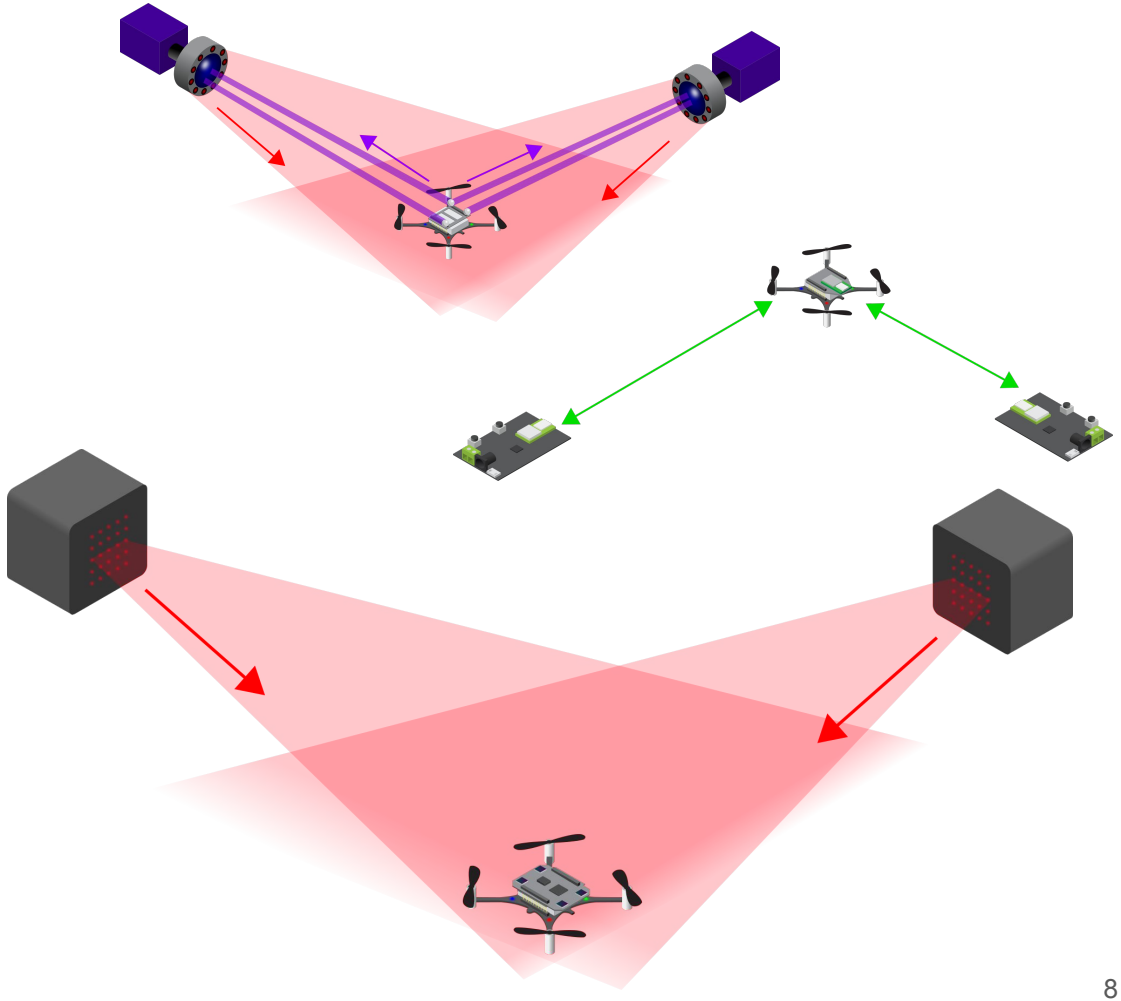


Crazyflie

- Quadrotor
- 4 DC coreless motors
- Battery

Positioning

- Motion Capture Systems
  - Markers
- Loco positioning systems
  - Ultra wide band
  - Like in the TED talk
- Lighthouse system
  - HTC vive VR system
- *Relative positioning*
  - *Flow-deck*

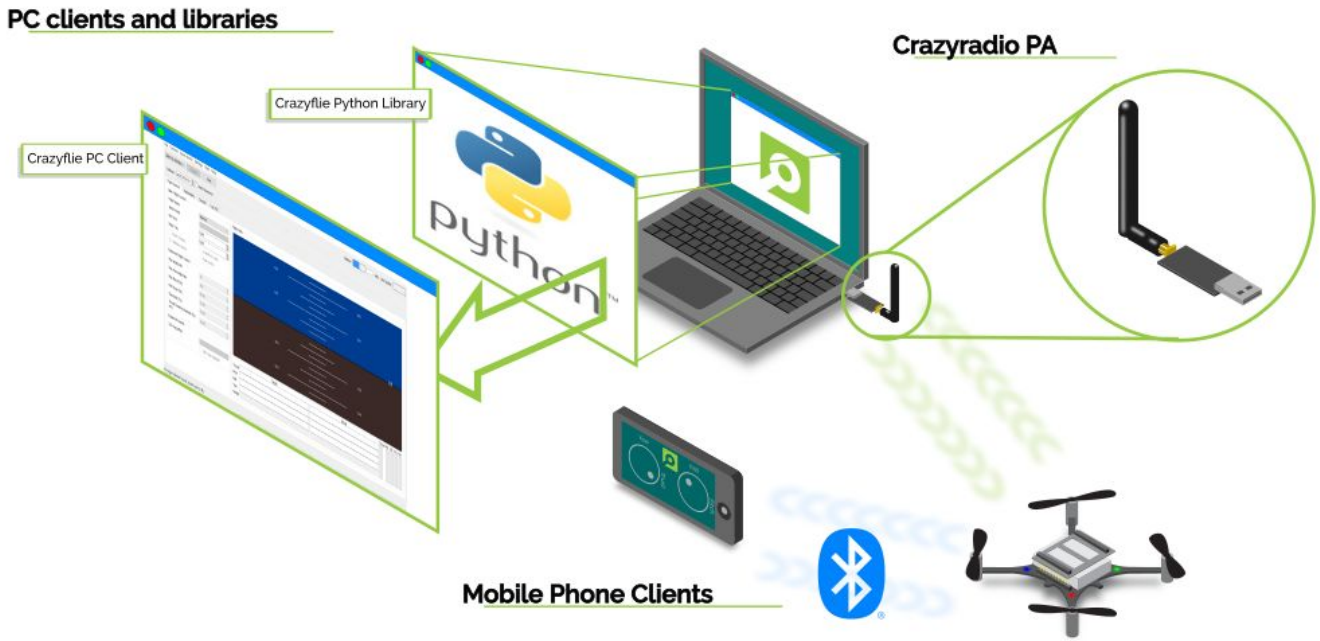


Demonstration Lighthouse

Show lighthouse positioning in action!

