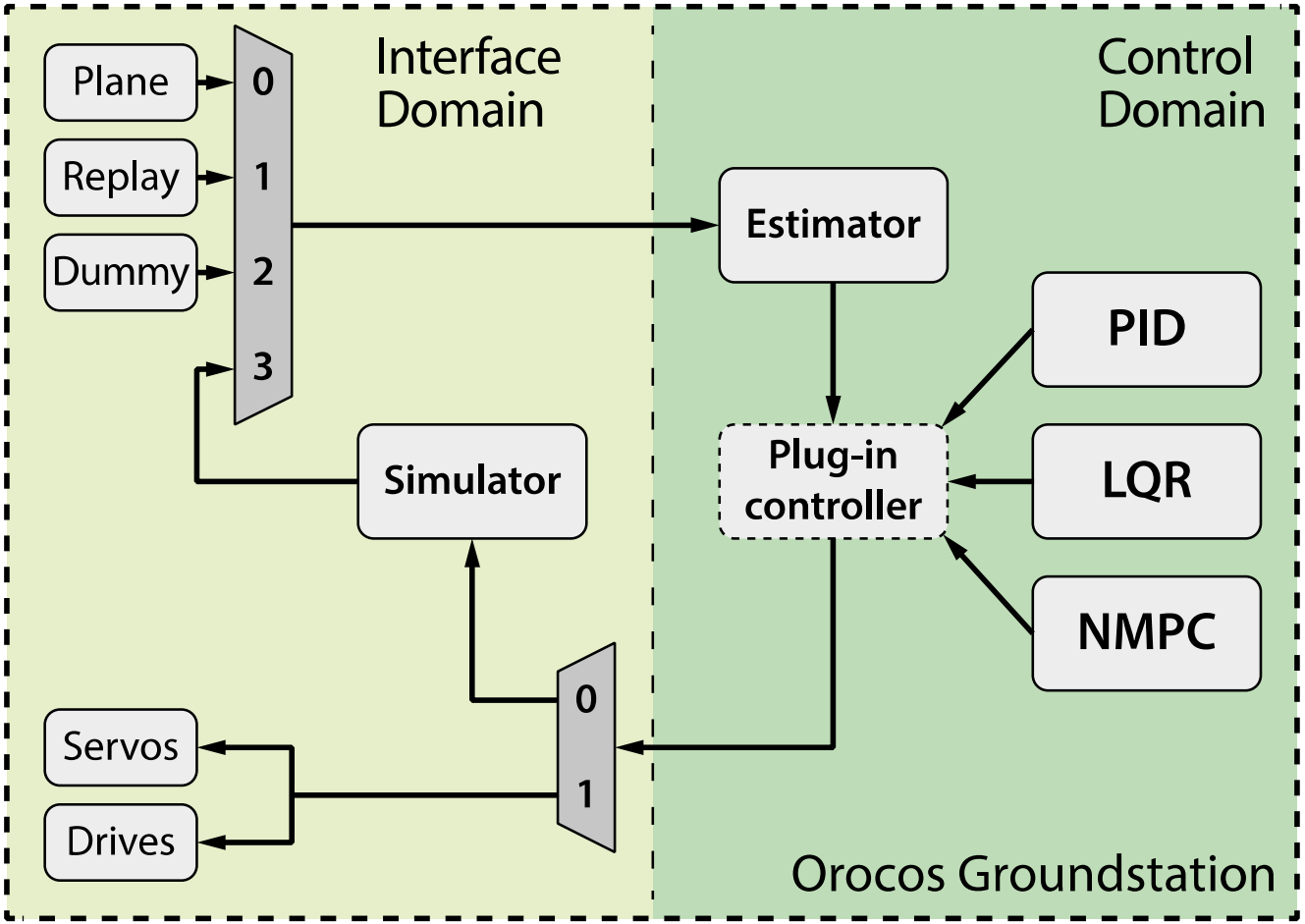
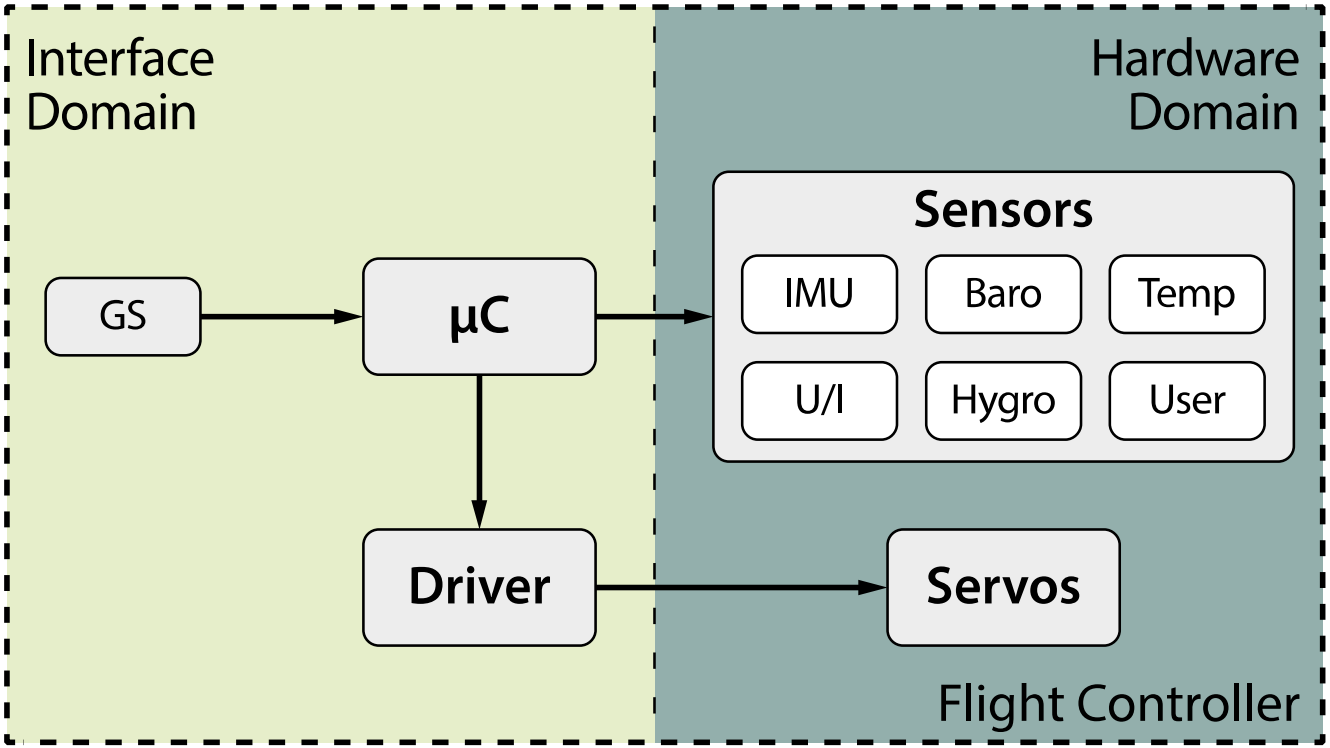
Data synchronization and time-keeping

