



DEE Departamento de Engenharia Elétrica
UFC

PPGEE
PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA ELÉTRICA
UNIVERSIDADE FEDERAL DO CEARÁ

GPAR
Grupo de Pesquisa em Automação,
Controle e Robótica

SEEL
SEMANA DE ENGENHARIA ELÉTRICA - UFC

Fusão Sensorial

Aplicações no Cotidiano e o Futuro da Robótica

Msc. Marcus Davi do Nascimento Forte

Introdução



GRAR
Grupo de Pesquisa em Automação,
Controle e Robótica



Introdução



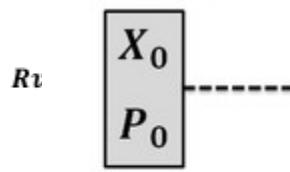
Introdução

3.2 Equivalence of Rota

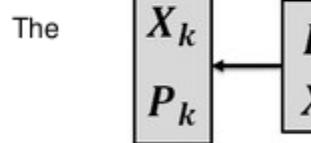
The general rotation mat
system around the axis \hat{r}

$$R = \begin{pmatrix} R_{xx} & R_{xy} & R_{xz} \\ R_{yx} & R_{yy} & R_{yz} \\ R_{zx} & R_{zy} & R_{zz} \end{pmatrix} = \begin{pmatrix} \dots & \dots & \dots \\ \dots & \dots & \dots \\ \dots & \dots & \dots \end{pmatrix}$$

For Initial State



= Output of Updated State



X : State Matrix

P : Process Covariace Matrix

K : Kalman Gain

Q : Process Noise Covariance Matrix

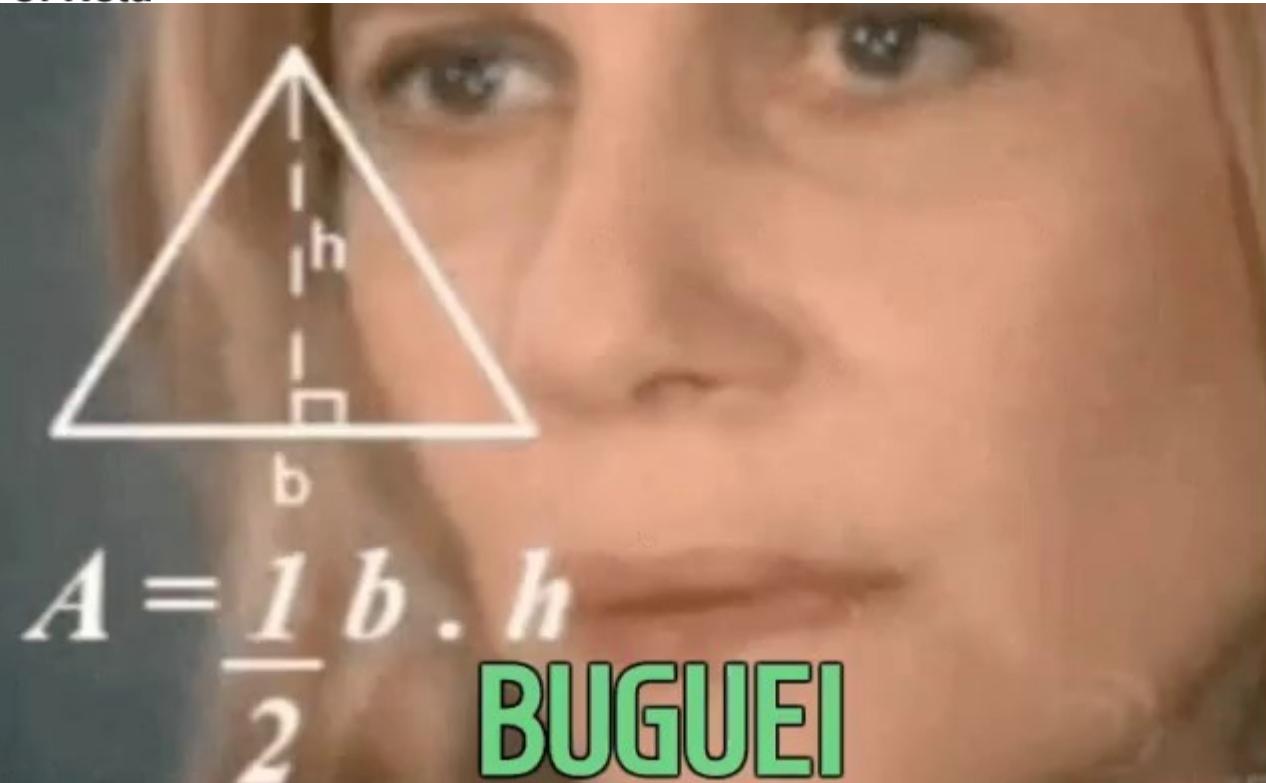
I : Identigy Matrix

R : Sensor Noise Covariance Matrix

Y : Measurement of the State

u : Control Variable Matrix

w : Predicted State Noise Matrix

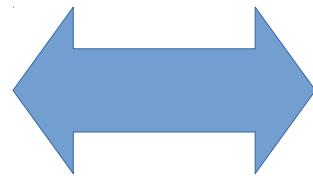


- $\Omega_2^2 + \Omega_3^2 + \Omega_4^2)$
- $\Omega_4 - \Omega_1 - \Omega_3)$
- $\Omega_3 - \Omega_2 - \Omega_4)$

, $S_\Phi) \dot{z}$
 $S_\Phi) \dot{z}$

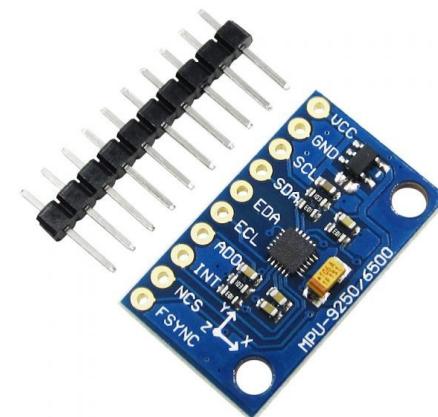
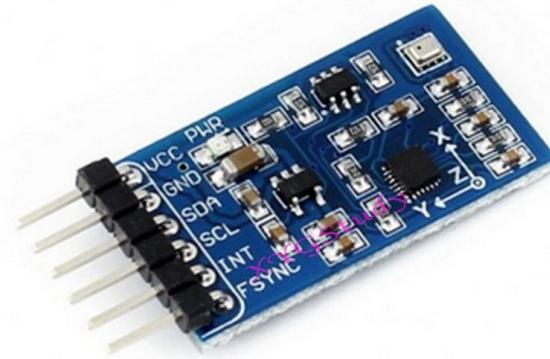
Introdução - O que é fusão sensorial?

