PX4 FLIGHT CORE

http://px4.io
.pixhawk STUDENT PROJECT

- Student team 2009, research since 2011
- EMAV 2009 Competition: 1st
- IMAV 2010 Competition: 2nd
Computer Vision and Geometry Lab

- Institute for Visual Computing, Computer Vision and Geometry Group (Prof. Marc Pollefeys)
- PIXHAWK (2008-) and sFLY (2008-2011) projects
- Using Asctec and PX4 hardware
SWISS LOVE DRONES
DOSSIER: DAS GRÖSSTE SOZIALE NETZWERK

«Die Schweiz ist das Silicon Valley der Robotik»

Von Alain Zucker. Aktualisiert am 04.04.2013
Internetguru Chris Anderson prophezeite eine neue industrielle Revolution. Diesmal will er als Unternehmer selbst dabei sein.
PERSONAL TIMELINE

LINUX IN 2008
AUTONOMY TAXONOMY

• ALFUS Autonomy levels definition:
  – LEVEL 5: Autonomous (providing a description)
  – LEVEL 4: Human Aided (providing a goal)
  – LEVEL 3: Human Directed (waypoints)
  – LEVEL 2: Tele-operation (tablet control)
  – LEVEL 1: Remote Control (model airplane)
AUTONOMOUS EXPLORATION

IROS 2012, Friedrich Fraundorfer, Lionel Heng, Dominik Honegger, Gim Hee Lee, Lorenz Meier, Petri Tanskanen, and Marc Pollefeys
NEW FRONTIERS FOR LINUX

• Obstacle detection and avoidance
  – Lidar
  – IR / Thermal

• GPS denied navigation
  – Optical flow
  – Visual inertial odometry

• Airframes beyond quadrotors
  – VTOL
  – Others
NEW FULL 3D ROS SIMULATION
VTOL CONTROL

http://px4.io
HARDWARE AND SOFTWARE

Autopilot Hardware

http://pixhawk.org

http://px4.io

Autopilot Platform
IMPACT

• Widely used in academia (ETH, CMU, UZH, DLR, MIT, …)
• Platform for third-party autopilots (e.g. APM)
• Widely adopted hardware
  – 3D Robotics (hardware development partner)
  – 3rd party producers of Pixhawk
  – 3rd party derived designs (Gumstix AeroCore)
OPEN HARDWARE WORKFLOW

Developers → designs

Unproven designs → prototypes

Proven and tested designs → Community

Review, consolidation, coordination
OPEN SOURCE COLLABORATION

• APM Dev team on middleware

• OSRF / ETH Zurich on ROS Simulator

• Paul Riseborough on EKF Fusion framework

• Pavel Kirienko on UAVCAN
AUTOPilot – PIXHAWK

• Flight Management Unit – Autopilot + Mission Manager
• 168 MHz Cortex M4F (FPU, 192 KB RAM, 1 MB flash)
• 10 DOF sensors
• Lots of connectivity (including CAN)
OPTICAL FLOW MODULE

400 Hz optical flow, 3 m/s/m velocity (ICRA 2013 paper)
CAN ECOSYSTEM — PIXHAWK ESC

• Current embedded buses (PWM, I2C) are limited:
  – Signal integrity (not differential)
  – Bandwidth
  – Feedback

• Pixhawk ESC design based on CAN, open hardware
PX4 SOFTWARE DESIGN

- Reusing existing standards
- MAVLink
- UAVCAN comms
- POSIX-style threading
- POSIX-style C and driver API
- Publish / subscribe design
- BSD
PX4 SOFTWARE ARCHITECTURE

- Layer model
- Multiple applications per layer
- pub() / sub() application interface
- Generalized I/O interface (supports e.g. CAN or PWM)
Safety Requirements

- Prevent midair collisions (separation, transponder)
- Prevent injuries on ground (parachute)
- Limit the scope of certification (safety module)

Safety Block reuse

- Pixhawk offers dedicated safety processor
- Certifying this part would make any system comply
LIGHTWEIGHT ORB — PUBLISHING

• Flat address space in NuttX
• uORB, lightweight object request broker

• publish:
  
  topic_handle = orb_advertise(ORB_ID(random_integer), &rd);

• subscribe:

  topic_handle = orb_subscribe(ORB_ID(random_integer));
SHELL AND SYSTEM STARTUP

• Shell via UART / USB
• Runtime configurable
• Bash-like startup scripts
• Automatic detection of peripherals and sensors ("plug and play")
• Supports custom configurations

#!/nsh
# mount microSD
Mount /dev/mmc(sd0) /fs/microsd
# start uORB
uorb start
PX4 PLATFORM PORTABILITY

- PX4 Flight Core Apps
- PX4 Middleware
- NuttX Device
- Linux ROS
- Linux Threads
- Pixhawk + Companion Computer
- System on Chip (CPU + DSP)
COMMUNICATION — MAVLINK

• Low-bandwidth protocol
  – 8 bytes overhead, up to 255 systems
  – One to one and swarm support

• Widespread use in low-cost UAVs
  – PX4
  – ArduPilotMega
  – UAVDevBoard
  – Paparazzi Port
COMPANION COMPUTER

- Pixhawk project runs distributed estimation & control on Linux and autopilot since 2009
- Higher level flight control on companion computer
- Lower level flight control on autopilot

http://wiki.ros.org/mavros
ARCHITECTURE FLEXIBILITY

DEEPLY EMBEDDED CONTROLLER
- Actuator & Sensor Interface
- Geofence & Safety Controller
- uORB pub/sub bus
- Trajectory Control
- Attitude Control

> 250 Hz
< 1 ms latency

LINUX COMPANION COMPUTER
- SLAM
- Obstacle Avoidance
- ROS pub/sub bus
- Attitude Control
- Trajectory Control

swappable execution location

Dronecode
CUV
ETH Zürich
CONTINUOUS INTEGRATION

• Unit testing on Travis

• Hardware testing in Hans

• Software-in-the-Loop testing in Jenkins
EXCURSION: QGROUNDCONTROL 2.3
Setup Experience
RC CONFIGURATION

![FLIGHT MODES CONFIG](image)

**Flight Modes Config**

Flight Mode switches can be assigned to any channel that is not currently being used for attitude control. All channels are displayed below. You can drag Flight Modes from the Flight Modes section below to a channel and drop it there. You can also drag switches assigned to a channel to another channel or back to the Unassigned Switches section. The Switch Display section at the very bottom will show you the results of your Flight Mode setup.

### Channel Assignments

- **Channel 1**: Unavailable
- **Channel 2**: Unavailable
- **Channel 3**: Unavailable
- **Channel 4**: Unavailable
- **Channel 5**: Unavailable

- **Channel 6**: Available
- **Channel 7**: Available
- **Channel 8**: Available

### Flight Modes

- **Main Mode**
  - Return
  - Hover
  - PosCtl

- **Allow setup to generate the thresholds for the flight mode positions within a switch (recommended)**

- **Switch Display**
  - Show live RC display

- **Mode Switch**
  - Auto
  - Assist
  - Manual
SENSOR CONFIGURATION
RTL CONFIGURATION

SAFETY CONFIG

Triggers For Return Home

- RC Transmitter Signal Loss
  - Return Home after 0.5 seconds
- Telemetry Signal Timeout
  - Return Home after 10 seconds

Return Home Settings

- Climb to altitude of 60 meters
- Loiter at Home altitude for 11 seconds

Home loiter altitude 30 meters
• Documentation
• Link Security / Safety Standard
• Convergence on simulation environment
• Convergence on post-flight data processing
THANKS!

http://px4.io