Github: crazyflie-lib-python/examples/autonomous_sequence_high_level.py

Client Software



Communication

radio://0/80/2M/E7E7E7E7E7.

- Crazyradio PA
  - Crazyradio Real-Time Protocol (CRTP)
- Unique URI
  - Medium
  - Channel
  - Communication Speed
  - Address
- Broadcast to multiple Crazyflies
  - Sure, as long as you are on the same channel

0xE7E7E7E701

0xE7E7E7E702

0xE7E7E7E703

HANDS-ON

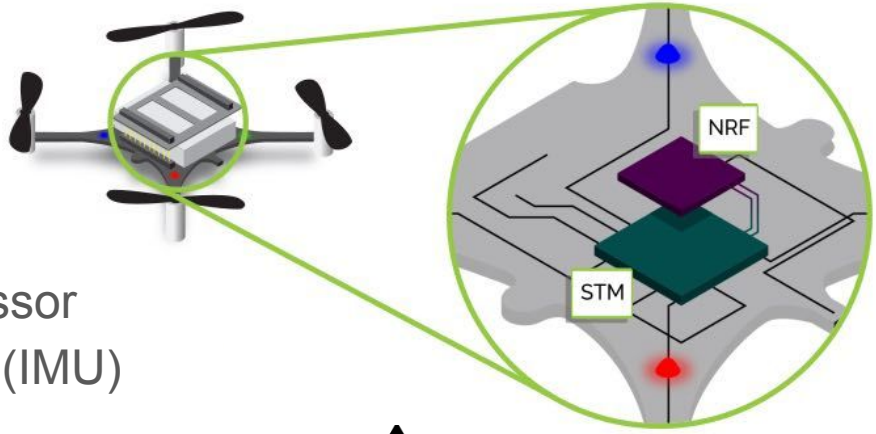
Connect to the Crazyflie

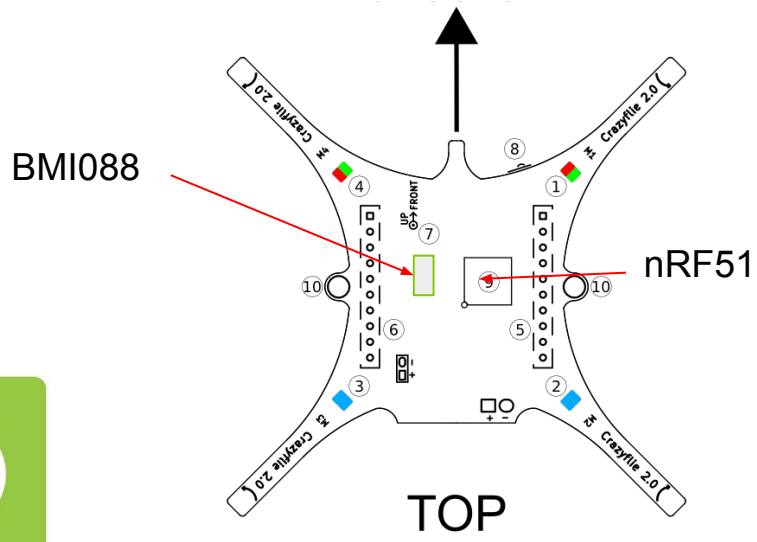
Show the CF client

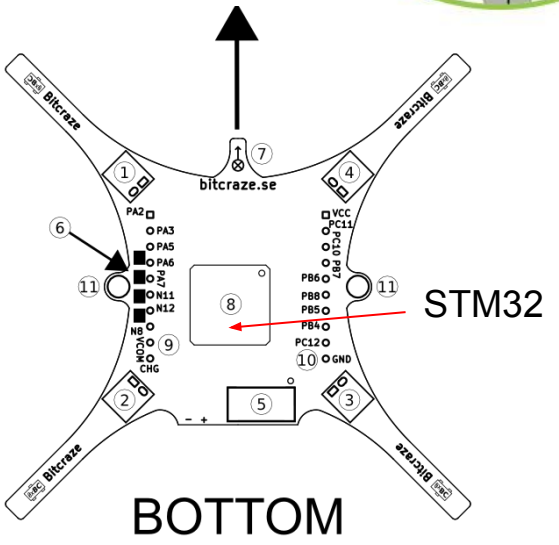
https://github.com/bitcraze/crazyflie-clients-python