- Percebendo o mundo - Sensor
 - Dispositivo que detecta mudanças no ambiente e codifica as detecções em sinais



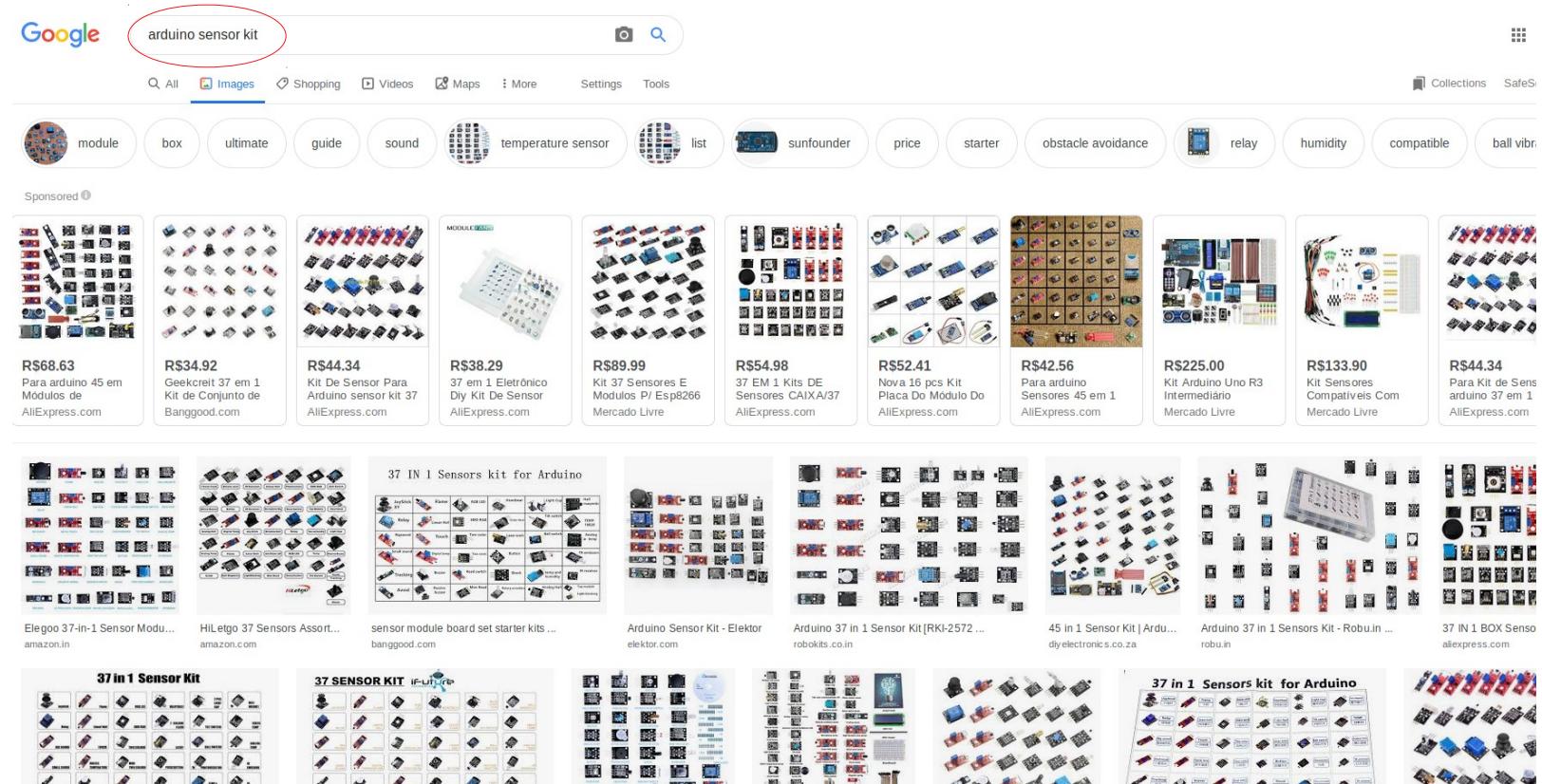
Introdução - O que é fusão sensorial?

- Tipos de Sensores
 - Distância
 - Luz
 - Magnéticos
 - Pressão
 - Chuva
 - Álcool
 - Fumaça
 - Humidade
 - ❤️
 - Som
 - Gás
 - Cor
 - Fluxo
 - Temperatura
 - Inclinação
 - Velocidades
 - “Acelerações”
 - Velocidades Angulares



Introdução - O que é fusão sensorial?

- Percebendo o mundo - Sensor



Introdução - O que é fusão sensorial?

- Acelerômetro
 - Tecnologia MEMS;
 - Mede “**Aceleração Própria**”;
 - Distribui sua leitura entre seus três eixos;
 - Medições Relativas ao **Quadro do Sensor!**
 - Vídeo!;
 - Mostra!;

PROBLEMA : RUÍDO CHATO

Introdução - O que é fusão sensorial?

- Giroscópio
 - Tecnologia MEMS;
 - Mede **Velocidades Angulares**;
 - Distribui sua leitura entre seus três eixos;
 - Medições Relativas ao **Quadro do Sensor!**
 - Vídeo!;
 - Mostra!;

PROBLEMA : BIAS CHATO!

Introdução - O que é fusão sensorial?

- Magnetômetro
 - Não MEMS!
 - Mede **Campo Magnético**;
 - Distribui sua leitura entre seus três eixos;
 - Medições Relativas ao **Quadro do Sensor**!
 - Vídeo!;
 - Mostra!;

PROBLEMA : SENSIBILIDADE CHATA

Introdução - O que é fusão sensorial?

- Fusão Sensorial
 - Combinação de Sensores de diferentes **NATUREZAS** mas que me ajudam a estimar uma mesma **MUDANÇA**
 - Melhor dos dois Mundos!
 - Com a Fusão, consegue-se compensar as limitações dos sensores!
 - Princípio Básico : Estimação de Sinais
 - Antigamente : Filtro Complementar
 - “Atualmente” : **KALMAN FILTER**

Aplicações

- Satélites / Naves / Estações Espaciais



ISS - International Space Station

Aplicações

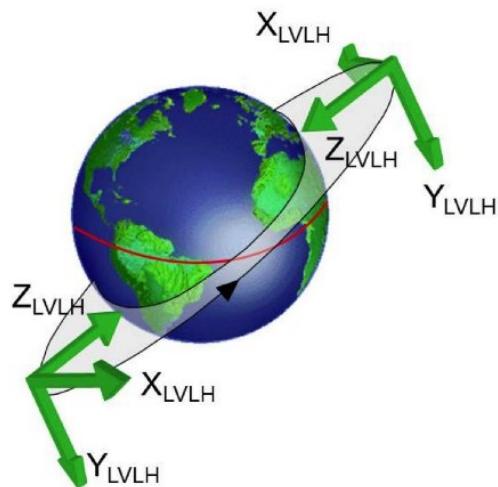
- Satélites / Naves / Estações Espaciais

ISS Attitude Orientation

The ISS generally flies in a local vertical, local horizontal (LVLH) attitude orientation, as shown in the figure below, using Control Moment Gyros to maintain the attitude without need for thruster firings.