Thorbjörn Jörger
Lehrstuhl für Systemtheorie
Institut für Mikrosystemtechnik - IMTEK
Albert-Ludwigs-Universität Freiburg

Groundstation

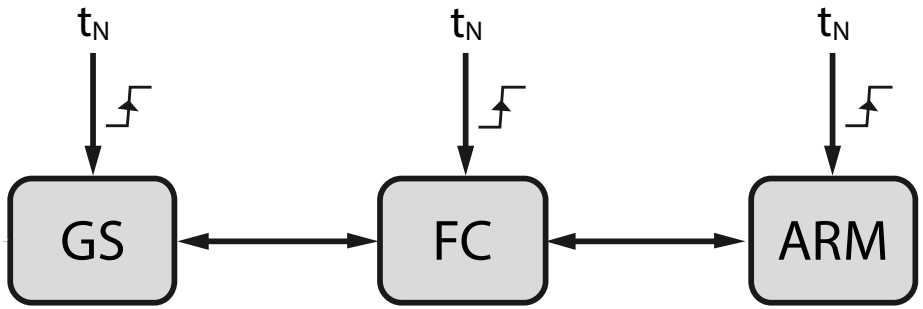


Flight Controller



Clock synchronization

- Reference pulse which occurs simultaneous in all systems
- 1PPS signal of GPS is the natural choice for outdoor experiments
  - ⊕ no information exchange between systems necessary
  - ⊕ Absolute and jump-free GPS time reference is also available
  - ⊕ Small jitter (15-50 ns) with cheap equipment, < 1 ns with better equipment
  - ⊖ Indoor Environment usually has to low signal strength



t_N is a synchronous timing pulse

Time keeping

- Each measurement gets a timestamp in a unified time frame
- Need for synchronous clocks

