Dr. T

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Ting Yuan

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This is the homepage of Dr. Ting Yuan, an autonomous system scientist specializing in Sensor Fusion, Object Tracking, Aero Tech, and Automotive Radar Perception Systems.

Google Scholar, Sunnyvale CA.

The World carries both individual and collective purposes:

- Individually, to share my domain knowledge learned from the fusion Maestro Dr. Yaakov Bar Shalom, my *BABY* Dr. Peter K Willett, and fellow researchers of ISIF/Automatica societies, such as Dr. Anders Lindquist, Dr. Peter Luh (RIP!) and Dr. Jianxun Li, and industrial experience from many former colleages and friends at the Mercedes-Benz RD of North America and Germany, such as Dr. Axel Gern, Dr. Luca Del Grossi, Dr. Juergen Dickmann, and Dr. Martin Fritzsche.
- Collectively, to talk and discuss in the autonomous society on specific topics with distinguished researchers, such as Dr. Perry Wang and Dr. Alexandre Alahi, and my interns and friends, such as Dr. Bharanidhar Duraisamy, Dr. Simon Romanski, and Dr. Krishanth Krishnan.

CHAPTER ONE

CONTENTS

1.1 Biography

Dr. Ting Yuan is the Chairman and Chief Scientist of the UniverSee Science Technology Inc., a Sensor Fusion Driven autonomous system solution provider. He has more than 15 years industrial/academia experience in Object Tracking, Sensor Fusion and Localization for aerospace and automotive applications. He had been a Research Scientist at the Mercedes Benz Research Development North America Inc., Sunnyvale, CA and principal Tech Lead for Autonomous Driving on China situations within the Autonomous Driving Department for nearly a decade, where his fields of endeavor lie in detection, classification and tracking of moving/static objects using information from camera, Radar and Lidar systems, as well as sensor fusion for the multi-sensor systems. He received his Ph.D. degree from the Electrical and Computer Engineering Department at the University of Connecticut, Storrs, Connecticut, USA. He holds an Associate Professorship (research line) at the SEIEE department of the Shanghai Jiao Tong University and currently the director of SSF (smart sensor fusion for autonomous systems) research laboratory.

Area of Specialization and Research

Sensor Fusion
: homogeneous/heterogeneous track/data fusion (T2TF); track/data association (T2TA); Multi-layer sensor fusion; multi-stage fusion with/without feedback.

Tracking
: KF/EKF/UKF/PF; interacting multiple model (IMM); extended object tracking.

Localization Mapping
: dynamic occupancy gridmap; Doppler-based localization; GraphSLAM.

Statistics
: hypothesis test; sufficient/complete/ancillary statistics.

Optimization
: convex optimization; expectation-maximization (EM); pattern search.

Estimation
: observability/estimability; Monte Carlo sampling; finite mixture models.

Professional Societies

IEEE
: Senior Member, 2012-present

SPIE
: Member, 2010-present

ISIF
: Assiciated Editor, Image Fusion, 2012-present

AutoAI
: Global Advisory Committee, 2019-present

mZone
: Technical Committee, Daimler Representative, 2020-present

Industrial and Academia Talks

2022 Fusion Tutorial
: Multi Sensor and Data Fusion Approachesfor Vehicular Automation Applications - Autonomous Driving: Concepts, Implementations and Evaluation, Linköping, Sweden

2021 Tech AD USA Key Panel
: Automotive Radar based Sensor Fusion Systems, Detroit, Michigan, USA.

2021 AutoSense USA Talk
: Automotive HD Radar Perception Systems: verification, validation and Testing, Detroit, Michigan, USA.

2021 Tsinghua Invited Talk
: Radar-based Sensor Fusion Systems, Tsinghua UniversityBeijing.

2020 Radar Tutorial
: High-Resolution Automotive Radar Perception Systems, Florence, Italy.

2020 AVL Workshop
: Autonomous Driving of Mercedes-Benz in China, Chengdu, Sichuan.

2019 AutoAI Keynote
: Sensor Fusion for Autonomous Driving in China: status, opportunities and paths, Shanghai, China.

2019 Fusion Tutorial
: Multi Sensor and Data Fusion Approaches for Autonomous Driving: Concepts, Implementations and Evaluation, Ottawa, Canada.

2019 UESTC Invited Talk
: Autonomous Driving in Daimler/Mercedes-Benz: Past, Present and Future. USTEC, Chengdu, Sichuan.

2018 Fusion Tutorial
: Multi Source and Multi Modal Sensor Fusion Strategies and Implementations in the world of Autonomous Driving, Cambridge, UK.