The ISS attitude varies about this LVLH hold in a sinusoidal motion every 90 minute orbit. An attitude is selected, called the Torque Equilibrium Attitude (TEA), that balances the torques on ISS such that the CMGs can be used to stabilize the ISS attitude. The TEA is within 15° degrees of 0,0,0 LVLH. The per orbit sinusoidal variation about the TEA is within 3.5° per axis.

Every 3 to 4 weeks a visiting vehicle docking occurs that necessitates thruster control and an attitude maneuver for the event. Sometimes the attitude maneuver is only a few degrees, and sometimes the maneuver is a 180° yaw or 90° pitch. The event can last a few hours up to a few days.

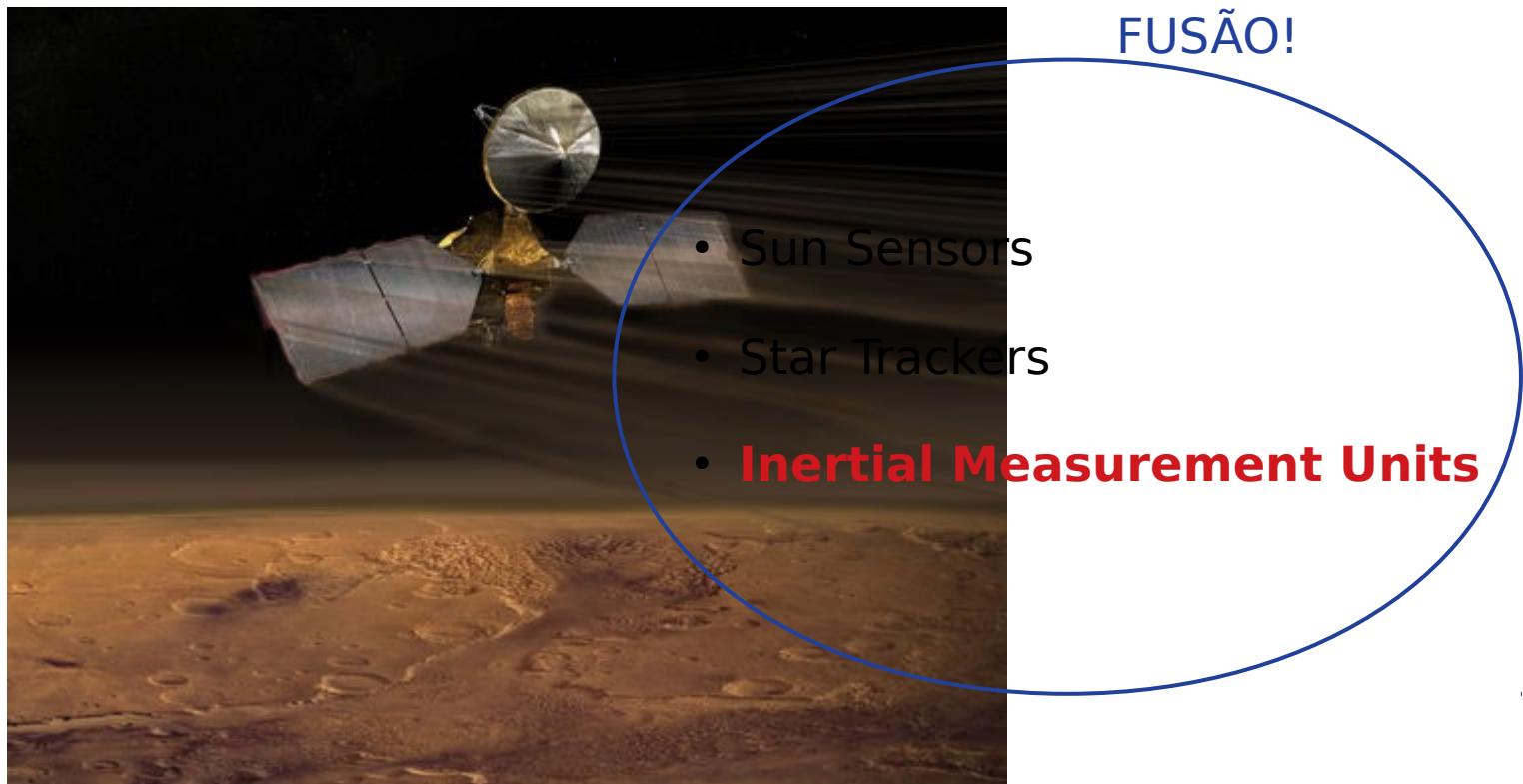


ISS Attitude Orientation

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Aplicações

- Satélites / Naves / Estações Espaciais



Mars Reconnaissance Orbiter Mission

Aplicações

- Satélites / Naves / Estações Espaciais



Aplicações

- Satélites / Naves / Estações Espaciais

VÍDEO ROCKET POUSANDO

Aplicações

- Satélites / Naves / Estações Espaciais



Mesmo princípio é aplicado a mísseis balísticos nucleares. . .

Before the gimballed thrusters come into place for landing, the rockets use **Attitude Control Systems**, which are a system of spouts that expel high-pressure gasses at different points around the capsule to reorient the rocket while in space so it can begin its descent with the thrusters facing downward.

Aplicações

• Satélites / Naves / Estações Espaciais

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SOFTWARE ENGINEER (EMBEDDED)

Hawthorne, CA, United States

SpaceX was founded under the belief that a future where humanity is out exploring the stars is fundamentally more exciting than one where we are not. Today SpaceX is actively developing the technologies to make this possible, with the ultimate goal of enabling human life on Mars.

SOFTWARE ENGINEER (EMBEDDED SOFTWARE)

As a software engineer on the Vehicle Embedded team, you will be creating software that is used to design, develop, launch and operate space-to-space and space-to-ground laser communications systems. You will help ensure our system is reliable, efficient and to provide high data rate communication across multiple SpaceX programs. You will engage with other SpaceX engineers to discover the needs of the mission and write highly reliable software that turns the mission into a reality. You will be responsible for the complete lifecycle of the software you create, from development to testing to operation during a mission.

Aerospace experience is not required to be successful here - rather we look for smart, motivated, collaborative engineers who love solving problems and want to make an impact on a super inspiring mission.

RESPONSIBILITIES:

- Develop highly reliable and available software systems
- Develop prototypes to prove out key design concepts and quantify technical constraints
- Write high quality structured microcontroller and Linux-based software for embedded processors (e.g. ARM, PowerPC, x86, etc.)