Flight Controller:

- Self designed timing framework
- 1PPS pulse for synchronization
- Intervals between pulses measured with precise quartz oscillator
- Absolute deviation below 10 µs

Time keeping

- Each measurement gets a timestamp in a unified time frame
- Need for synchronous clocks

Groundstation:

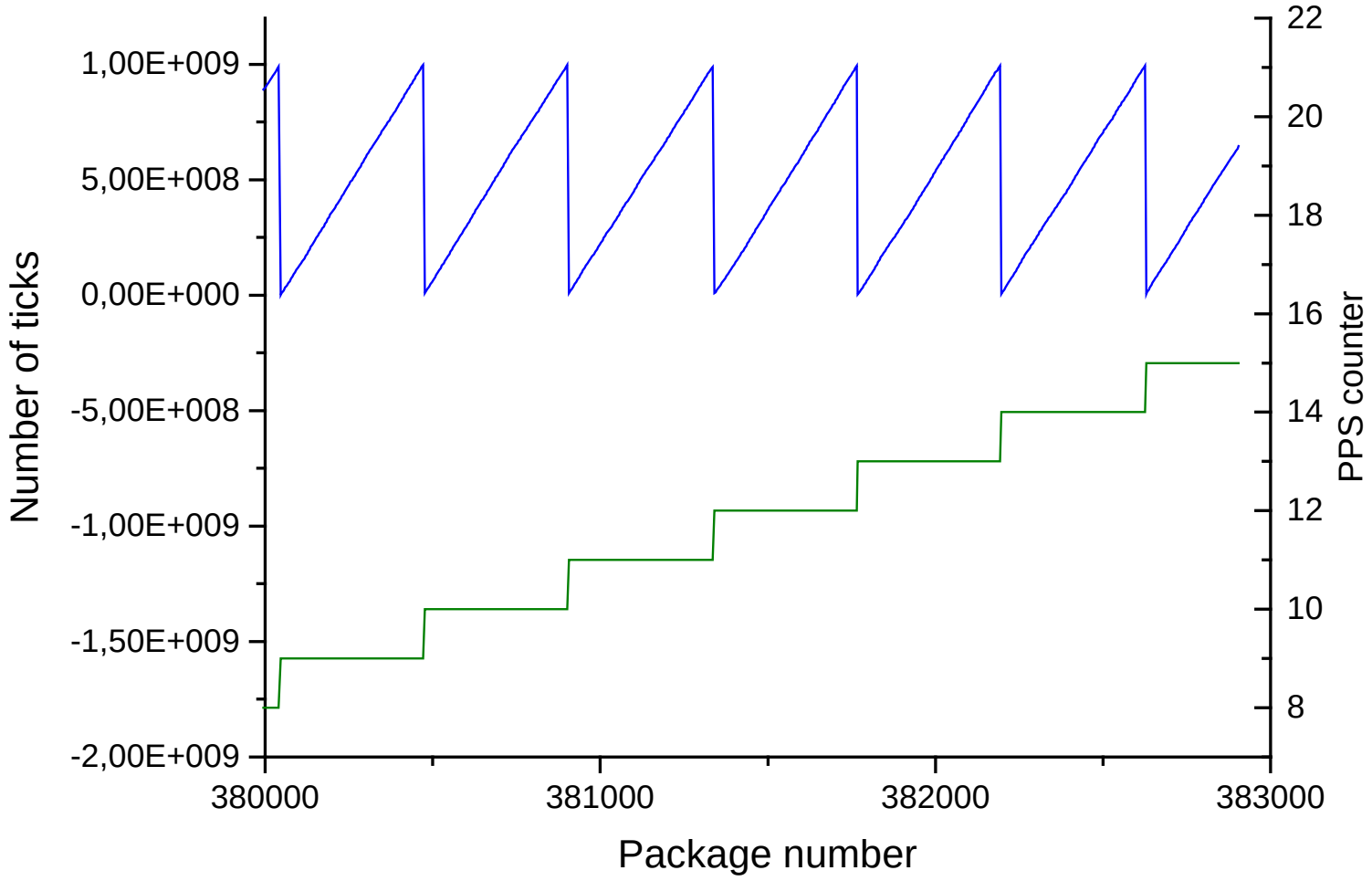
- Synchronized with UTC via GPS
- Less than 1 µs deviation from true time
- Essentially a Stratum 1 time server
- Automatic synchronization on startup < 2 min
- GS references ticks and PPS pulses to UTC
- Keeps track of all quartz oscillators in the system

