Maintaining vertical gardens using quadrotor aerial inspection

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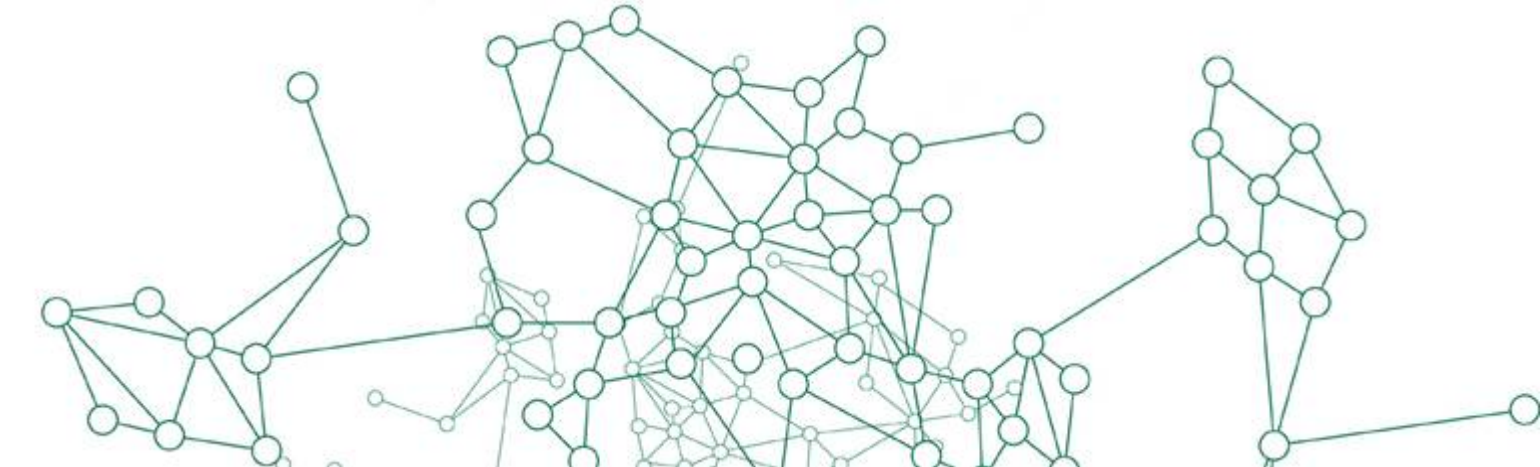
Prof. Dr. Sc. Alexey Bulgakov

http://www.humboldt-foundation.de



Vertical Gardens concept

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- Big cities, limited green surfaces
- Ergonomic design
- Difficult to maintain, specialization required

Conventional ways limitations

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- Vertical planting layout
- High-rise structures
- High risk involved
- Insecticide

Why quadrotor?

- Cheap, maintenance-friendly
- Practically no flight setup required
- Ability to transport loads
- Can be equipped with sensors
- High maneuverability
- Ability to reach difficult corners

Why automating maintenance process?

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- Resource efficiency
- Avoid risks/ severe injuries
- Multitasking

