GYROSENSORS IN AIRBAG

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Presentation flow

- Gyro sensor basics
- Specifications in gyros
- Devices and applications
- Inertial measurement unit
- Intelligent Human Airbag System
What is Gyro Sensor?

- Gyro is an instrument, which senses inertial angular motion, angular rate, about its input axis without external reference.
- It is an inertial sensor.
- A diverse range of physical laws are used to construct gyros operating currently, and hence, many technologies are present based on which various gyros are built.
Types of Gyroscopes

- Broadly, there are 3 basic types of gyroscope:
  - Rotational (classical) gyroscope
    - Based on conservation of angular momentum of a spinning rotor
  - Vibrating Structure Gyroscope
    - Based on Coriolis effect on a vibrating mass
  - Optical Gyroscopes
    - Based on Sagnac effect
Specifications

- A gyroscope sensor has the following basic specifications:
  - Measurement range
  - Number of sensing axes
  - Nonlinearity
  - Working temperature range
  - Shock survivability
  - Bandwidth
  - Angular Random Walk (ARW)
  - Bias
  - Bias Drift
  - Bias Instability
Specifications

- **Measurement range**: specifies the maximum angular speed which the sensor can measure, and is typically in degrees per second (°/sec).
- **Number of sensing axes**: measures the angular rotation in one or two or three axes. Multi-axis sensing gyros have multiple single-axis gyros oriented orthogonal to one another.
Specifications

- Vibrating structure gyroscopes are usually single-axis (yaw) gyros or dual-axis gyros, and rotary and optical gyroscope systems typically measure rotation in three axes.

- **Nonlinearity**: measured as a percentage error from a linear fit over the full-scale range, or an error in parts per million (ppm).
Specifications

- **Working temperature range**: operating temperatures range from roughly -40°C to anywhere between 70 and 200°C
- **Shock Survivability**: typically measured in g’s (1 g = earth’s acceleration due to gravity)
- Gyroscopes are very robust, and can withstand a very large shock (over a very short duration) without breaking
Specifications

- **Bandwidth**: measures how many measurements can be made per second, and is measured in Hz.
- **Angular Random Walk (ARW)**: a measure of gyro noise and has units of deg/hour or deg/sec
- **Bias**: the signal output when gyro is not experiencing any rotation. This error is always present and represents a rotational velocity
Devices

- **Analog Devices ADXRS610**
  - **Description:** ±300 degrees per second Single Chip Yaw Rate Gyro with Signal Conditioning
  - **Nonlinearity:** 0.1% of Full-Scale Range
  - **Working Temperature Range:** -40°C - 105°C
  - **Shock Survivability:** 2000g
  - **Bandwidth:** Adjustable (0.01 - 2500 Hz)
Devices

- **Invensense IDG500**
- ±500/110 degrees per second dual-axis gyroscope
- Two separate outputs per axis for standard and high sensitivity:
  - **X-/Y-Out Pins:** 500°/s full scale range
    - 2.0mV/°/s sensitivity
  - **X/Y4.5Out Pins:** 110°/s full scale range
    - 9.1mV/°/s sensitivity
Devices

- Sparkfun SEN-08189 6 DoF Inertial Measuring Unit
  - Uses 3 ADXRS150 ($\pm150^\circ$/s max rate) gyroscopes
  - Nonlinearity: 0.1% of Full-Scale Range
  - Working Temperature Range: -40°C - 85°C
  - Shock Survivability: 2000g
  - Bandwidth: Adjustable (Typical Bandwidth: 40Hz)
Vibrating Structure gyroscope
ADXR 300
Applications

- Mostly used in military navigation, guidance, and attitude determination, as well as in commercial aviation
- Also being used in safety and stability devices in automobiles, control of industrial and construction equipment, and in biomedical uses, involving activity monitoring
Inertial Measurement Unit

- A set of accelerometers and gyros assembled along the orthogonal axes of a cluster together with the associated electronics and frame assembly, is termed Inertial Measurement Unit (IMU)
- It provides specific force information and attitude
- Specific force is the measure of acceleration due to inertial forces as measured by accelerometers
- Attitude is autonomous detection of position, velocity, and direction
Measurements in IMU

- The measurement of Roll, Pitch and Yaw entails the use of 3 linear accelerometers and 3 rate gyros to measure rotational velocity. These components are geometrically positioned to provide X, Y and Z co-ordinate based measurements, respectively:
IMU