BASIC QUALIFICATIONS:

- Bachelor's degree in computer science, engineering, math, or science discipline OR 2+ years of experience in software development.
- Development in C, C++ or a similar language for embedded systems or Linux

PREFERRED SKILLS AND EXPERIENCE:

- Strong software design and development skills
- Thorough knowledge of systems, computer architecture, software development, networks, and electronics
- Experience developing fault tolerant software
- Have shipped embedded software in high volume products or real-time products that require high reliability and fault tolerance
- Hardware debug experience, including familiarity with tools such as the oscilloscope, logic analyzer, protocol analyzer (SPI, CAN, Ethernet or similar)
- Significant understanding of embedded software principles and ability to contribute in design sessions
- Strong skills in debugging, performance optimization and unit testing
- Effectively worked as a team member and in large code bases
- Creative approach to problem solving and exceptional analytical skills
- Ability to work effectively in a dynamic environment with changing needs and requirements
- Ability to work independently and in a team, take initiative, and communicate effectively

[APPLY NOW](#)

DATA & CONTROL SYSTEMS ENGINEER

McGregor, TX, United States

SpaceX was founded under the belief that a future where humanity is out exploring the stars is fundamentally more exciting than one where we are not. Today SpaceX is actively developing the technologies to make this possible with the ultimate goal of enabling human life on Mars.

DATA & CONTROL SYSTEMS ENGINEER (INSTRUMENTATION AND CONTROLS)

The Data and Control Systems (DCS) Engineer job is a multi-faceted position responsible for flight hardware interfaces and ground support data and control systems used in our rocket. Development test stands in McGregor, Texas. You will design wire harnesses and electrical interface systems, lead electrical integration, and assist with test operations during static fire. You will also manage the product development of DCS components of customer SpaceX and vendor data acquisition and control, very harnesses, and a suite of instruments. These systems support test operations that enable safe, economical and reliable access to space.

RESPONSIBILITIES:

- Develop, maintain, and upgrade test site data acquisition systems; identify hardware requirements and complete schematic, layout, and validate DAQ hardware configurations; troubleshoot DAQ hardware related problems
- Provide technical support for avionics/instrumentation on test stands; provide and update drawings of harnesses/interfaces, electrical power, and data/control systems; provide documentation for assembly, installation, and removal of harnesses and connectors
- Design/improve and document grounding and shielding of data systems
- Define, coordinate, and execute avionics integration activities in Texas, including identifying, designing, reviewing, building, installing, and functional checking wire harnesses
- Conduct troubleshooting and resolution of test site equipment issues
- Drive improvements to vehicle design or Texas test site equipment and procedures to avoid repeated issues, prevent anomalies before they cause further issues, and reduce integration time
- Create and maintain avionics-related flight software configuration files, Texas test scripts, launch software configuration files, test procedures, and relevant flight test plan sections
- Monitor data, as needed, during test operations and provide input to the team concerning potential anomalies, sequences, operation of the vehicle's avionics systems, and readiness for orbital test phase
- Review and verify health and performance of avionics on the test articles by reviewing not the acceptance test data, creating and maintaining data reduction code, and compiling reports
- Provide other related duties, as assigned, for the purpose of ensuring an efficient and effective work environment

BASIC QUALIFICATIONS:

- Bachelor's degree in electrical engineering, computer engineering, or other engineering field

PREFERRED SKILLS & EXPERIENCE:

- Excellent communication skills – both written and verbal
- Passion for advancing the commercial space industry and human spaceflight
- Strong work ethic and drive to succeed as part of a high functioning team
- Ability to work in a fast paced, autonomous, and demanding test-atmosphere
- Experience with analog and digital instrumentation engineering techniques in a unique work environment to solve problems and facilitate testing
- Ability to rapidly change responsibilities while working in a high-paced, challenging work environment
- Ability to work with analogies, be resourceful, and manage multiple priorities
- Knowledge of high-reliability processes and robust documentation practices
- Demonstrated ability to design, implement and troubleshoot data acquisition and control hardware
- Some knowledge of and experience in analog and digital to analog converters, power supply components and design, analog testing & troubleshooting techniques, and signal integrity, layout and grounding principles
- General schematic capture and printed circuit board (PCB) design, verifier and validation experience
- Proficient in noise reduction, shielding, grounding techniques, termination and analog and digital filtering to provide high fidelity measurements
- Demonstrated practical knowledge of electromagnetic interference (EMI) principles and measurement techniques
- Experience working with instrumentation, including pressure transducers, thermocouples, RTDs, accelerometers, strain gauges, flow meters, load cells, relay, and solenoid valves which are most commonly used in this role
- Ability to quickly troubleshoot wiring needed for various interfacing of data systems and sensors
- Proficient in electronic skills such as soldering, insulation and wire splicing, and component selection
- Experience with electrical power distribution, working knowledge of NFPA 70 and NFPA 70E
- Experience with National Instruments (NI)K2000/DAQ data acquisition systems
- Experience with LabVIEW, Python, and/or C/C++ programming
- Understanding of various industrial bus protocols such as Modbus, EtherCAT and EtherNet/IP

[APPLY NOW](#)

FIRMWARE ENGINEER

Hawthorne, CA, United States

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FIRMWARE ENGINEER

Hawthorne, CA, United States

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FIRMWARE ENGINEER

The embedded software team is responsible for architecting, developing and verifying firmware for SpaceX vehicles. The team works closely with electrical engineers, software engineers and customers across the company to deliver high quality products on a rapid development schedule. Successful applicants will take responsibility for the development, testing and deployment of mission-critical avionics systems as part of a close-knit team of exceptional software engineers.

RESPONSIBILITIES:

- Deliver highly reliable embedded software for SpaceX designed hardware
- Work with engineers across the department to develop new products, from prototype through production and flight
- Take ownership of your firmware products, including verification testing and writing documentation
- Follow the SpaceX flight software development process and write great software for manned spaceflight

BASIC QUALIFICATIONS:

- Bachelor's degree in computer science, engineering, math or science discipline
- 2+ years of experience writing embedded software in C, C++ or a similar language

PREFERRED SKILLS AND EXPERIENCE:

- 2+ years developing software for the ARM Cortex family or a similar microarchitecture
- Working knowledge of hardware level software development, including use of timers, interrupts, hardware peripherals such as SPI controllers and ADCs, bootloaders and debug tools
- Experience programming and testing high reliability, safety critical, and fault tolerant systems
- Hardware debug experience, including familiarity with tools such as the oscilloscope, logic analyzer, protocol analyzer (SPI, CAN, Ethernet or similar)
- Familiar with common electronic components and comfortable reading circuit design schematics and contributing to hardware design discussions
- Strong understanding of operating system fundamentals, including schedulers, network stack, file system, memory management
- Experience with defensive programming, continuous testing and similar high-reliability software development strategies
- Excellent leadership, communication and teamwork skills

Aplicações

- Aeronaves



Aplicações

• Aeronaves

Sensor Fusion Approach for Aircraft State Estimation using Inertial and Air-Data Systems

F. Schettini, G. Di Rito, R. Galatolo and E. Denti
Dipartimento di Ingegneria Civile ed Industriale
Università di Pisa, Largo Lucio Lazzarino 2
Pisa, Italy
f.schettini@ing.unipi.it

Abstract — This paper describes a Kalman filter that integrates the measurements coming from inertial system, GPS receiver and air data system with self-aligning probes to provide accurate sensing of the aircraft state in all the flight phases. A particular attention has been focused on the angle of attack and sideslip angle reconstruction. The evaluation of these angles becomes challenging during manoeuvres with high load factors, typical for high-performance aircraft. In these conditions, the air data elaboration accuracy is significantly lowered by the sensors' dynamics. The paper demonstrates that a relevant improvement of accuracy can be obtained in both high and low frequency range, and specific tests campaign has been carried out with a simulation platform including the flight simulator of a light military jet trainer.