Experimental Setup

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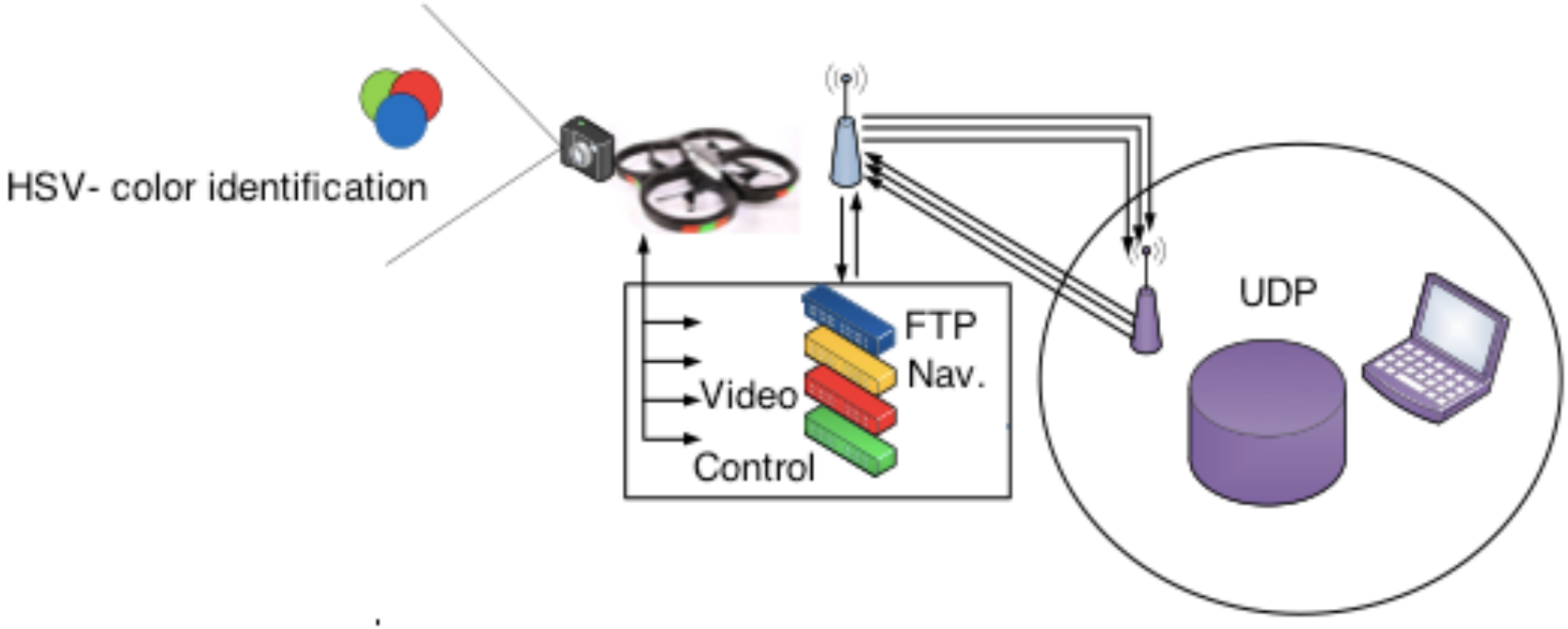

Quadrotor dynamics

$$[1]\ \ddot{X} = (sin\psi sin\varphi + cos\psi sin\theta cos\varphi)\frac{U_1}{m};$$

$$[2]\ \ddot{Y} = (-cos\psi sin\varphi + sin\psi sin\theta cos\varphi)\frac{U_1}{m};$$

$$[3]\ \ddot{Z} = -g + (cos\theta cos\varphi)\frac{U_1}{m};$$

$$[4]\ \dot{p} = \frac{I_{YY}-I_{ZZ}}{I_{XX}}qr - \frac{J_{TP}}{I_{XX}}q\Omega + \frac{U_2}{I_{XX}};$$

$$[5]\ \dot{q} = \frac{I_{ZZ}-I_{XX}}{I_{YY}}pr - \frac{J_{TP}}{I_{XX}}p\Omega + \frac{U_3}{I_{YY}};$$

$$[6]\ \dot{r} = \frac{I_{XX}-I_{YY}}{I_{ZZ}}pq + \frac{U_4}{I_{ZZ}}.$$

Coordinates Transformation

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$$[7]\ d(x) = H_h = H * \tan(\varphi + \alpha);$$

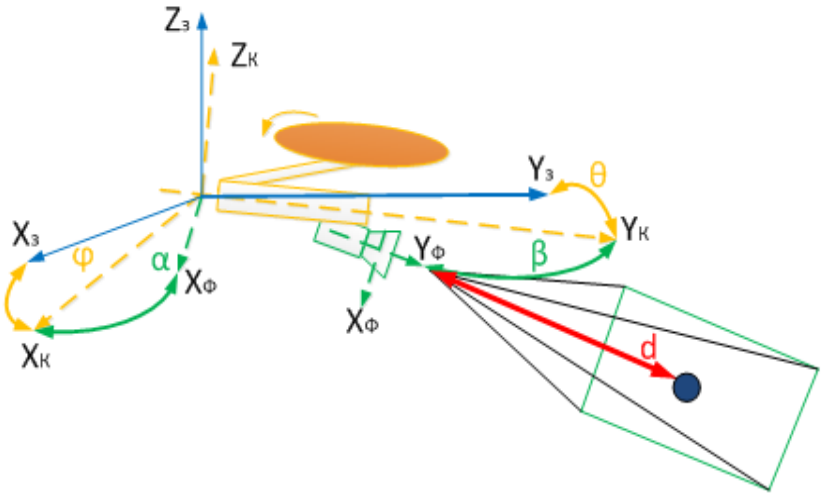
$$[8]\ d(y) = H_v = H * \tan(\theta + \beta);$$