Back to the hardware

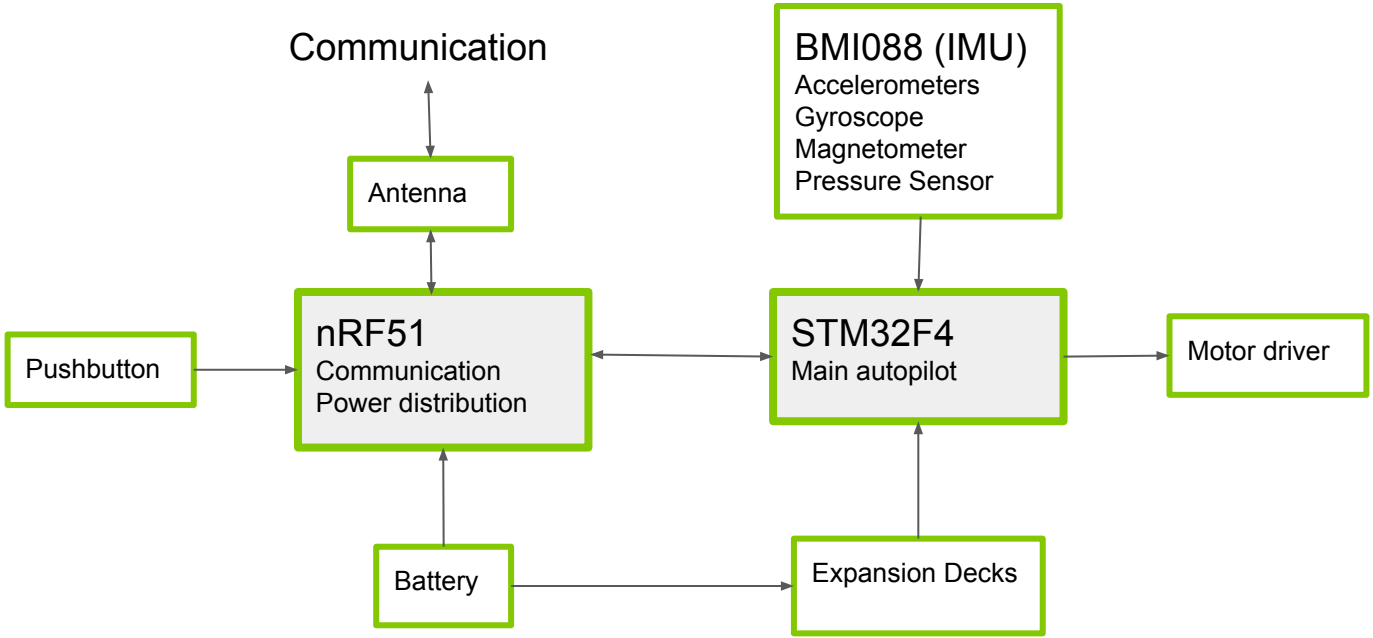
- STM32F4: Autopilot Microprocessor
- nRF51: Communication Microprocessor
- BMI088: Internal Measurement Unit (IMU)





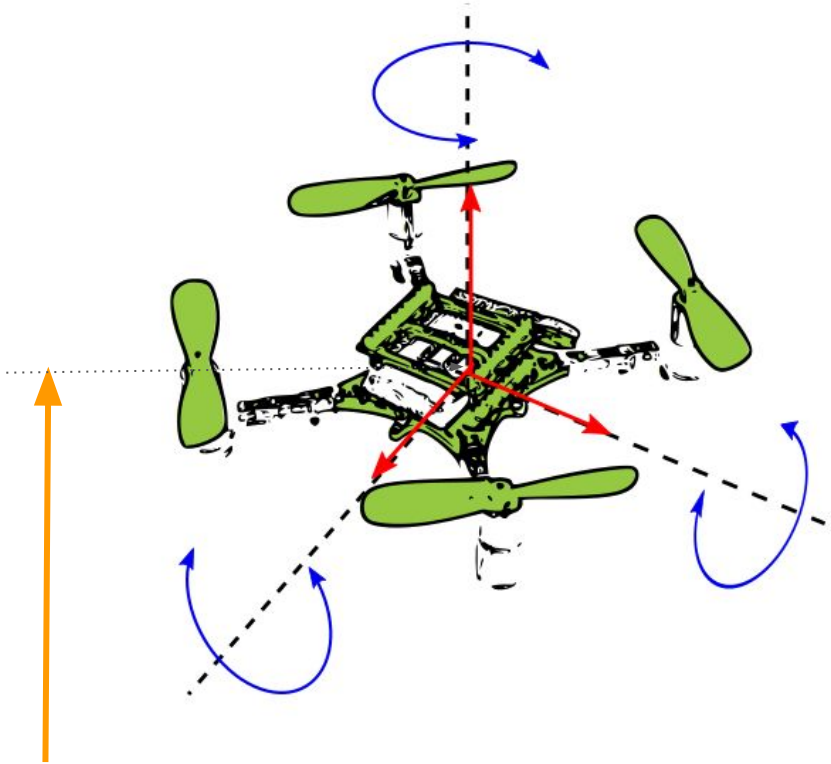


Hardware component connections



Internal Measurement Unit (IMU)

- Accelerometers
- Gyroscope
- Pressure Sensor

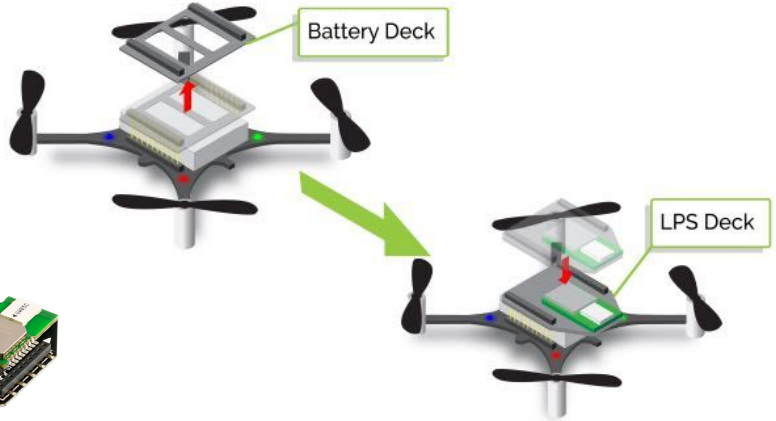


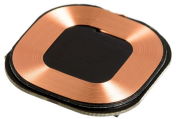
HANDS-ON

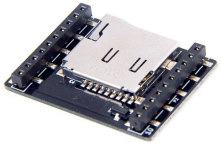
Plotting tab in CFclient to show raw IMU values

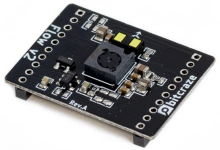
https://github.com/bitcraze/crazyflie-clients-python