Time keeping

GPS devices – Furuno GT-87 / GF-8701:

- Lock on GPS, GLONASS, Galileo, QZSS, SBAS
- Precise PPS generation < 15 ns
- For PPS generation, only one satellite necessary
- Sensitive enough for indoor operation (-161 dBm)
- After startup and lock-on, separate devices generate PPS pulses with less than 100 ns difference
  - Deviation gets smaller over time, as clock disciplination progresses
  - When lock is lost, drifts with 1µs/100s (hold-over)

Result: Nicely timed measurements



Synchronous control system

- Measurements taken at a fixed frequency
- All clocks in the system need to be synchronous

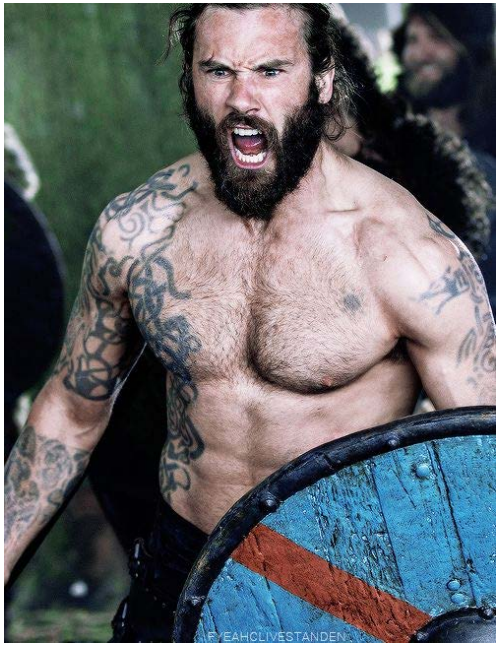
Synchronization method:

- Measurements need to be triggered externally
  - Not all sensors support this
  - Difficult to implement and maintain
  - Manual calibration

    Change one thing

    Repeat previous step

Thor likes his hammer, so let’s look for an easy and “swift”, but effective solution



Methods of “Forced Synchronization”

Resampling method: Just ignore the problem

- Simply take the latest available value
  - Easiness: ⊕⊕
  - Brutality: ⊕⊕
  - Effectiveness: ? (Should work well, if the signal is slowly changing)
  - Introduces discretization noise and potential systematic errors

Resampling method: Ignore the problem a little less

- Same as above, but increase the sampling rate
  - Easiness: ⊕
  - Brutality: ⊕
  - Effectiveness: ? (Linearly reduces the time since last measurement)
  - That is what we do/did but lets try a more subtle approach

Methods of “Forced Synchronization”

Resampling method: Linear approximation

- Take the last two values and approximate the current value
  - Easiness: ⊕⊕
  - Effectiveness: ? (Should work well, if the signal is slowly changing)

Methods of “Forced Synchronization”

Resampling method: Moving average aka. FIR filter

- The N last samples are averaged with a windowing function
- Higher sampling rates are beneficial
- Necessary for fulfilling Nyquist criterion and to prevent aliasing
- Reduces Gaussian noise
- Introduces delay
- Discontinuity of rectangular windowing function introduces side-lobes to the signal spectrum
  - Rectangular window not optimal