$$[9]\ X_{\text{П}} = \frac{x}{\Pi x} \cdot \cos\left(\arctan\left(\frac{H_v}{H_h}\right)\right);$$

$$[10]\ Y_{\text{П}} = \frac{y}{\Pi y} \cdot \sin\left(\arctan\left(\frac{H_v}{H_h}\right)\right);$$

$$[11]\ \rho_x = \sqrt{X_{\text{П}}{}^2 + Y_{\text{П}}{}^2} \cdot cos\left(\arctan\left(\frac{H_v}{H_h}\right)\right);$$

$$[12]\ \rho_y = \sqrt{X_n{}^2 + Y_n{}^2} \cdot sin\left(\arctan\left(\frac{H_v}{H_h}\right)\right),$$



Fuzzy Logic Controller

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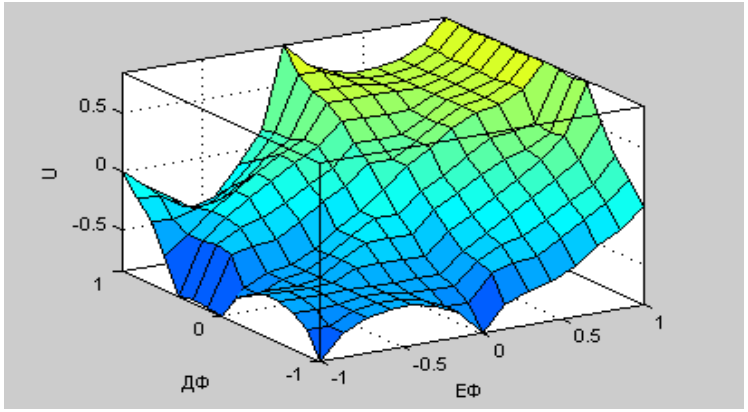