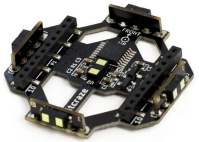
Expansion Decks

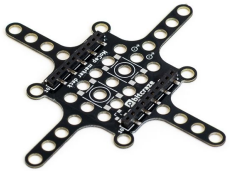




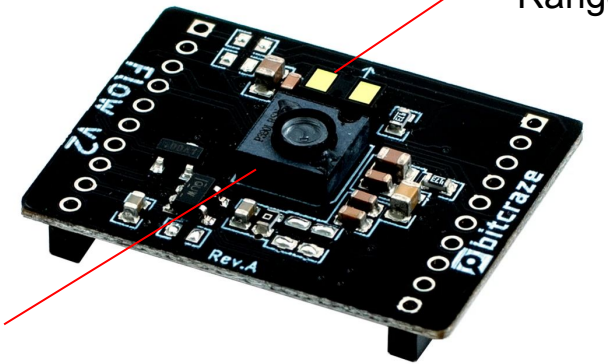






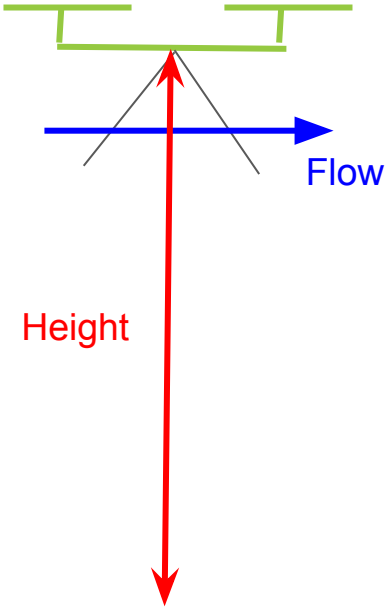


Flowdeck



VL53L1x
Range sensor

PMW3901
Optic Flow Sensor



Relative vs global position!

HANDS-ON

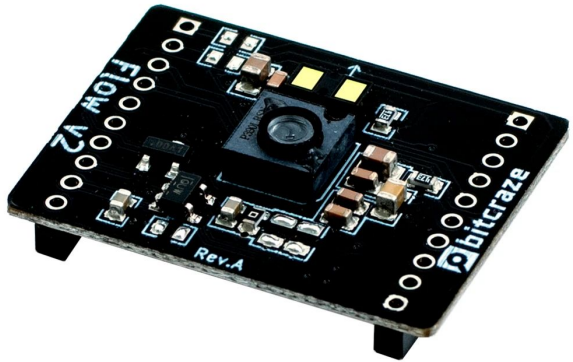
Introduction to console-tab

CFclient logging with flowdeck measurements

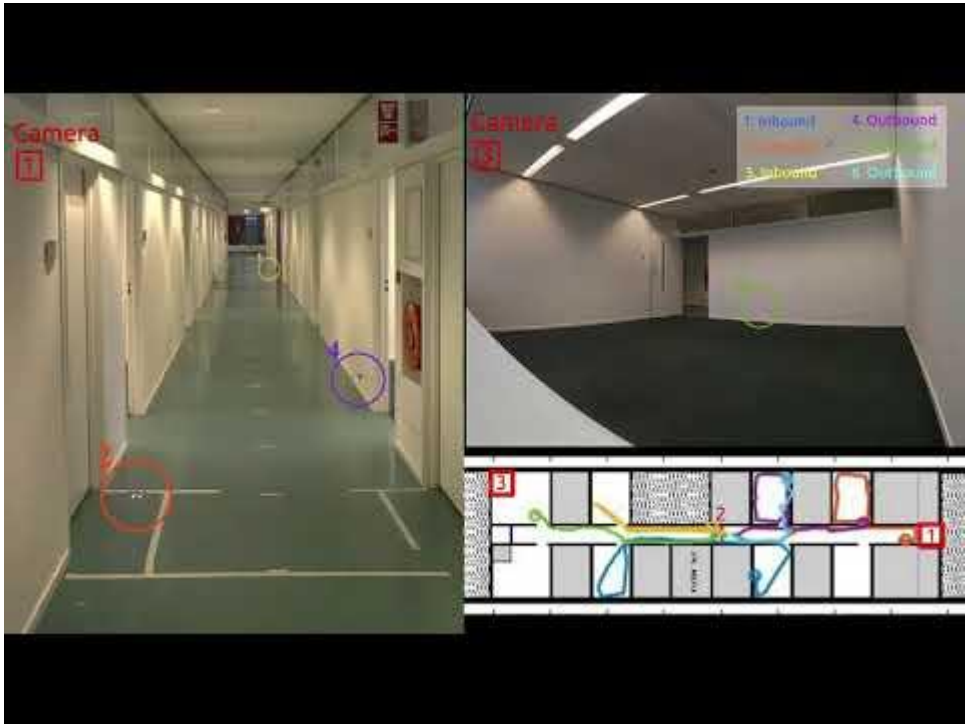
https://github.com/bitcraze/crazyflie-clients-python

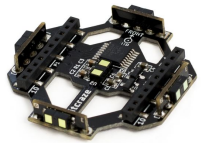
Recap of the last hour

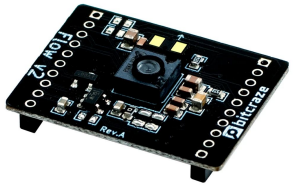
- Crazyflie
- CFclient and logging
- Flowdeck