Keywords—Air data measurements; Kalman filter; simulation; self-aligning probe.

[5][6][7] and to enhance the management of redundancies [8][9]. The basic concept is to take advantage from the peculiar characteristics of each measurement, so that the high precision of the ADS during steady-state flight phases [10][11][12] and the one of the IMU during fast manoeuvres can be combined.

In the paper, a Sensor Fusion Filter (SFF) for the evaluation of Angle of Attack (AoA) and Angle of Sideslip (AoS) is presented and validated in terms of both performance and robustness via flight simulation.

II. PROPOSED SENSOR FUSION APPROACH

The developed SFF integrates three independent measurements, which include data that are accurate at specific and different frequency ranges.

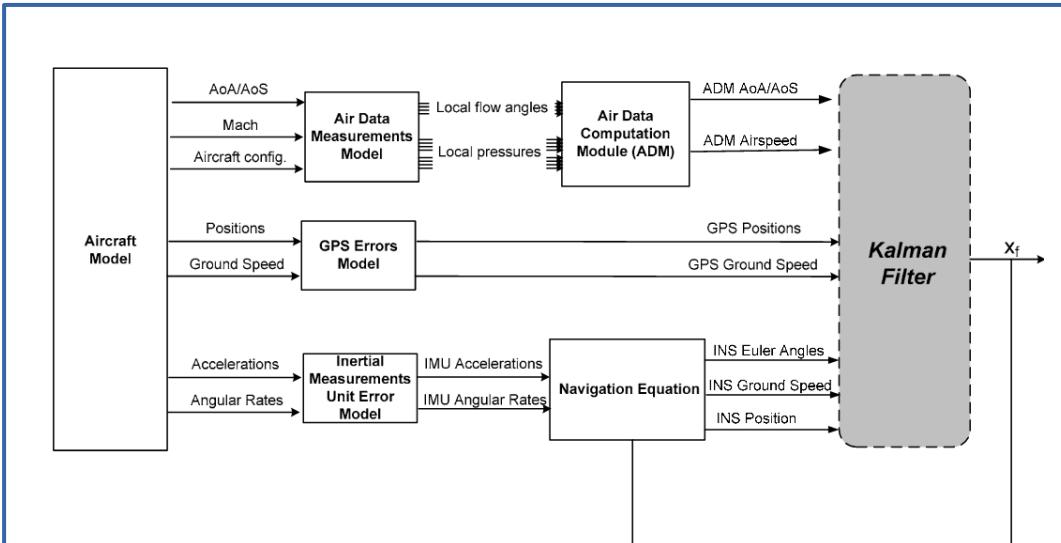


Fig. 1 – Working scheme of the simulation platform for the filter verification.

Artigo Científico

Modelo de uma aeronave

Aplicações

- Aeronaves

- Fusão Multi-sensor (1^a Camada)
- Fusão Multi-Aeronave (2^a Camada)



Lockheed Martin
F-35 Lightning II

Aplicações

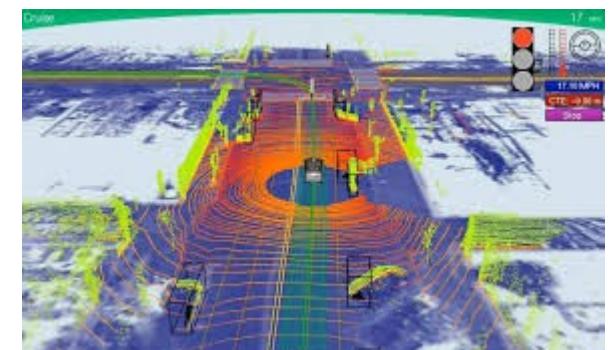
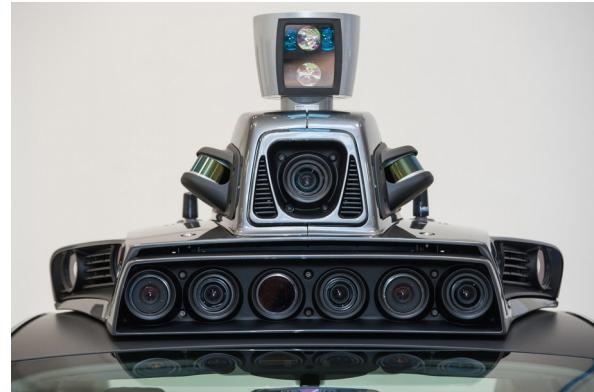
- Carros Autônomos / Self-Driving Car



Aplicações

- Carros Autônomos / Self-Driving Car

- Mais variados sensores
 - Câmera
 - Lidar
 - GPS
 - IMU
 - Odometria
 - Ultrassom
 - Radar



Dificuldade : Requer muito processamento rápido!

AJEITAR IMAGENS

Aplicações

- Carros Autônomos / Self-Driving Car

Other sensing and localization

The sensors discussed above aren't the only source of information for a self-driving car to know where it is and where to go. Other source inputs include Inertial Measurement Units (IMUs), GPS, Vehicle-to-Everything (V2X) communication, and high definition maps.

Bringing it all together

All of these sensors output different types of data – and lots of it. This requires a considerable computing platform to fuse the data together and create a consolidated view of the vehicle's environment. Launched in 2019, Level Five Supplies is a comprehensive supplier of autonomous vehicle hardware and technology.