2018 USTC Invited Talk
: Sensor Fusion for Autonomous Driving, USTC, Hefei, Anhui, China.

2018 AutoAI Berlin Talk
: Sensor Fusion for Vulnerable Road Objects in Autonomous Vehicles, Berlin, Germany.

2017 Fusion Tutorial
: Multi-sensor Fusion for Autonomous Vehicles, Xi'an, Shaan Xi, China.

2016 ESTS Talk
: Multi-sensor Association/Fusion in Linear and Nonlinear Systems, Emerging Sensing Technologies Summit, Melbourne, Australia.

2016 Fusion Tutorial
: Sensor Fusion for Intelligent Vehicles, Heidelberg, Germany.

2016 Radar Invited Tutorial
Automotive Radar Systems at Daimler AG/Mercedes Benz: Past, Present, and Future, Philadelphia, PA.

MISCs

Best Paper Award
Object Tracking with De-Autocorrelation Scheme for a Dynamic Occupancy Gridmap System, 2016 IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI 2016), Baden Baden, Germany, Sep. 2016.

Springer Book Chapter
Track-to-Track Fusion in Linear and Nonlinear Systems, Advances in Estimation, Navigation, and Spacecraft Control. Springer Berlin Heidelberg, 21-41, 2015.

IET Book Idea
DSRC-based V2X for Cooperative Driver Assistant System", in discussion, IET (Institution of Engineering and Technology), UK.

Artech House Invited Book Idea
Automotive Radar Perception Systems, in discussion, Artech House, Boston, USA.

1.2 Autonomous Systems

Autonomous driving (AD) poses unique challenges for complicated vehicle environments. The beautiful future of AD attracts distinguished teams and researchers, employing state-of-the-art technologies, such as deep learning, sensor fusion, extended object tracking, and high resolution sensor systems, to take the jewel in the crown of the AI/automotive industry.

Now it is universally acknowledged that the autonmous systems consist of four major components:

- Mapping & Localization,
- Environment Perception,
- Intelligent Planning,
- and DBW Control.

However, the divided components are not really decoupled, resulting in extreme complex and bulky autonomous driving systems.

If we make a comparison with the **stone-age** PC industry (as shown in the Fig.01), it is not hard to conclude that the autonomous system nowaday is still at its early stage.

Based on our deep domain knowledge and long-term experience in the AD society, we have predicted that a possible history of AD systems could be more or less like the one shown in Fig.02.

No matter what, the technical difficulity of AD systems lies in the following three fundamental aspects:

1. data,
2. algorithms,
3. and computation.

Fig. 1: Fig. 00: Perception Vehicle at Garage (Silicon Valley, CA)