Example with the Flowdeck





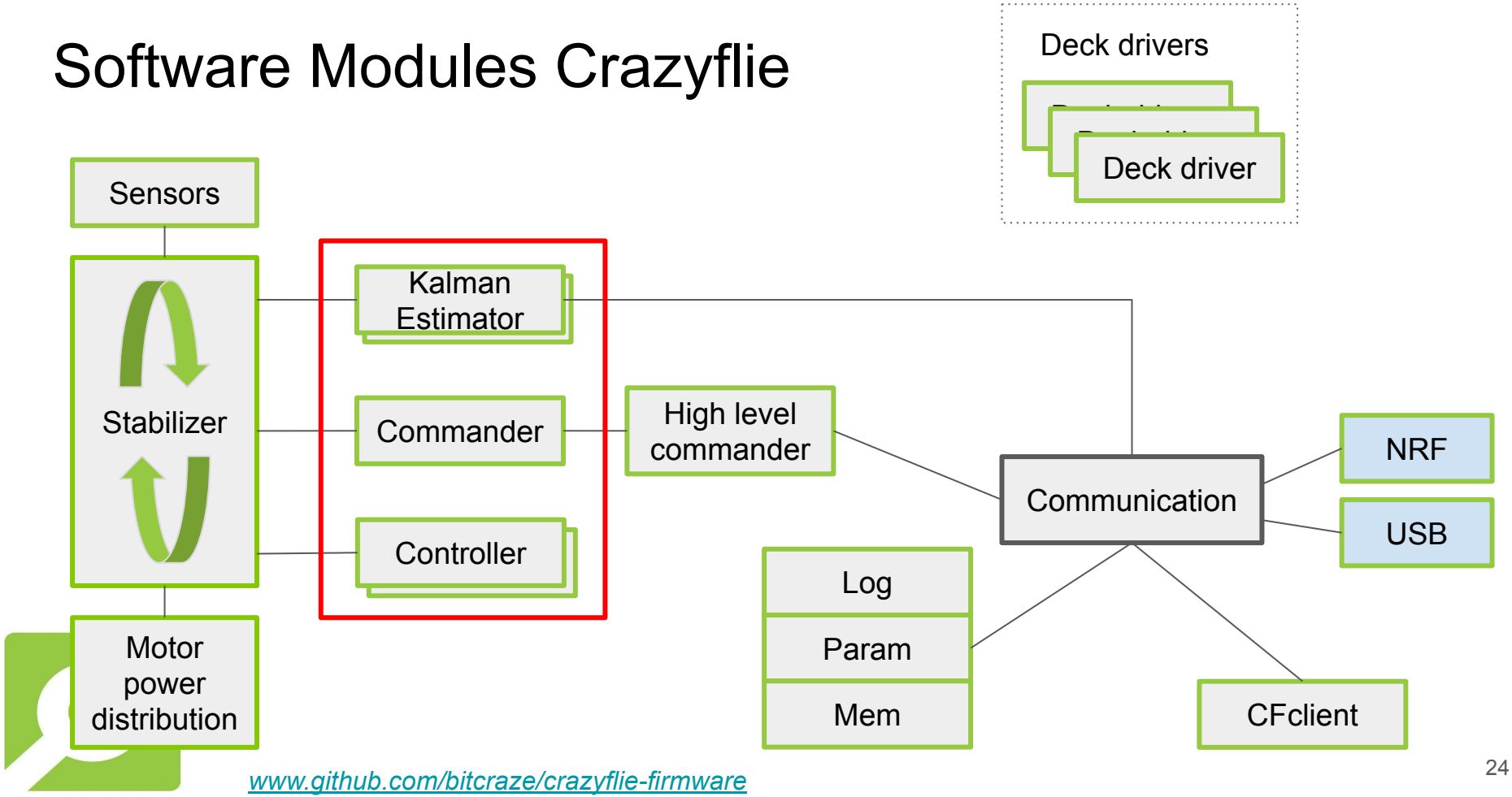


Minimal navigation solution for a swarm of tiny flying robots to explore an unknown environment (Science Robotics) K.N. McGuire, C. De Wagter, K. Tuyls, H. Kappen,

What do you need to fly?

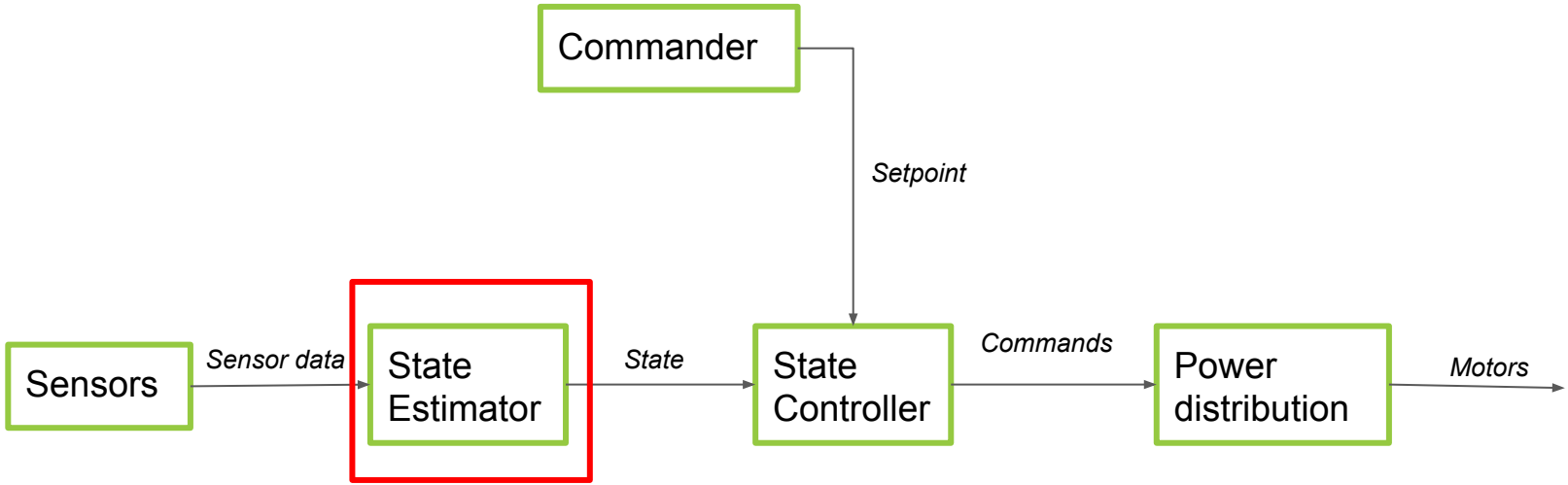
- Hardware (last hour)
- Software (firmware)