Aplicações

- Drones (Autônomos)
 - Falar do Projeto

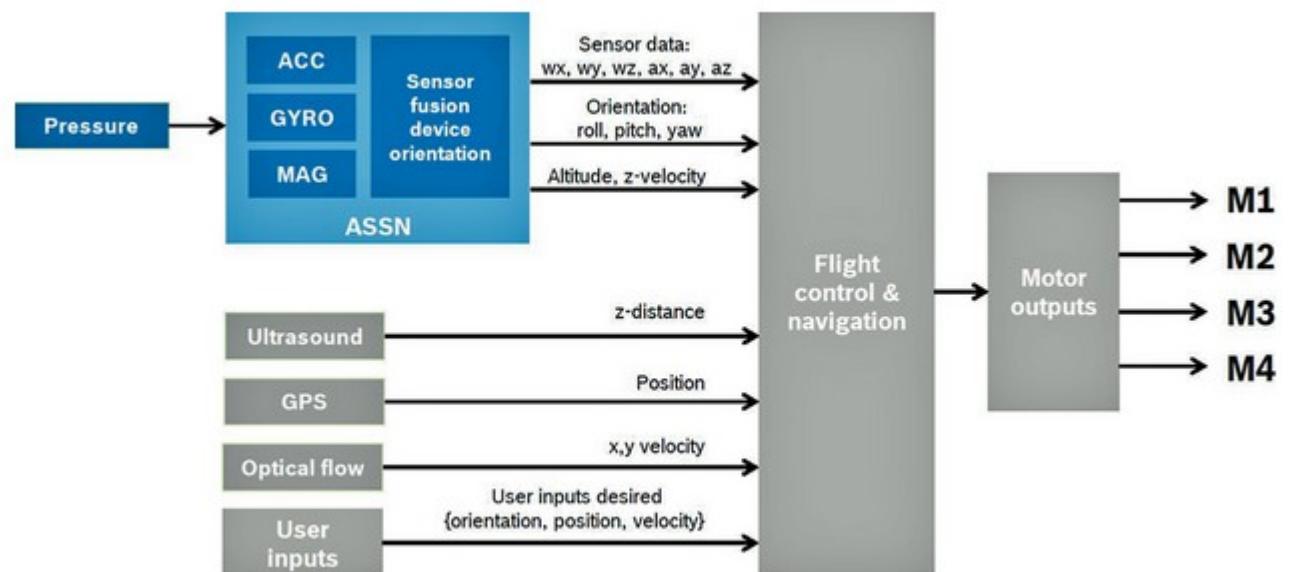


Fig. 3: BMF055 (ASSN) usage as AHRS in drone application.

Aplicações

- Drones (Autônomos)
 - Falar do Projeto



Aplicações

- Drones (Autônomos)
 - Matemática

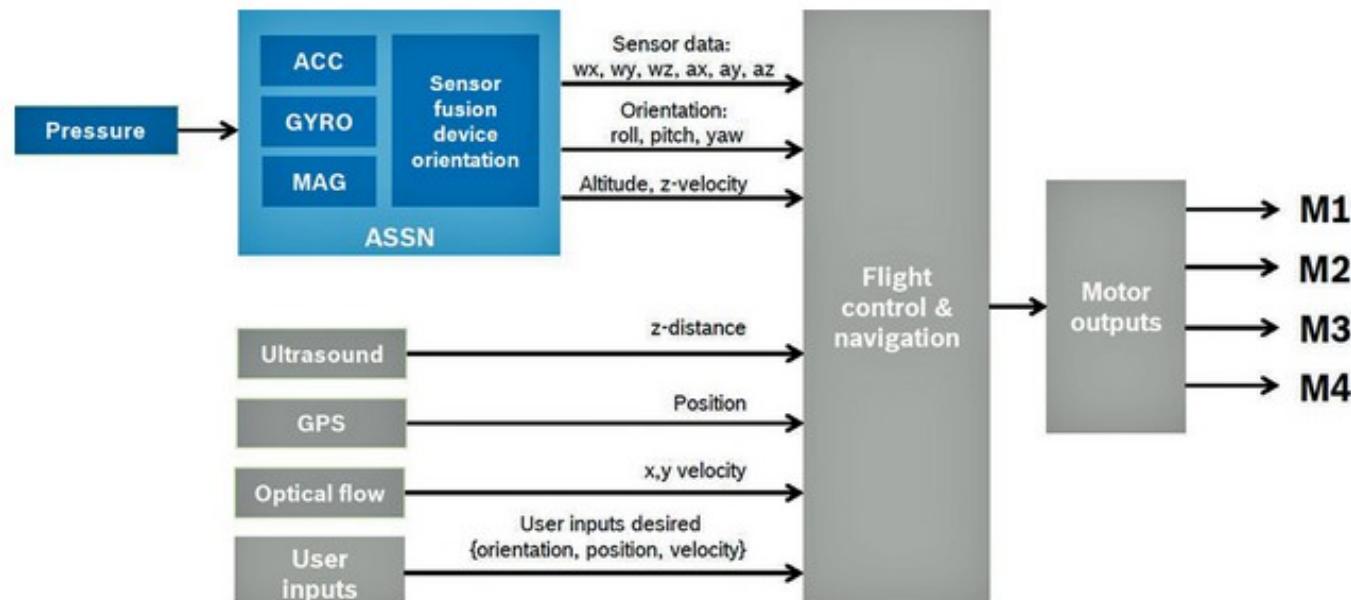


Fig. 3: BMF055 (ASSN) usage as AHRS in drone application.