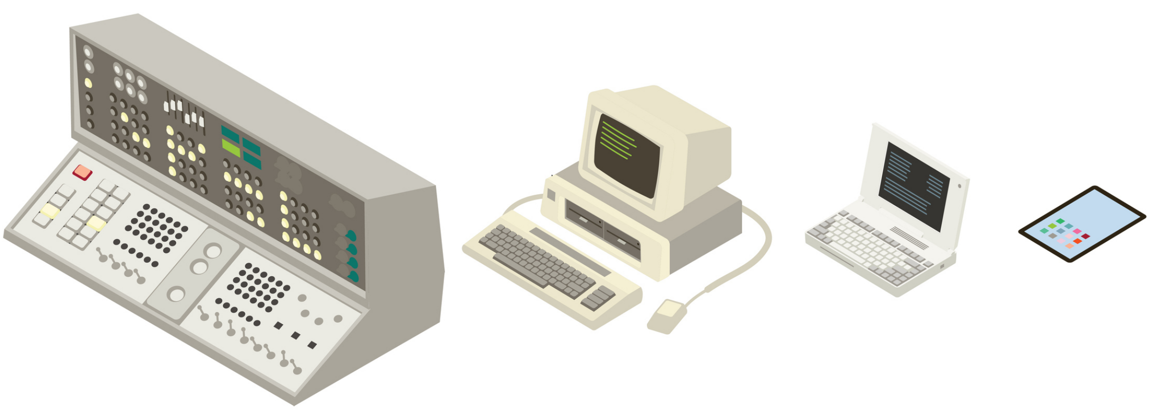

Fig. 2: Fig. 01: Brief History of PC

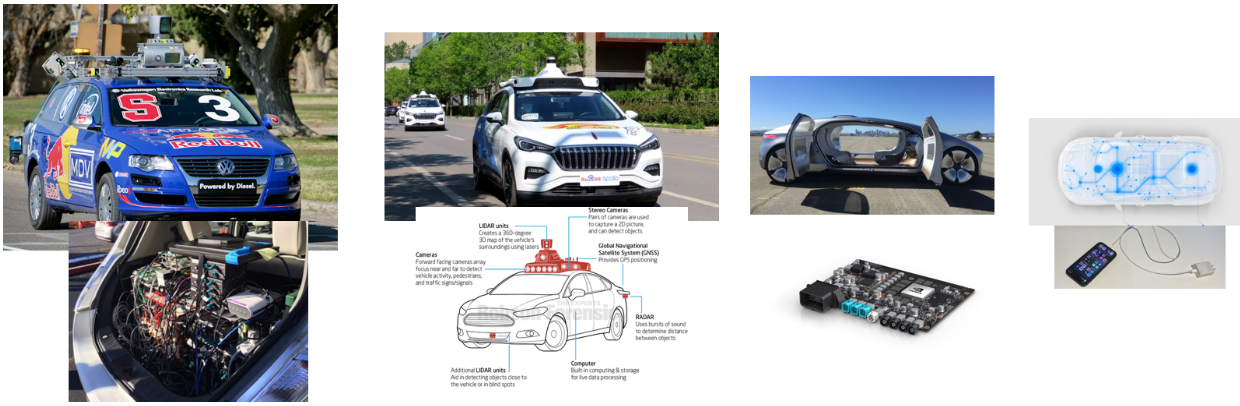

Fig. 3: Fig. 02: A Possible History of AD

Mckinsey once shows an automotive software and EE network map, reflecting the intriguing correlation of the three fundmantal aspects in current automotive industry.

Data and Data Digitalization

For an AD system, this is all about sensing systems for data accessing, data collection, data housing, data security, data serialization, data format, data interface and such.

Customized sensor is the essence in the regard.

The major vehicle percpetion sensors are:

- mmwave radar,
- camera,
- and lidar.

Each has its own unique properties and supports different applications, due to different physical mechanisms.

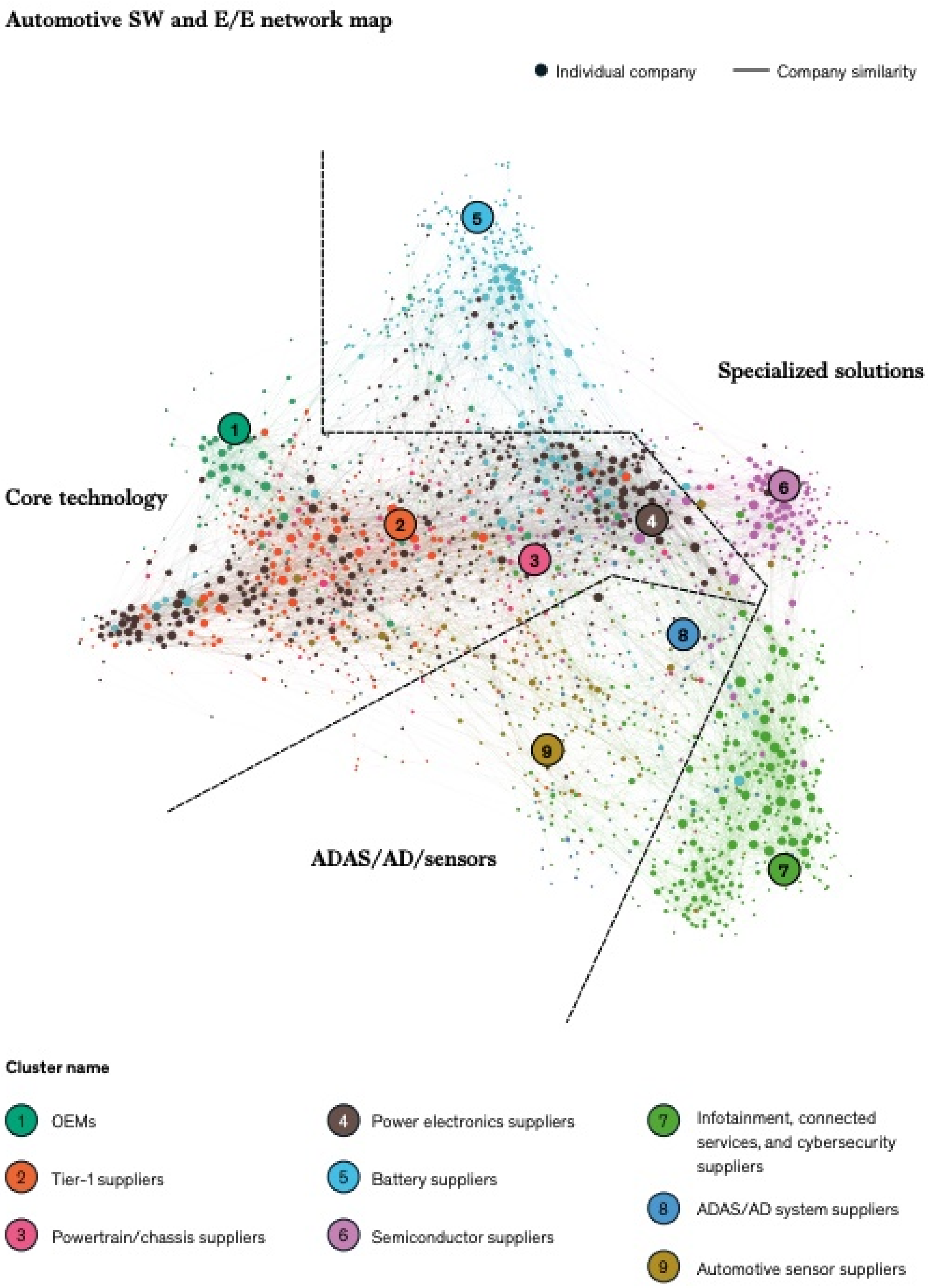

Fig. 4: Fig. 03: Automotive SW and EE Map.