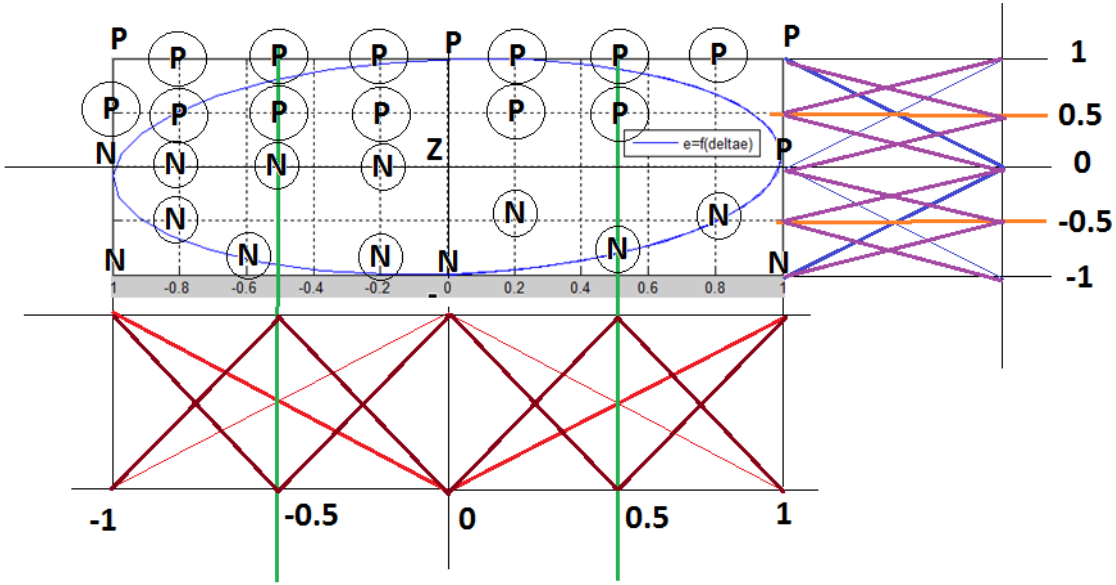

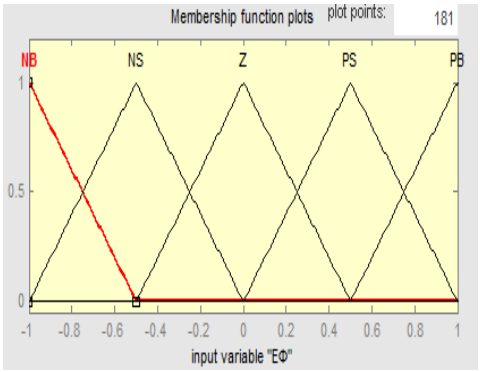

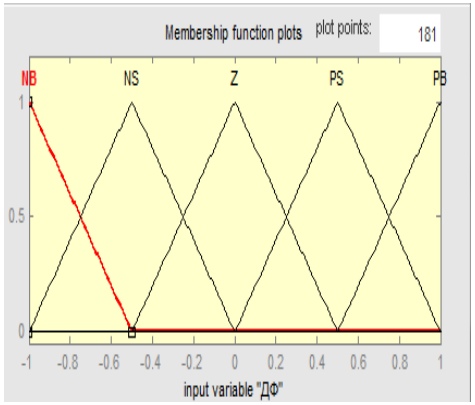

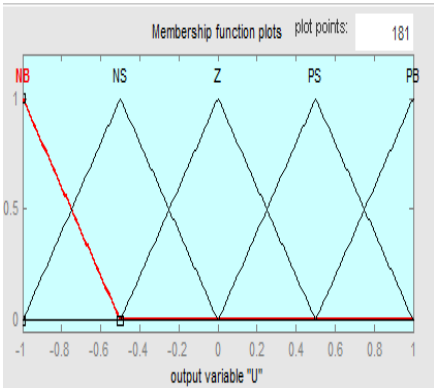

Simulation Results

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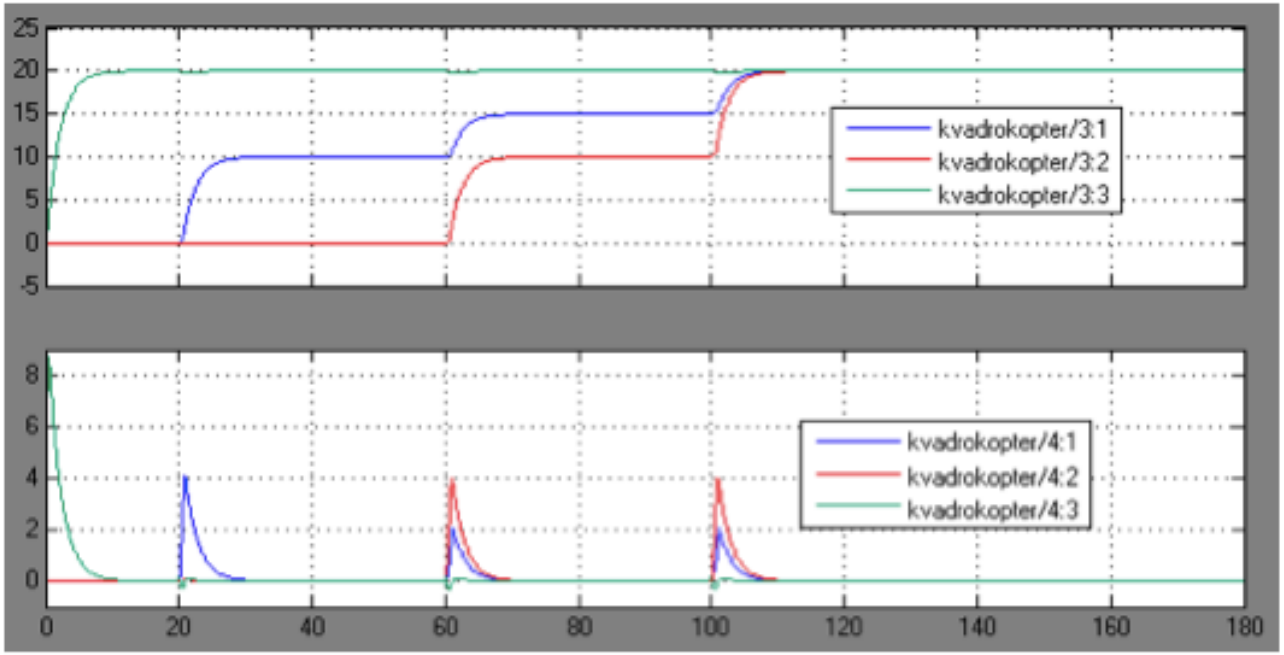

Quadrotor position control with reference to GPS waypoints.
Horizontal axis – time [s], vertical axis- position [m]

