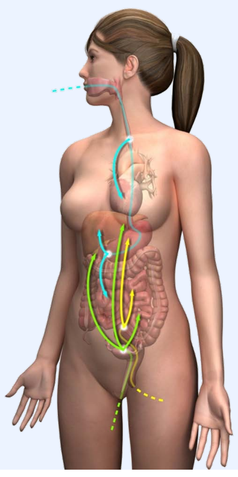
Endoscopic Orientation Correction

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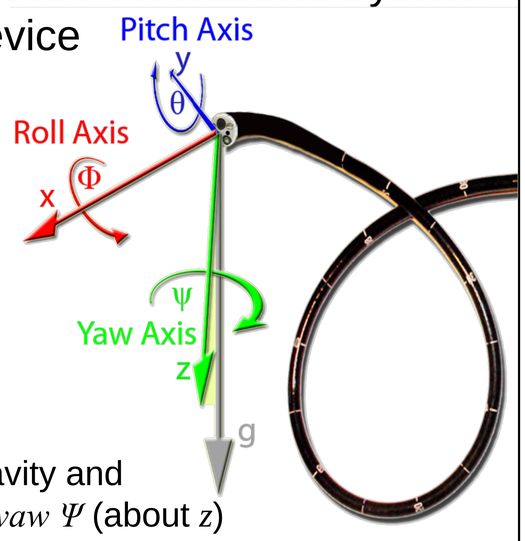
Introduction



- A still unsolved problem with flexible endoscopy in Natural Orifice Translumenal Endoscopic Surgery (NOTES) is the missing information about the image orientation [1].
- Tip retro-flexion of non-rigid endoscope causes image rotation angles up to *±180 degree* [2].

Idea

- Simple idea: Integrate a Micro Electro-Mechanical System (MEMS) based inertial sensor device in the endoscope's tip [3].
- Measures influencing forces in three orthogonal directions.
- If not moving, only acceleration of gravity has an effect on the three axes.



With: $F_{x,y,z}$: measured acceleration, g: gravity and *roll* Φ (around x), *pitch* Θ (around y) and *yaw* Ψ (about z)

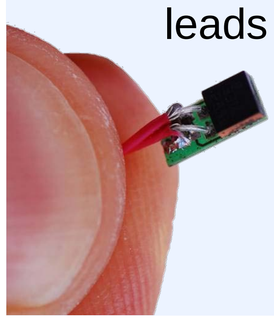
Method

- How to chose IMU (Inertial Measurement Unit) rotation parameters to get back to a spatial orientation with $z \| g$?

$$\begin{pmatrix} F_x \\ F_y \\ F_z \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos(\Phi) & \sin(\Phi) \\ 0 & -\sin(\Phi) & \cos(\Phi) \end{pmatrix} \cdot \begin{pmatrix} \cos(\Theta) & 0 & -\sin(\Theta) \\ 0 & 1 & 0 \\ \sin(\Theta) & 0 & \cos(\Theta) \end{pmatrix}$$

$$\begin{pmatrix} \cos(\Psi) & \sin(\Psi) & 0 \\ -\sin(\Psi) & \cos(\Psi) & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 0 \\ 0 \\ g \end{pmatrix} = \begin{pmatrix} -\sin(\Theta)g \\ \sin(\Phi)\cos(\Theta)g \\ \cos(\Phi)\cos(\Theta)g \end{pmatrix} \qquad (1)$$

- To handle ambiguity for $\pm\pi$ the two-argument function atan2 leads to *roll* Φ for $F_x \neq \pm g$ and *pitch* Θ for all values:



$$\frac{F_y}{F_z} = \frac{\sin(\Phi)\cos(\Theta)}{\cos(\Phi)\cos(\Theta)} \Rightarrow \Phi = \arctan 2(F_y, F_z) \qquad (2)$$

$$F_x = -\sin(\Theta) \cdot g \quad \Rightarrow \quad \Theta = \arcsin\left(\frac{-F_x}{g}\right) \qquad (3)$$

