Friedrich-Alexander-Universität
Erlangen-Nürnberg

ZENTRALINSTITUT FÜR MEDIZINTECHNIK

Correspondence:
Kurt Höller
Central Institute of Healthcare Engineering (ZiMT)
Krankenhausstr. 2-4
D-91054 Erlangen
Tel.: +49 9131 85-26861
Fax: +49 9131 85-26862
hoeller@zimt.uni-erlangen.de

K. Höller, S. Hempel, A. Schneider, J. Jahn, J. Guttiérrez, T. Wittenberg, J. Hornegger, and H. Feußner

Rectification of Endoscopic Images by Gravity

In: J. Hornegger, K. Höller, M. Spiegel, and H.- P. Niedermeier, Eds., Proc. Pattern Recognition in Medical and Health Engineering ’10, ISBN 978-3-00-031916-7, pp. 105–107, Pattern Recognition Lab, FAU Erlangen-Nuremberg, Kloster Banz, Germany, April 2010.

Rectification of Endoscopic Images by Gravity

K. Höller[1,2,3], S. Hempel[2,3], A. Schneider[3], J. Jahn[4], J. Guttierrez[4], T. Wittenberg[4], H. Feußner[3], and J. Hornegger[1,2]

[1] Central Institute of Healthcare Engineering (ZIMT), Friedrich-Alexander-University Erlangen-Nuremberg, Erlangen, Germany
[2] Pattern Recognition Lab, Department of Computer Science, Friedrich-Alexander-University Erlangen-Nuremberg, Martensstr. 3, 91058 Erlangen, Germany
[3] Workgroup for Minimal Invasive Surgery MITI, Klinikum r.d. Isar, Technical University Munich, Germany
[4] Fraunhofer Institute for Integrated Circuits (IIS), Erlangen, Germany

Abstract. Image rotation correction even in non-rigid endoscopic surgery (particularly NOTES) can be realized with a tiny MEMS tri-axial inertial sensor placed on the tip of an endoscope by measuring the impact of gravity on each of the three orthogonal axes. After an initial calibration the rotation angle can be estimated with some calculations out of these three values. Achievable repetition rate is above the usual endoscopic video frame rate of $30Hz$, accuracy is about one degree. The image rotation was performed by rotating just digitally a capture of the endoscopic analogue video signal which can be realized in real-time. Improvements and benefits have been evaluated in animal studies: Coordination of different instruments and estimation of tissue behaviour regarding gravity related deformation and movement was considered to be much more intuitive having a stable horizon on endoscopic images.

1 Method

One of the biggest problems with flexible endoscopy in Natural Orifice Translumenal Endoscopic Surgery (NOTES) [1] is the missing information about image orientation [2]. Thus, tip retro-flexion of a non-rigid endoscope causes image rotation angles till ±180 degrees.
Our approach to measure this orientation angle is to integrate a Micro Electro-Mechanical System (MEMS) based inertial sensor device in the endoscope's tip, which measures influencing forces in three orthogonal directions [3,4]. If the endoscope is not moving, only the acceleration of gravity has an effect on the three axes. Using an arc tangent function the rotation angle Φ can be computed out of acceleration values F_y and F_z on the two axes y and z orthogonal to the endoscopic line of view in x-direction:

$$\Phi = \arctan2(F_y, F_z) \qquad (1)$$

First, a preceded 3×3 calibration matrix, which incorporates misalignment and scaling errors [5], has to be retrieved by initial measurements. Moreover a peak elimination is the result of clever down sampling the measuring frequency, which is considerably higher than the image frame rate, using a weighted sum algorithm. To avoid bouncing or jittering images as a result of the angle correction, additional filtering is necessary.