Software Modules Crazyflie



www.github.com/bitcraze/crazyflie-firmware

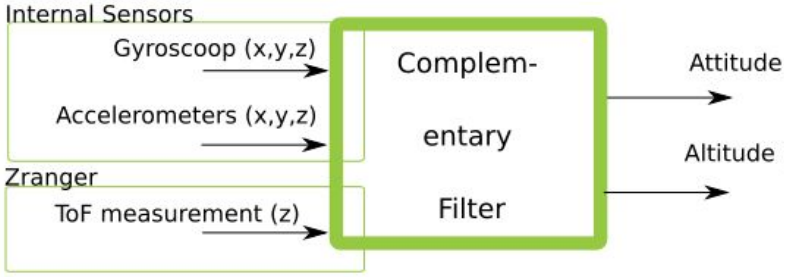
Flow from sensors to motors

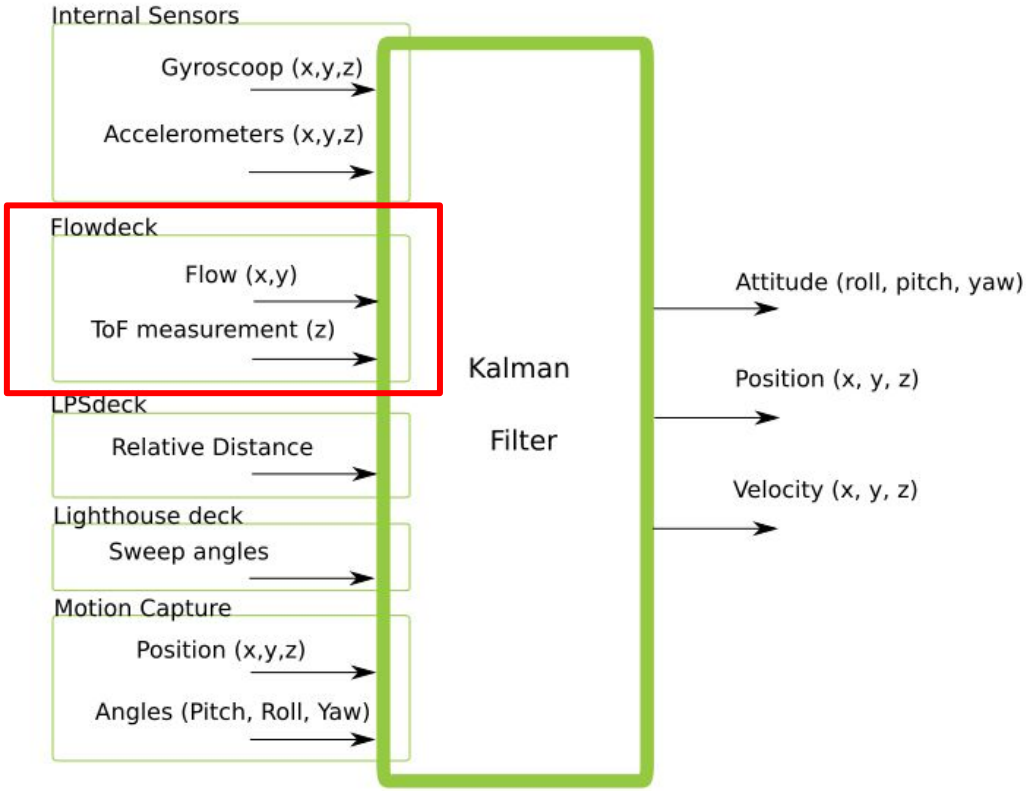


crazyflie-firmware/src/modules/src/stabilizer.c

State estimation

- Complementary Filter
- Extended Kalman Filter





Extended Kalman Filter

- Originally implemented by ETH Zurich*
- Quadrotor Motion Model*
- Measurement Models**
  - UWB lps system
  - Lighthouse system
  - Flowdeck

*Mueller, Mark W., Michael Hamer, and Raffaello D'Andrea. "Fusing ultra-wideband range measurements with accelerometers and rate gyroscopes for quadrocopter state estimation." *2015 IEEE International Conference on Robotics and Automation (ICRA)*. IEEE, 2015.

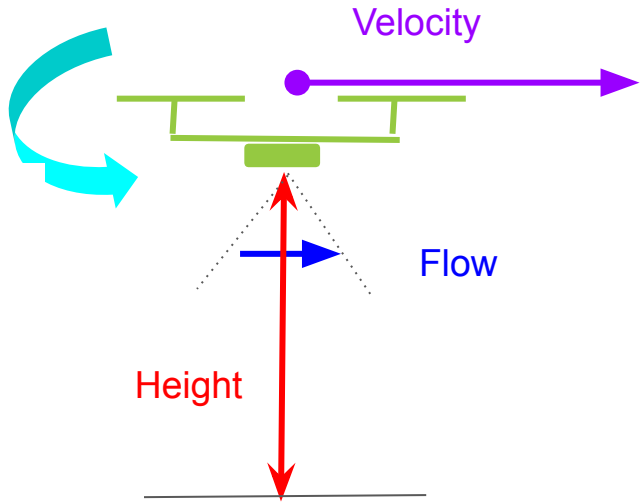
*Mueller, Mark W., Markus Hehn, and Raffaello D'Andrea. "Covariance correction step for kalman filtering with an attitude." *Journal of Guidance, Control, and Dynamics* 40.9 (2016): 2301-2306.

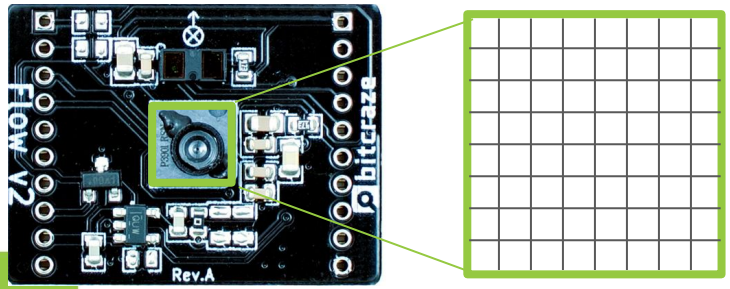
***crazyflie-firmware/src/modules/src/estimator/estimator_kalman, .../kalman_core.c*