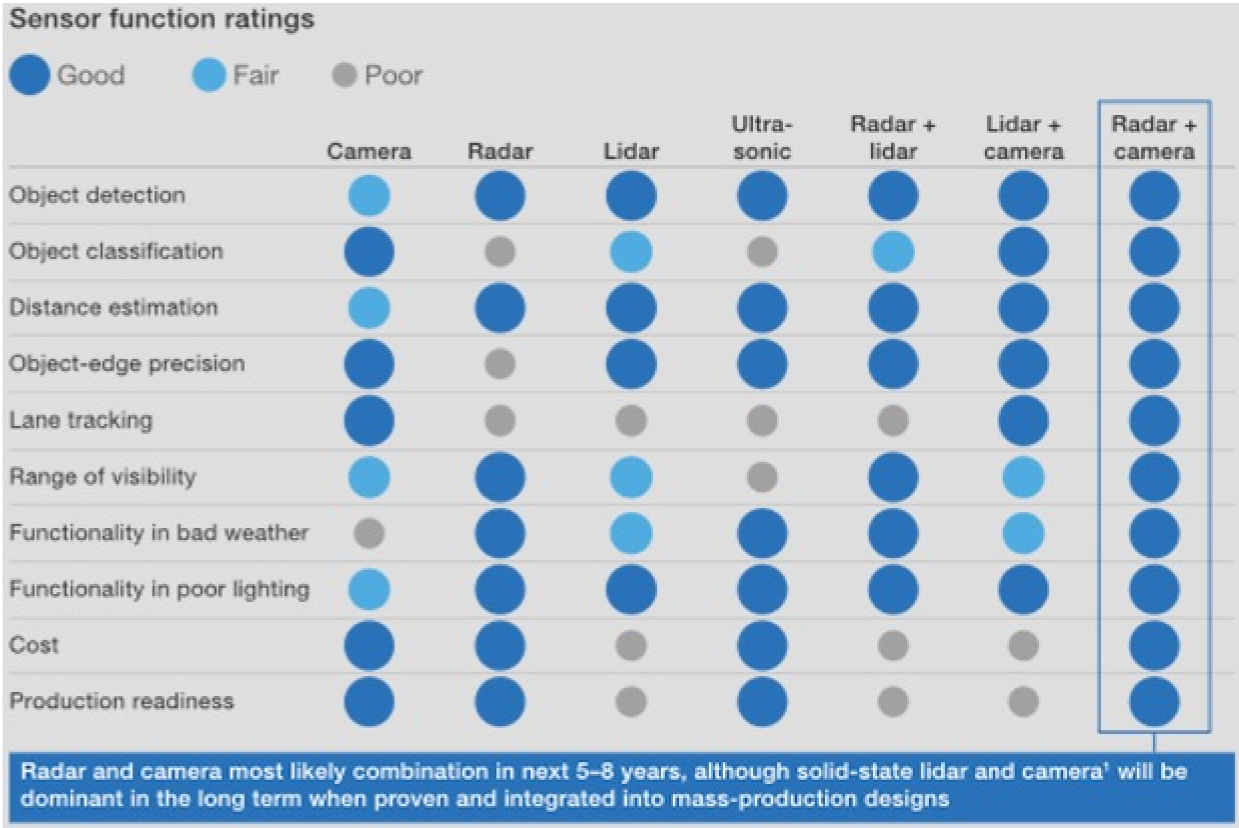

Fig. 5: Fig. 04: Sensor Modalities.

We will particularly talk about the topic of automotive Radar perception systems.

The biggest challenge in the Data aspect lies in the data digitalization caused **sensor multi-modality**. This falls into the domain of Heterogeneous Fusion.

Algorithms and Functionalities

The algorithms directly reflects the four major components of an AD system.