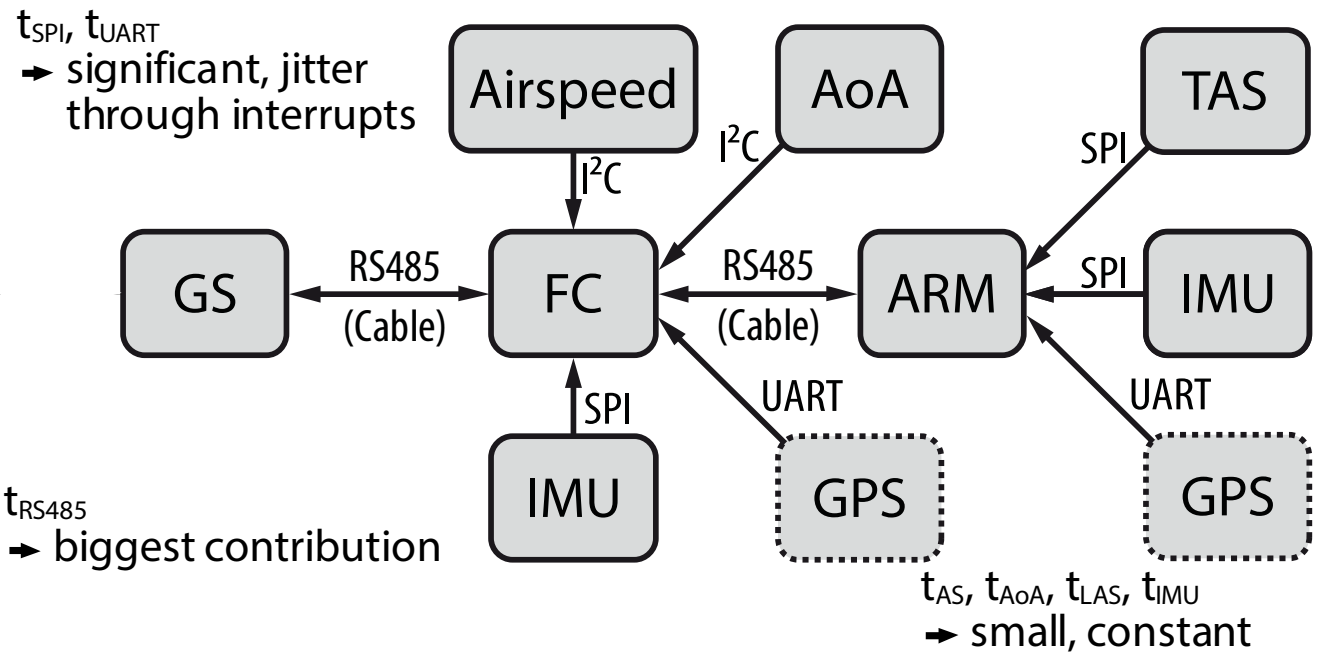
Methods of “Forced Synchronization”

Resampling method: FIR filter with Hamming window

- Much better suppression of side-lobes
- Higher computational cost
- Possible overkill

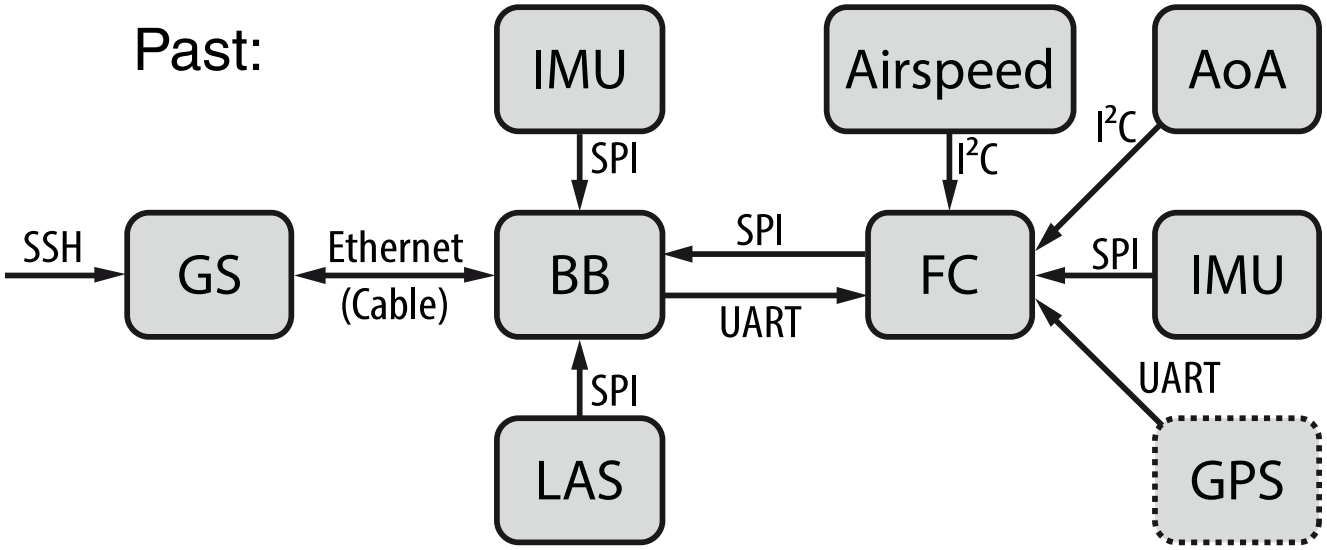
Discussion

Delay overview



Sensor fusion

- It is desirable to have all sensors fused at one point
  - Time keeping and synchronisation much easier
  - Easier to maintain
- Fast and low jitter connection to controller
  - More time for NMPC calculations in each time step



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