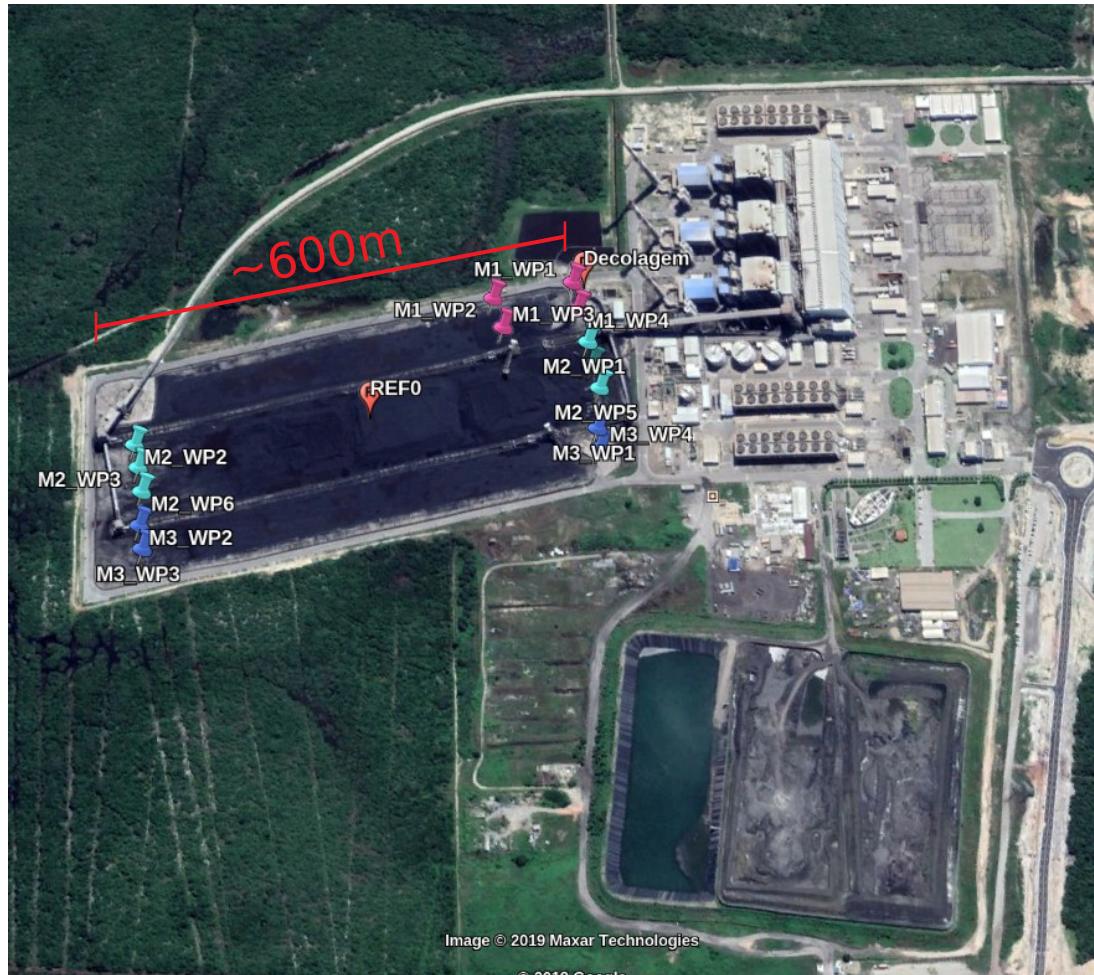
Aplicações

- Drones (Autônomos)
 - Projeto de Pesquisa

FOTOS

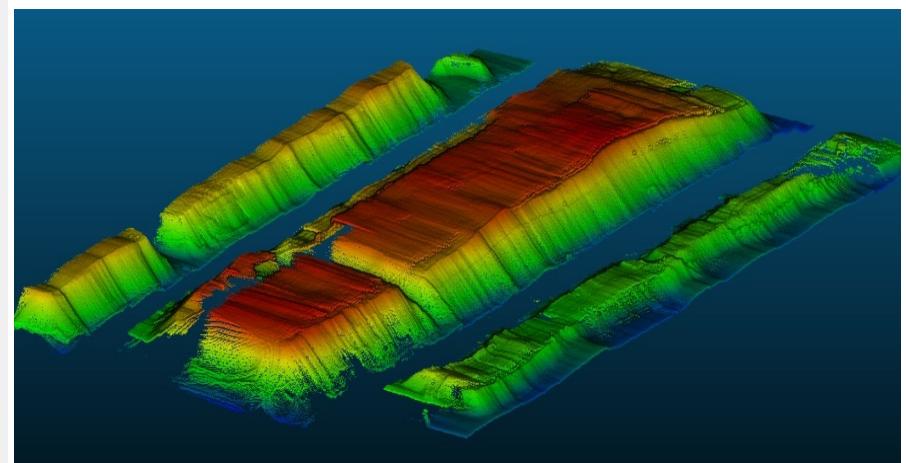
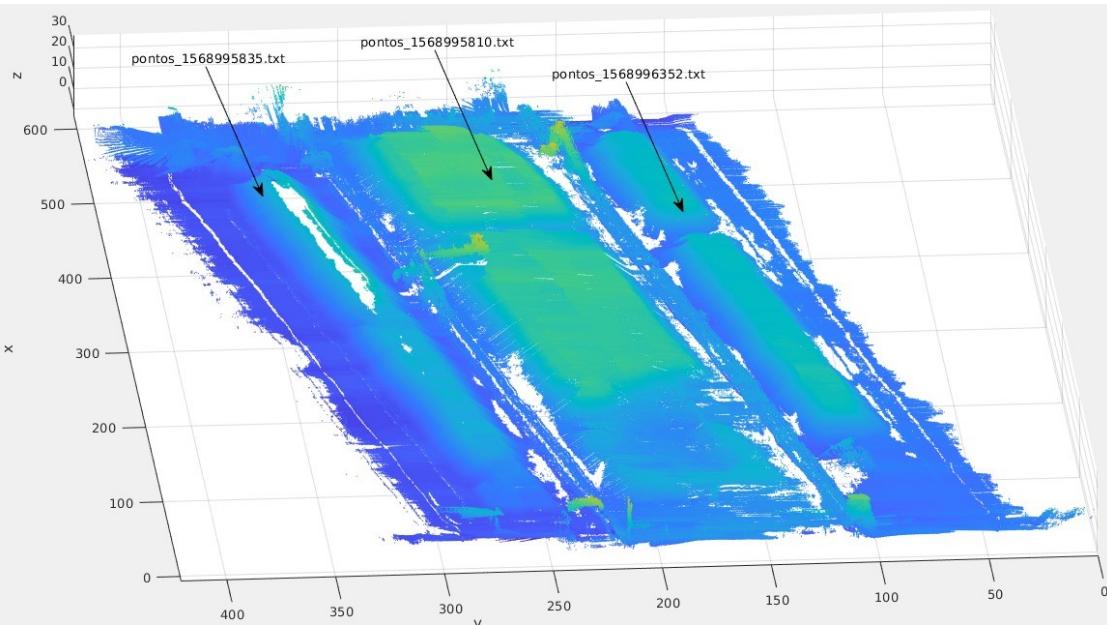
Aplicações