1. Popular algorithms for the simultaneous localization and mapping (SLAM) problem can be found in the OpenSLAM page.

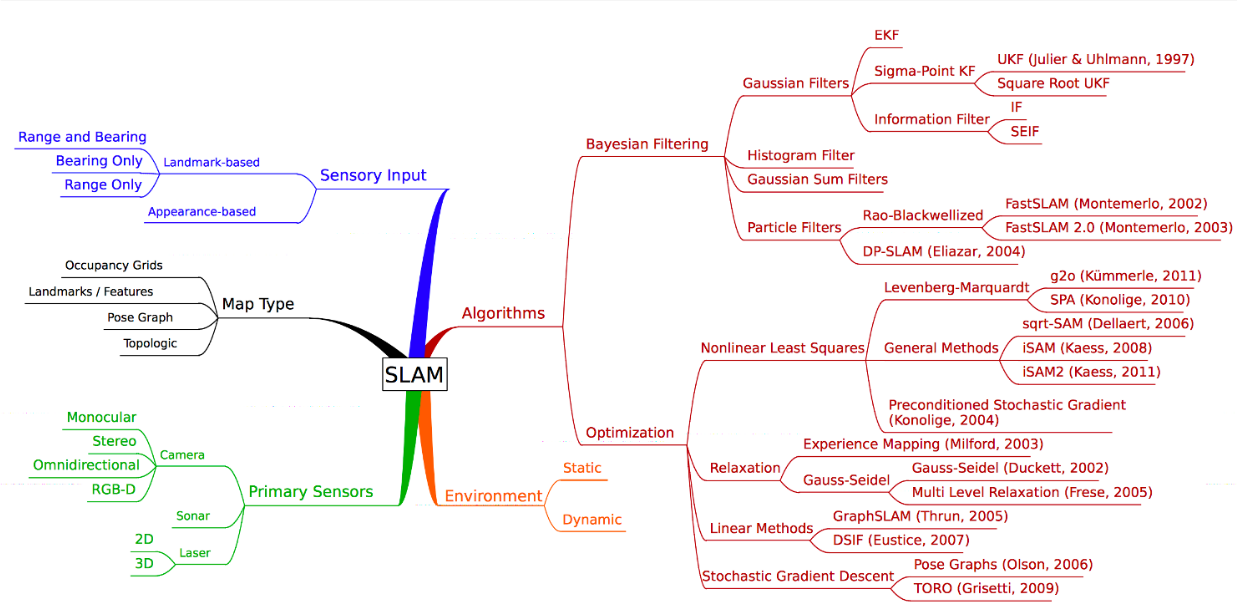

Fig. 6: Fig. 05: SLAM Taxonomy (courtesey of Dr. Ramona Stefanescu).

In this regard, a de facto standard of the vehicle HD-Map systems is called OpenDRIVE.

2. Sensor Fusion is the Swiss Army Knife for data digitalization.

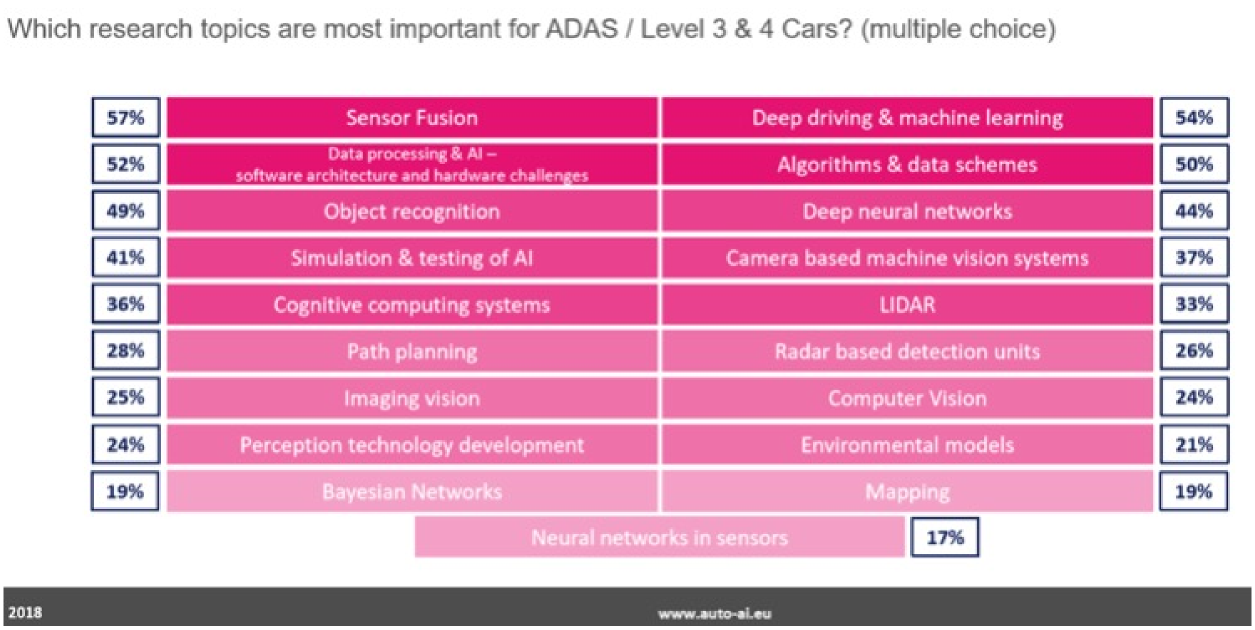

Fig. 7: Fig. 06: Sensor Fusion is considered the most important.