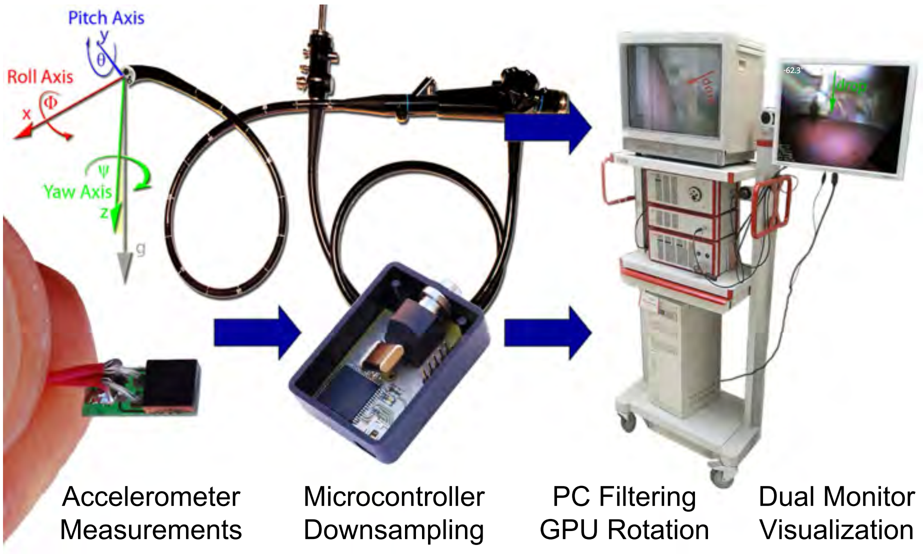

Fig. 1. EndoSens Hardware with ENDOrientation Algorithm for Endoscopic Image Rectification

Hence, prior to angle calculation, the measures of each axis are filtered with a Hann filter to smooth angle changes and with a minimum variation threshold to suppress dithering.
With the employed sensor there is a uniform quantization of 8 bit for a range of $\pm 2.3g$ for each axis. This implies a quantization accuracy of $0.018g$ per step or 110 steps for the focused range of $\pm g$. This is high enough to achieve a durable accuracy even to a degree within relatively calm movements. This is possible as roll angle Φ is calculated out of inverse trigonometric values of two orthogonal axes. Single extraordinary disturbed MEMS values or superposed accelerations with the same order of magnitude as gravity are suppressed by the ENDOrientation algorithm [6].

2 Results

During a porcine animal study, the navigation complexity of a hybrid endoscopic instrument during a NOTES peritoneoscopy with the well established trans-sigmoidal access [7] was compared with and without automated image rotation. To evaluate the benefit of automated real-time MEMS based image rectification, four different needle markers were inserted through the abdominal wall to the upper right, lower right, lower left and upper left quadrants. These four needle markers had to be grasped with a trans-abdominal introduced endoscopic needle holder under standardized conditions. The minimum time, the mean time and the maximum time have been lower with image rectification for every position [8]. All participating surgeons considered the complexity lower using our ENDOrientation technique.

References

1. Rattner, D., Kalloo, A.: ASGE/SAGES working group on Natural Orifice Transluminal Endoscopic Surgery: White Paper October 2005. Surg Endosc vol 20 (2006) 329-333.
2. Höller, K., Petrunina, M., Penne, J., Schneider, A., Wilhelm, D., Feussner, H., Hornegger, J.: Taking endoscopy to a higher dimension: Computer Aided 3-D NOTES. In: Proc. 4th Russian-Bavarian Con-ference on Bio-Medical Engineering, Zelenograd, Moscow, MIET (July 2008) 33-37.
3. Höller, K., Penne, J., Schneider, A. et al.: Endoscopic orientation correction. In: Medical Image Computing and Computer Assisted Intervention, 12th International Conference Proceedings MICCAI'09 London, UK (September 2009) 459-466.
4. Höller, K., Schneider, A., Jahn, J. et al.: Orientation of Endoscopic Images: Rectification by Gravity. In: J Biomed Eng, August 2010, in Press.
5. Höller, K.: Characterization and modeling of an inertial sensor for navigation of autonomous systems. Friedrich-Alexander-Universitt Erlangen-Nrnberg (October 2005).
6. Höller, K., Penne, J., Schneider, A. et al.: Suppression of shock based errors with gravity related endoscopic image rectifcation. In: Proc. 5th Russian-Bavarian Conference on Bio-Medical Engineering Munich, Germany (July 2009) 43-47.
7. Wilhelm, D., Meining, A., von Delius, S., et al.: An innovative, safe and sterile sigmoid access (ISSA) for NOTES. Endoscopy vol 39 (2007) 401-406.
8. Höller, K., Schneider, A., Jahn, J. et al.: Clinical evaluation of ENDOrientation: Gravity related rectifcation for endoscopic images. In: Proceedings of the ISPA, Salzburg, Austria (September 2009) 713-717.