- Drones (Autônomos)
 - Projeto de Pesquisa



Aplicações

- Drones (Autônomos)
 - Projeto de Pesquisa



Aplicações

- Robôs Autônomos
 - Mars Rover → Robô Explorador/Navegador



Aplicações

- Robôs Autônomos
 - Nanook

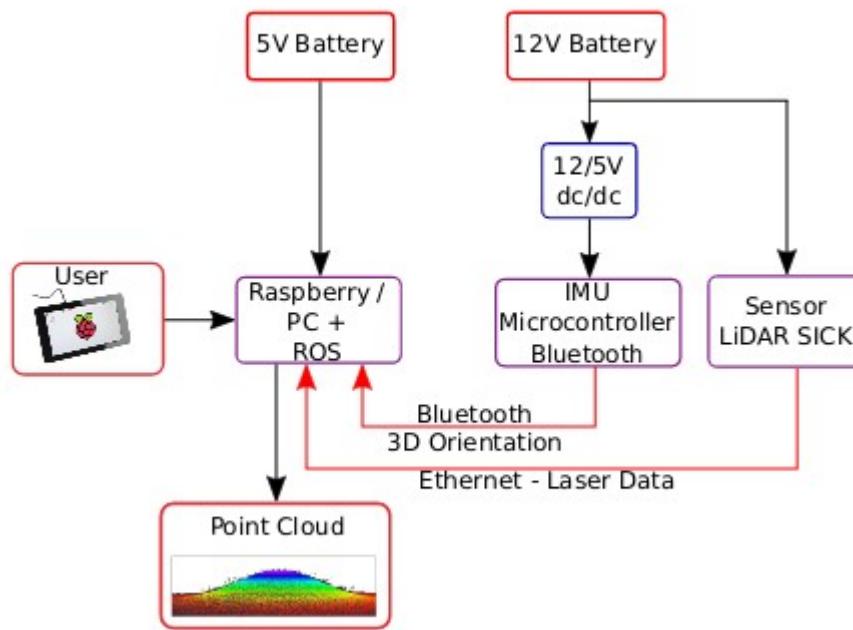
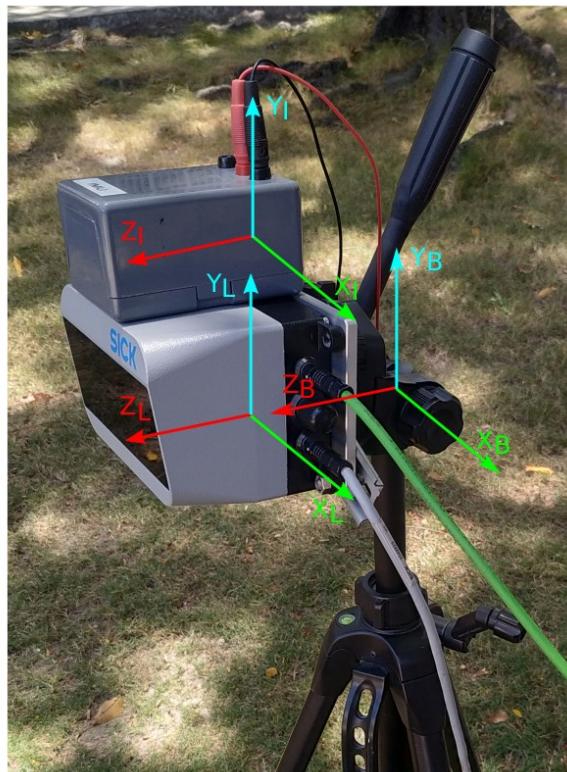


Sensores:

- Odometria
- IMU + Bússola
- GPS*
- LiDAR
- Ultrassom*

Aplicações

- TLS
 - Sistema Integrado (ROS)



Aplicações

- TLS

VAMOS BATER UM SCAN?

Aplicações

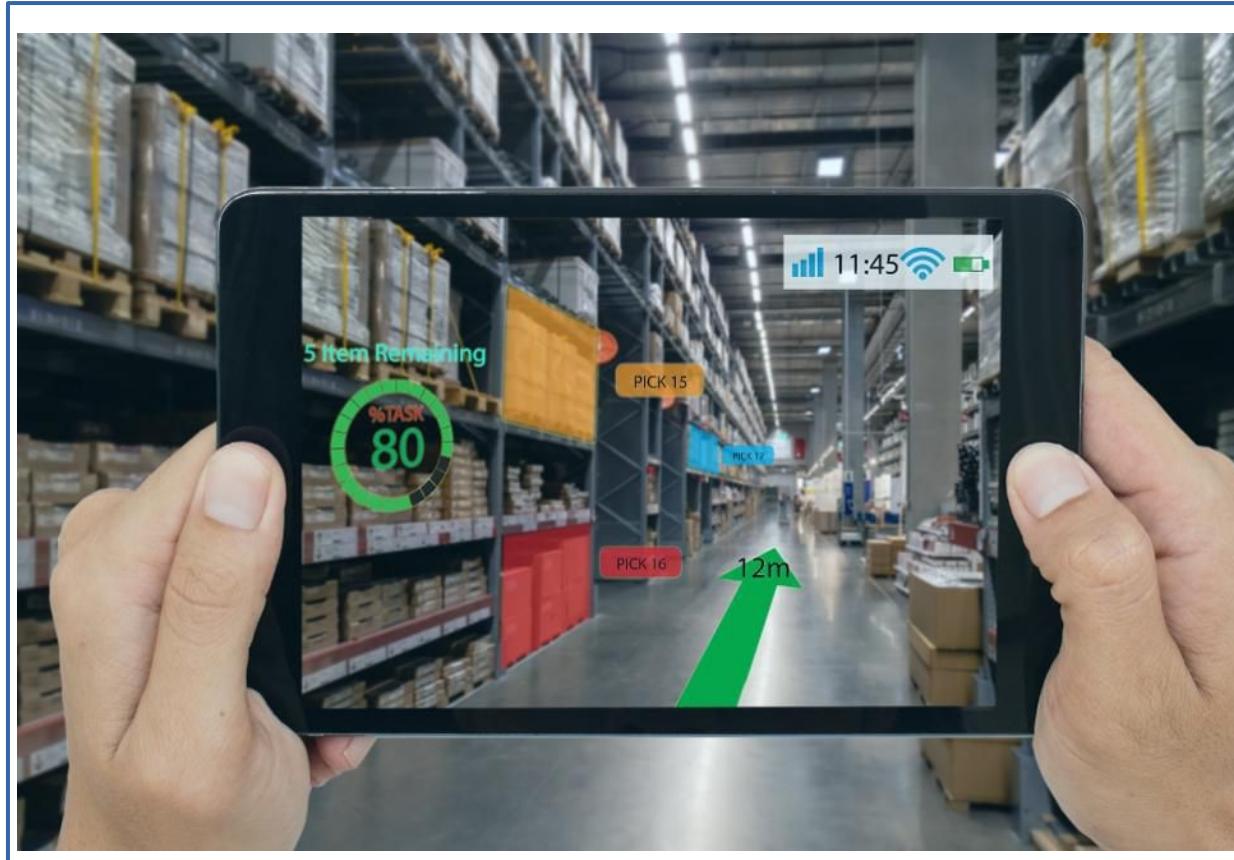
- Realidade Virtual



- Uso de sensores iniciais e magnetômetros
- Requer cômputo rápido e preciso = pesquisar

Aplicações

- Realidade Aumentada



Aplicações

- SmartPhone



uber



Aplicações

- SmartBand
 - Detector de Queda
 - Detector de Passo
 - Detector de Pulso
 - Detector de Exercício
 - **TEM MAIS**



Conclusão

- Requisitos disso tudo?
 - (Muito) AMOR
 - Matemática
 - Computação/Programação
 - **TEM MAIS ?**

Conclusão

- Onde eu começo ?
 - Eventos
 - DTEC
 - SEEL
 - Programa de Extensão
 - RAITEC
 - GPAR
 - Bolsas (Voluntárias)
 - Pós-Graduação
 - Pesquisar é TOP :)

Conclusão

MUITO OBRIGADO PELA SUA ATENÇÃO !