Nowadays, sensor fusion is considered as the bottleneck technology for realization of autonomous driving.

How the sensor fusion theory originated from mainly aerospace scenarios can be applied to automative applications is the ultimate task I have been carrying out in the last decade.

We will have a comprehensieve and intensive discussion on the topic of sensor fusion later.

3. Intelligence Planning is a fun topic but it would not be the focus of our discussion.
4. Drive-By-Wire Controller

   The most painful issue for developing an autonomous system for an algorithm researcher is to open an interface to communicating with vehicle.

   This is achieved by the so-called drive by wire (DBW) system.

   The DBW is nowadays essential for EV and AV systems. The EPS, EPB, iBoost, VCU and other systems have been integrated hardware units for vehicle control.

   4.1 EPS

   The EPS controls and assists with the support of an intelligent electric motor the vehicle steering. Based on the steering signal from the torque sensor, the control unit calculates the optimal steering support and sends the information to the electric motor to provide the necessary assistance.

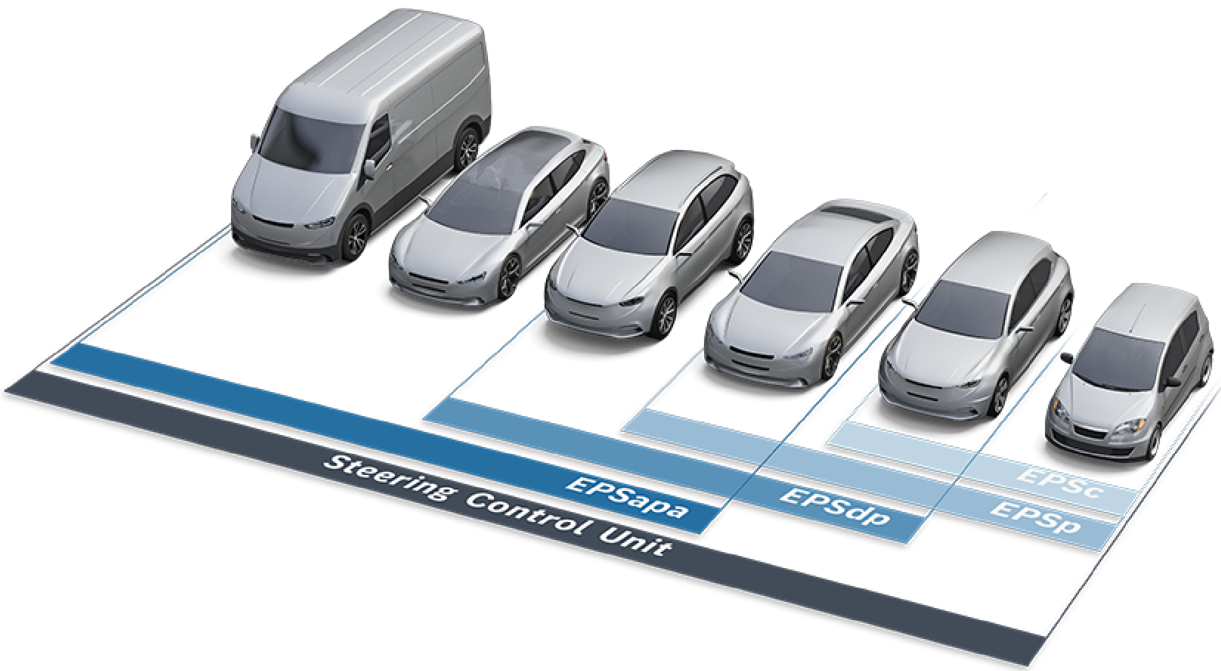

Fig. 8: Fig. 07: EPS Systems.

   4.2 EPB

   An electronic parking brake (EPB), also known as an electric parking brake or electric park brake, is an electronically controlled parking brake, whereby the driver activates the holding mechanism with a button and the brake pads are electrically applied to the rear wheels.[1] This is accomplished by an electronic control unit (ECU) and an actuator mechanism. There are two mechanisms that are currently in production, Cable puller systems and Caliper integrated systems.[2] EPB systems can be considered a subset of Brake-by-wire technology.

4.3 iBooster

The iBooster can be used with all drivetrain configurations and is particularly suited to hybrid and electric vehicles.

The control principle behind the iBooster is similar to that of vacuum brake boosters: in vacuum brake boosters, a valve controls the air supply to provide a boost to the force applied from the driver‘s foot. With the iBooster, the actuation of the brake pedal is detected via an integrated differential travel sensor and this information is sent to the control unit. The control unit determines the control signals for the electric motor, while a three-stage gear unit converts the torque of the motor into the necessary boost power. The power supplied by the booster is converted into hydraulic pressure in a standard master brake cylinder.