- Inertial sensors (gyros) used in IMU are categorized into 3 performance grade requirements
  - **Strategic Grade**
    - Bias stability \(0.0001°/\text{hr}\), Nonlinearity 50 ppm
  - **Navigation Grade**
    - Bias stability \(0.001 - 0.1°/\text{hr}\), Nonlinearity 1 - 100 ppm
  - **Tactical/Commercial Grade**
    - Bias stability \(0.1 - 10000°/\text{hr}\), Nonlinearity >100 ppm
Towards a Mobile Airbag System Using MEMS Sensors and Embedded Intelligence

Guangyi Shi, Cheung-Shing Chan, Guanglie Zhang, Wen J. Li, Philip H.W. Leong and Kwok-Sui Leung
Abstract

- This paper introduces the development of a mobile human airbag system designed for fall protection for the elderly. A Micro Inertial Measurement Unit (µIMU) that is 66 mm x 20 mm x 20 mm in size is built. This unit consists of three dimensional MEMS accelerometers, gyroscopes, MCU, and a Bluetooth module. It records human motion information, and, with a Support Vector Machine (SVM) training process, it can be used to classify falls and other normal motions successfully with an SVM filter. Based on the SVM filter, an embedded DSP (Digital Signal Processing) system is developed for real-time fall detection.
Also, a smart mechanical airbag deployment system is finalized. This system weighs 253.5 grams (including a 42.5 g compressed CO2 cylinder) with dimensions of 190 mm length, 57 mm width and 30 mm height. The response time of the mechanical trigger is 0.133 seconds, which has been proven in our lab to allow enough time for compressed air release before a person falls down to the ground. The integrated system is tested, and the feasibility of the airbag system for real-time fall protection is demonstrated.
Introduction

- With increasingly aging population, there will exponential increase in the number of elderly individuals who suffer from injury from falls.
- Worldwide, there are 4 million hip fracture cases every year, and annual mortality rate is 30.8%.
- This also leads to huge medical and rehabilitation expenditure.
- There are commercially available hip protectors, but they have a poor compliance rate.
- To build a protective system, the idea of automobile airbag systems is applied.
Basic concept of Intelligent Human Airbag System
Concept

- When an elderly person loses his or her balance, the MEMS micro sensors in the belt detect his or her disorientation and trigger the inflation of the airbag on the correct side in a few milliseconds before the person falls to the ground.

- There are two main parts to this project
  - electronic part that works with an algorithm to judge a fall and send a trigger signal to the airbag inflator
  - mechanical part, which includes the inflator structure for compression, airbag deployment control, and airbag design
µIMU Design

- Accelerometer - ADXL203 (AD Inc.)
- Gyro - muRata ENC-03 angular rate gyros

These are low-cost and relatively high-performance sensors with analog signal output.

The output signal of sensors are measured directly with A/D converters inside the µController.
• μC - ATMEL ATmega32
• The digital sample rate of the microcontroller is 200 Hz, which ensures rapid reaction to human motion.
• Bluetooth module - TDK Systems blu2i Module; connected directly to μC via USART port connection
• μIMU sensors and the Bluetooth module are housed on a PCB
• Two Li batteries of 3.6 V can power the unit for ~3 hours.
• The µIMU can realize two functions:
  ◦ data collection and transmission to the computer wirelessly, which can be analyzed or trained using an SVM. Later, the data can be transmitted to DSP chips for real-time analyses
  ◦ a gate recognition algorithm can be downloaded to discriminate a falling motion and trigger the airbag for inflation
Schematic chart of \(\mu\)IMU system
SVM training process

- The MCU first converts the sensor outputs to digital signals and then transmits the packed data signal sequentially via a Bluetooth module to a computer.
- Hundreds of recordings are made to form a database for SVM training.
- After training, the best features are selected to form a classifier for falling-motion recognition.
The problem of recognition of falling-down motion in real time is addressed as binary pattern recognition with SVM

- Set up a motion database of “falling-down” and “non-falling-down” examples using the \( \mu \)IMU
- Use a supervised PCA (Principle Component Analysis) to generate and select characteristic features
- Implement SVM training to produce a classifier.
Schematic chart of SVM training
Airbag Release System (before triggering)
Airbag Release System (after triggering)
• The entire fall-sensing, mechanical triggering, and airbag inflation process must be completed within ~0.9 sec in order for the system to protect a falling human.

• The airbag inflation process is engineered to ensure that the airbags could be inflated within 0.333 sec.
Pressures and Mass Flow rate comparison between simulation and experimental result

(a) Pressures

(b) Mass flow rates
Independent Airbag System: High-speed camera analyses
Independent demonstration with µIMU and deployment system
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THANKS