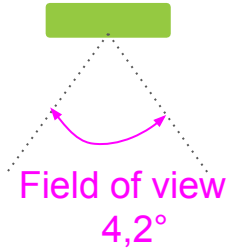
Velocity calculation Flowdeck

$$\dot{x} = \frac{h \cdot \theta_{px} \cdot \Delta n_x}{\Delta t \cdot N_x}$$

Sample time







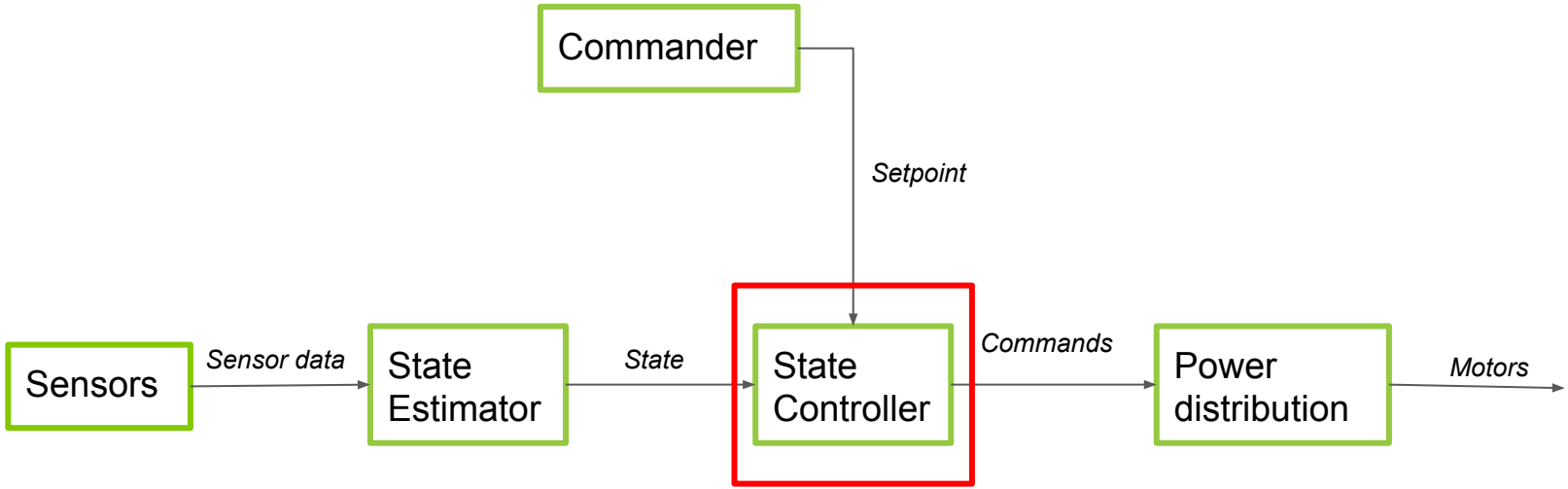
Modelling and Control of the Crazyflie Quadrotor for Aggressive and Autonomous Flight by Optical Flow Driven State Estimation, M. Greiff, Master's thesis, Lund University, 2017

HANDS-ON

- Make state estimation logging group
- Show position estimates

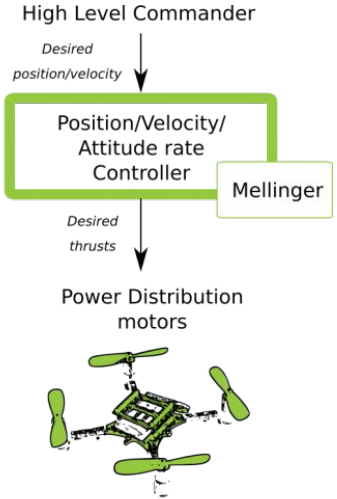
https://github.com/bitcraze/crazyflie-clients-python

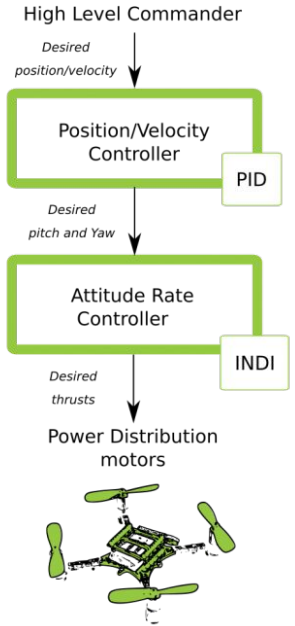
Flow from sensors to motors

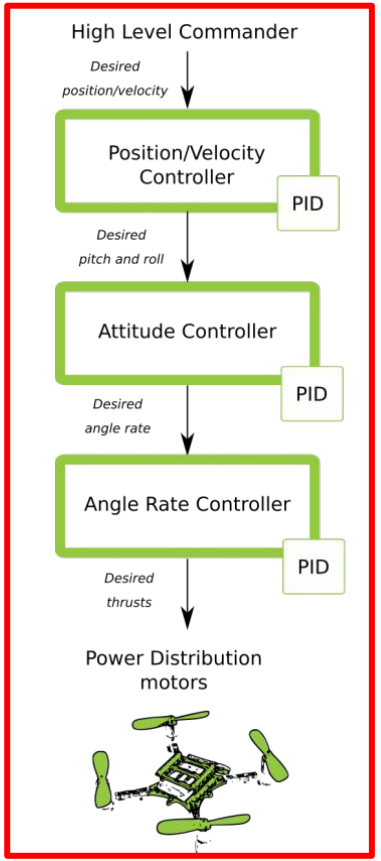


Controllers

- Levels of control
  - Position/velocity
  - Attitude
  - Attitude rate
- Types
  - PID
  - Incremental nonlinear dynamic inversion (INDI) *
  - Mellinger **



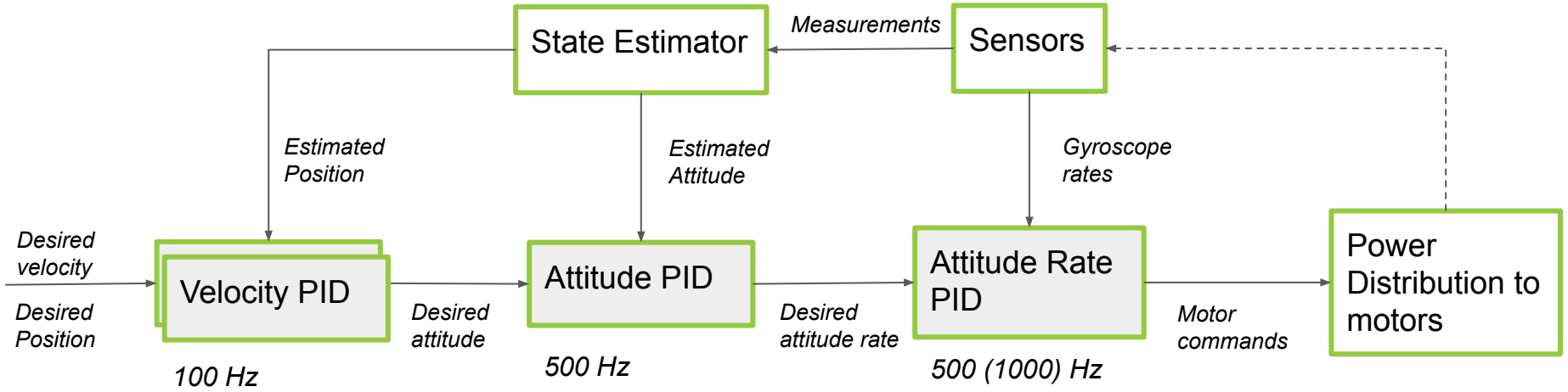




* E. de Smeur et al. "Adaptive incremental nonlinear dynamic inversion for attitude control of micro air vehicles." *Journal of Guidance, Control, and Dynamics* 38.12 (2016): 450-461.
** Implemented by: E.Smeur and A.L.O. Paraense: crazyflie-firmware/src/modules/src/controller_indi.c (2019)*