4.4 VCU

The VCU coordinates the components in the powertrain or even assumes some of their functions. This includes control of the inverter and battery management system as well as transmission and engine control. Battery charging control (communication with the charging station via a standardized interface) can be integrated in the VCU as well.

This facilitates the introduction of new functionalities, including interconnected functions, and saves resources in the subsidiary control units. In addition, the introduction of a new level of abstraction in the E/E architecture makes variant handling of changing powertrain components much easier.

Due to its modular and configurable hardware and software, the vehicle control unit can be flexibly designed to meet future requirements. Two conceptions are available:

The VCU Standard (VCU-S) uses resource-optimized technology based on the latest engine management generation. It is based on classic micro-controller technology and scalable to fit customer demands. The complexity in the chains of effect is significantly increased through the integration of cross-domain functionalities.

The design of the VCU-S as an Embedded Integration Platform involves separate and independent partitions within the electronic control unit. As a result, it offers the necessary reduction of complexity, quick and easy integration and updates, legacy software integration, multipartner collaboration, mutually agreed safety concepts and much more.

The VCU Performance (VCU-P) sets new standards in vehicle control. It is a departure from previous concepts. It uses micro-processor technology, up to several gigabytes of RAM and flash memory and simultaneous legacy SW support thanks to hypervisor and VRTE technology. The VCU-P also allows scalable feature expansion.

Nowadays the DBW can be a standard unit for AD applications in differen scenarios. The detachment between driver and the car’s controls has been furthered by the introduction of DBW, yet more electrification of a once mechanical job.

The challenge for autonomous system functionalities lies in the deeply coupled function compoents and algorithm accuracy/reliablity/real-time-ness.

Computational Capability and Units

The computional unit/processor is one of the most competitive lines in the industry.

NVidia stock is rocket high due to the high demands of computational capability for AD sensing data.

Xilinx tries to solve the issue from its speciality in SoC.

NXP,

Horizon

The challenge of AD computional complexity lies in limited bandwidth and high computational volume caused time latency.

1.3 Sensor Fusion

1.4 Object Tracking

We mainly put our emphasis on autonomtive object tracking, especially the extended object tracking.

Tracker uses mainly three elementary knowledge:

- noise model: uncertainties.
- system dynamics: state evolution and prior information,
- measurement system: sensor,

to extract two essential information:

- quality, i.e., accuracy and reliability, higher than the raw measurements
- inference information, not directly available in the measurements.

For serious Bayesian researchers, it is highly recommended to read[1]:

1. **Purple Bible**
   Estimation with Applications to Tracking and Navigation by Yaakov Bar-Shalom, X. Rong Li and Thiagalingam Kirubarajan.
2. **Yellow Brick**
   Tracking and Data Fusion: A Handbook of Algorithms by Yaakov Bar-Shalom, Peter K. Willett and Xin Tian.
3. **Grey Manual**
   Design and Analysis of Modern Tracking Systems (Artech House Radar Library) by Samuel Blackman and Robert Popoli.

Stone Soup by DSTL

A wonderful **point target** tutorial for industrial engineers is presented by the Defence Science and Technology Laboratory (DSTL), called Stone Soup.

Stone Soup is developed in Python with six major components: framework, data, algorithms, metrics, simulators, and sensor models. The framework is the core of the project and as a software architecture in a modular fashion integrating all essence in Tracking (such as dynamic/measurement models, noise metrics and simulators).

[1] mentioning my name, you might get some discount, :-)

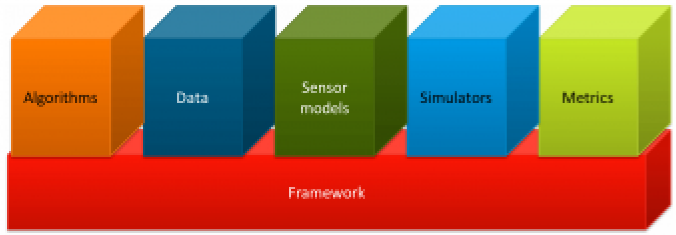

Fig. 9: Fig. 01: Stone Soup Structure

One of our major efforts is to design an Extended Object Tracking Framework similar to the Stone Soup.

However, before applying the tracking/estimation theory originated from aerospace systems for automotive applications, we must understand their common ground and differences.

Automotive Tracking versus Aerospace Tracking

Automotive	**Aerospace**
weak Gaussian assumption	strong Gaussian assumption
extended object	point target
kinematic and shape association	probablistic association

Let us call the system **OCEAN**.