Altitude effects on flight stability

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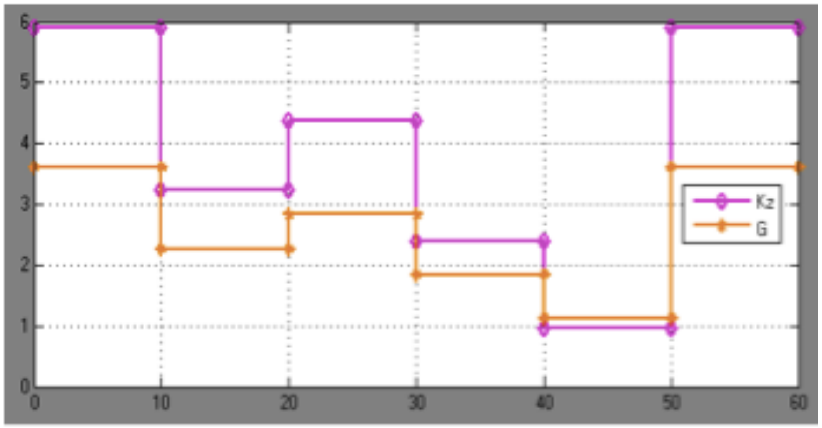
F- the load of the wind on the quadrotor
S- the exposed area
P- the wind pressure
C is the drag coefficient
Kz - the exposure coefficient
G - the gust factor
H- flight altitude

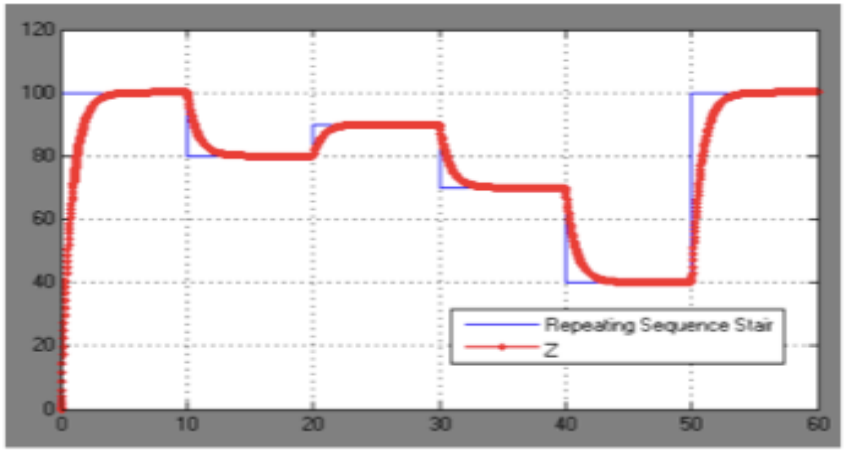
$$F = S * P * C * K_z * G$$

$$K_z = (H/33)^{2/7}$$

$$G = 0.65 + \frac{0.6}{(H/33)^{1/7}}$$



Simulation of K_z and G with attitude Variation.
Horizontal axis- altitude [m], vertical axis- K_z and G.



Altitude simulation results of high-rise inspection task.
Horizontal axis- time [s], vertical axis- altitude [m].

Visual Odometry real-time results

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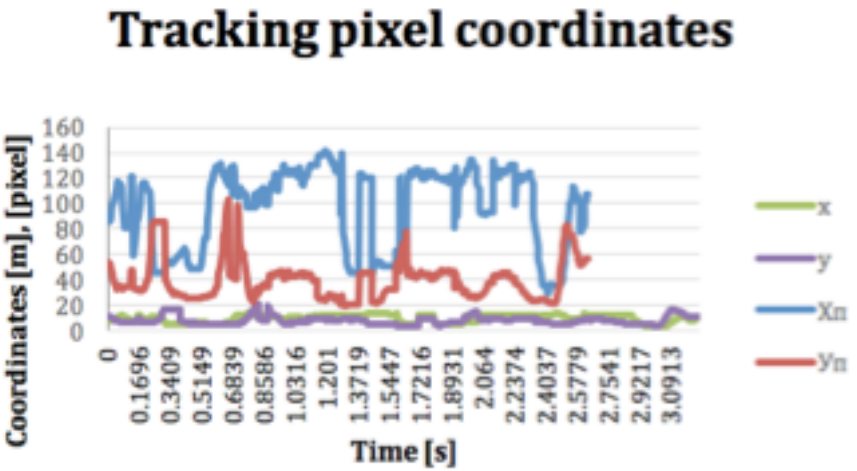


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11 Color Middle Middle (69, 72)
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Visual odometry Trajectory tracking

Possible applications

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- Visual odometry + proximity sensor = 3D maintenance
- Single or swarm robotics
- Vertical/ horizontal plantation zones, roof plantation
- Visual Odometry + infrared thermal image acquisition = Moisture detection (rice, tea plantation)

Thank you very much for your attention!