** Daniel Mellinger, Vijay Kumar:Minimum snap trajectory generation and control for quadrotors. IEEE International Conference on Robotics and Automation (ICRA), 2011.
*** Implemented W. Hönig & J. A. Preiss: crazyflie-firmware/src/modules/src/controller_mellinger.c*

Cascaded PID control



crazyflie-firmware/src/modules/src/controller_pid.c
crazyflie-firmware/src/modules/src/attitude_pid_controller.c
crazyflie-firmware/src/modules/src/position_controller_pid.c

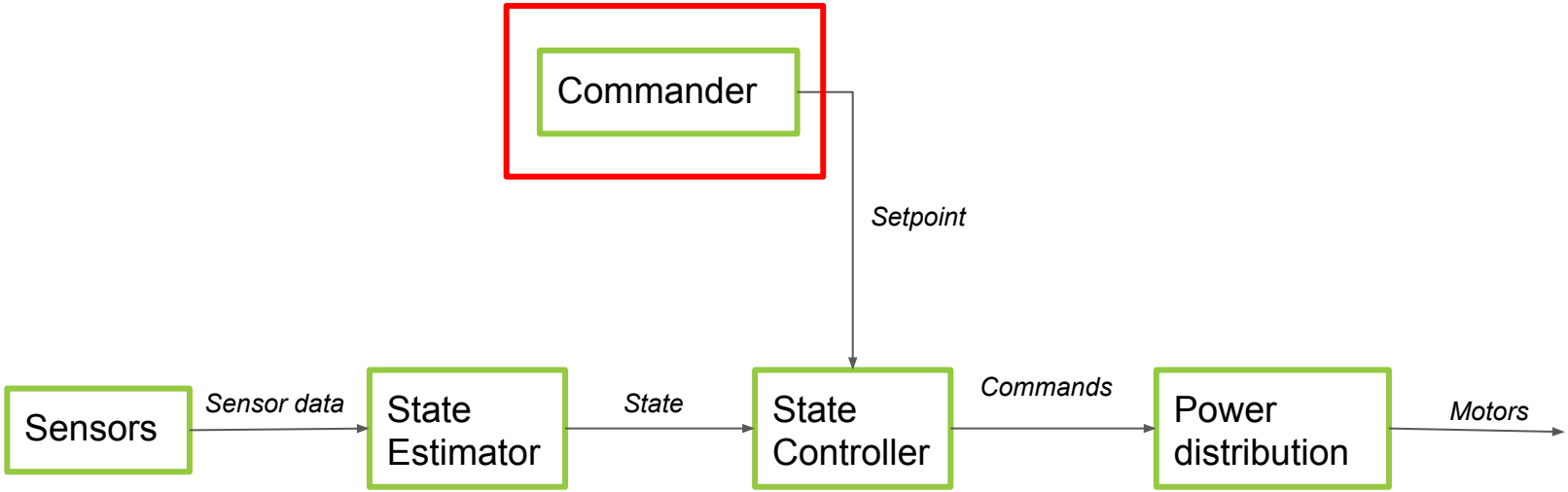
HANDS-ON

Let the crazyflie fly in the air for the real

Tune the gains of the controller

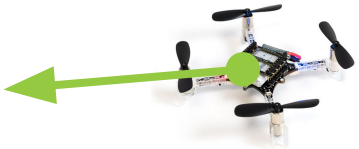
Github: crazyflie-lib-python/examples/tuning/PID_controller_tuner.py

Flow from sensors to motors

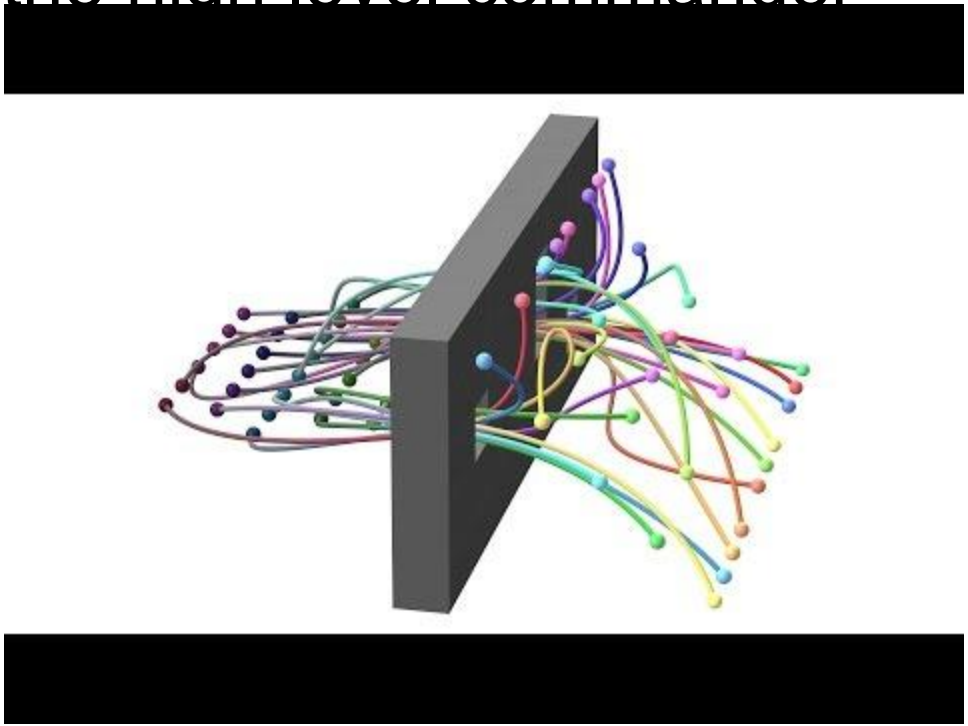


Commanders

- Attitude commander
- Position/velocity commander
- High Level commander



Example of the high level commander



Preiss, James A., et al. "Downwash-aware trajectory planning for large quadrotor teams." *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE, 2017.

HANDS-ON

- Go through an example python script
- Show a flight with the flowdeck (and multiranger)

Github: crazyflie-lib-python/examples/multiranger_push.py

Contact

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