Ocean by UniverSee

The **Ocean** consists mainly of the following modules:

1. Framework for extended object tracking (EOT)
2. Dynamic model set
3. Measurement model set
4. Mutltiple model toolbox
5. Association scheme
6. Performance metrics
7. Pre-Processing tool

1.5 Aero Tech

1.6 Automotive Radar

1.7 News

1.8 Blogs

CHAPTER

TWO

EVENTS

Fusion22 of ISIFSweden, June 2022.

UniveSee is proud to be a sponsor for the Fusion22 at Sweden (ISIF 25th International Conference on Information Fusion, July 2022). Clicking our logo, you will find our product advertised in the reputable event.

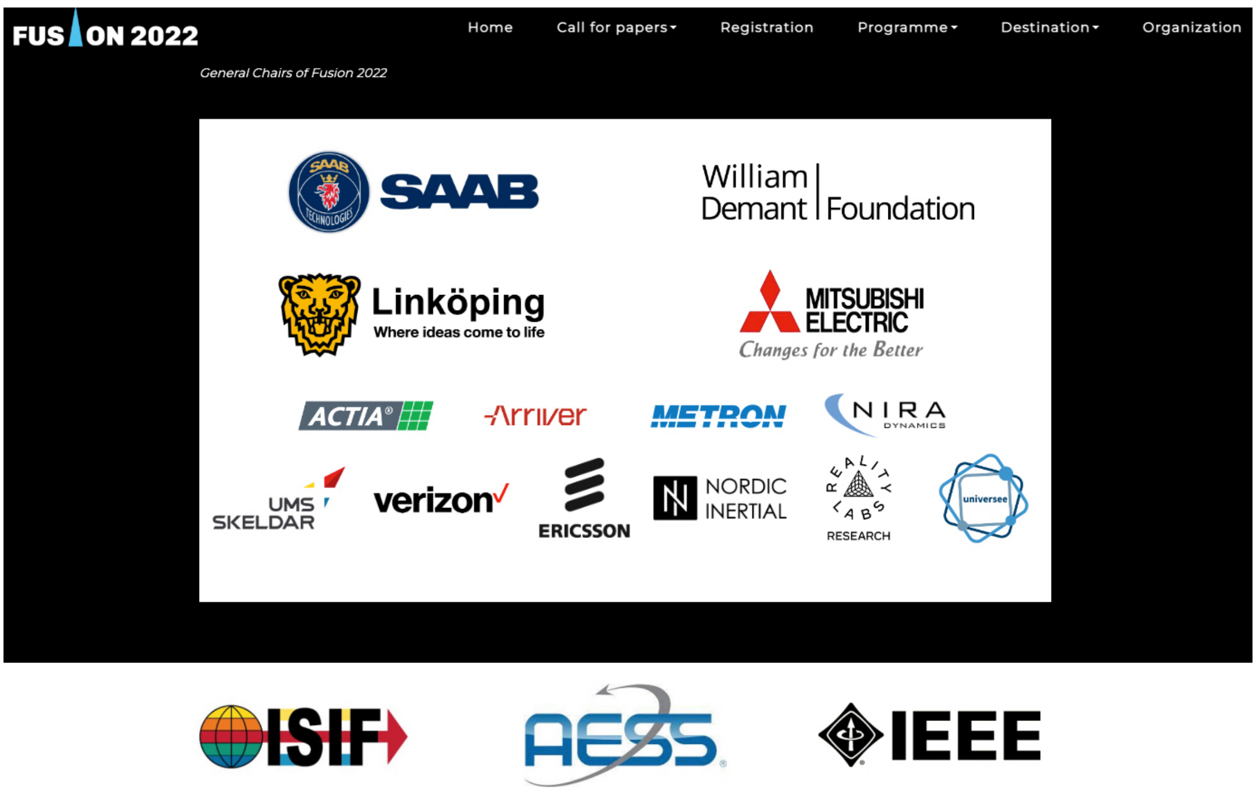

Fig. 1: Fig. 01: UniverSee at Fusion'22

We also have a tutorial at the Programme/Tutorial Sessions with title:

Multi-Sensor and Data Fusion Approaches for Vehicular Automation Applications - autonomous driving: concepts, implements and evaluation.

Invited Seminar at AviTec, Beijing, April 2023.

Dr. Ting Yuan and Dr. Anders Lindquist together on behalf of SSF lab. at SJTU join the committee of AviTec (China Civil Aviation Technology and Equipment Corporation Limited), including the Chairman Xinhong Zhou, VP Weiliang Tao and other Chief Engineers, with an intense discussion on topics of digitalization and Autonomy for Smart Airport.

Fig. 2: Fig. 02: SSF and AviTec on Aero-Autonomy

This is a meaningful event, reaching a verbal agreement on potential deep cooperation via an AviTec-SJTU joint research center.

CHAPTER

THREE

CONTRIBUTORS

Dr. Ting Yuan