Filtering

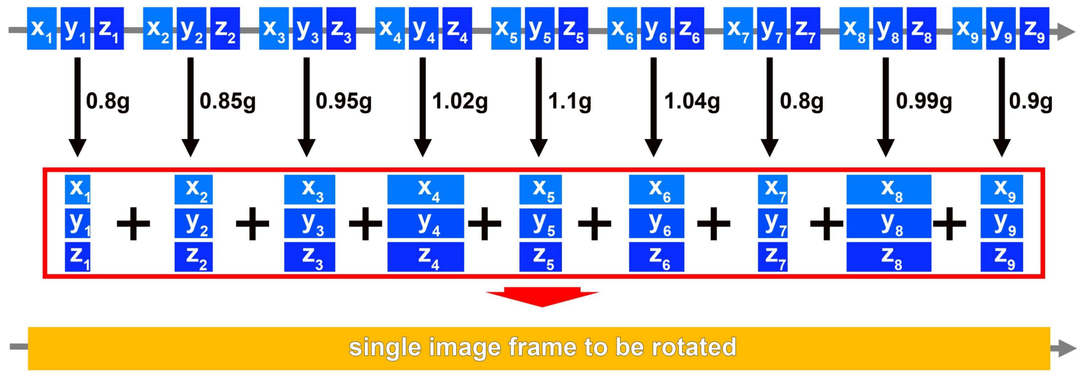
- Filtering is done with a new intelligent weighted sum approach:

$$\begin{pmatrix} F_x \\ F_y \\ F_z \end{pmatrix} = \sum_{i=1}^{n} \left(\begin{pmatrix} F_{x_i} \\ F_{y_i} \\ F_{z_i} \end{pmatrix} \cdot w_i \right) \cdot \left(\sum_{i=1}^{n} (w_i) \right)^{-1} \qquad (3)$$

$$w_i = \frac{1}{\frac{1}{w_0} + \left| \sqrt{{F_{x_i}}^2 + {F_{y_i}}^2 + {F_{z_i}}^2} - g \right|} \qquad (4)$$



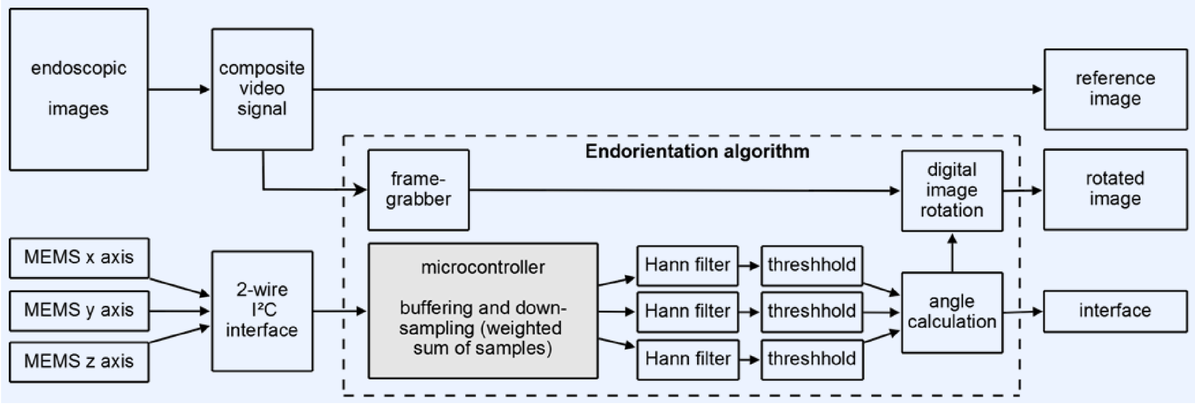
- Accelerations far away from gravity have less impact:



Implementation

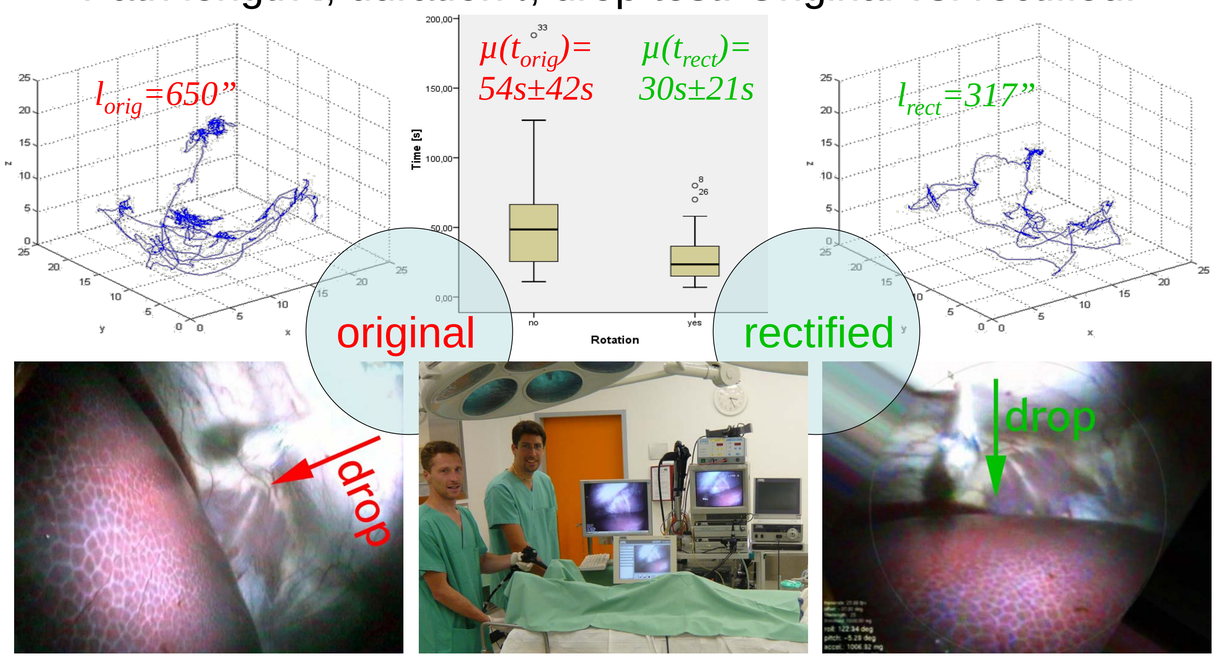
Two-step “Endorientation” algorithm for use of sensor data:

1. Fast down sampling and weighted sum filtering on “EndoSens” micro controller hardware.
2. Parameter controlled Hanning and threshold filtering and GPU-based image rotation by PC software:



Clinical Evaluation

- Path length l, duration t, drop test: Original vs. rectified:



Conclusion

- Achievable repetition rate is even after filtering above the common endoscopic video frame rate of *30Hz*
- Shock-resistent accuracy is about one degree
- Image rotation is performed digitally in real-time
- Clinical Evaluation: Significantly more accurate with by factor 2 shorter paths and nearly half the duration
- Movement and Coordination of different instruments were rated to be much more intuitive with a stable horizon

[1] Höller, K. et al.: Taking endoscopy to a higher dimension: Computer Aided 3-D NOTES. In: Proc. 4th Russian-Bavarian Conference on Bio-Medical Engineering, pp. in press, Zelenograd, Moscow, MIET, July 2008
[2] Höller, K. et al.: Clinical evaluation of Endorientation: Gravity related rectification for endoscopic images. In: Proc. of the ISPA. (2009) pp. in press
[3] Höller, K. et al.: Suppression of shock based errors with gravity related endoscopic image rectification”, In Proc. 5th Russian-Bavarian Conference on Bio-Medical Engineering, pp. in press, Munich, Germany, July 2009