Dual High-Resolution Radar Tracking

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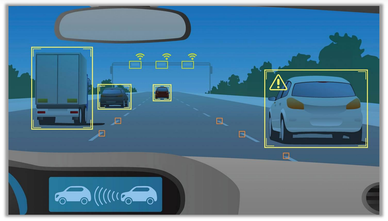
EECOMOBILITY (ORF) &
HEVPD&D CREATE

LOW-BANDWIDTH SOLUTIONS



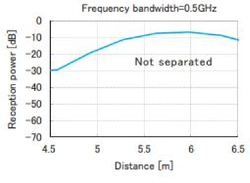
Currently used *sub-4GHz bandwidth radars* used in vehicles with *Autonomy Levels 2 and 3* provide low number of detections, with object separation of 1 meter or above. Low resolution results in inability to fully estimate target's dynamics, or estimation in a timely manner in general.

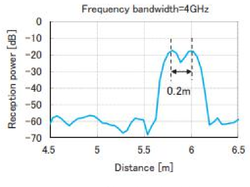
According to NHTSA [1], these radars fail in numerous scenarios associated with dynamic environments or limited visibility of the target's profile section, making them ill fit for higher levels of autonomy that demands operation in urban environment.

As the industry is moving towards higher levels of vehicle autonomy, a demand for the ultimate automotive sensors grows. Having a long history of application in *Level 1* systems such as ***A**daptive **C**ruise **C**ontrol* (**ACC**), radars have recommended themselves as a perfect match of cost and performance.

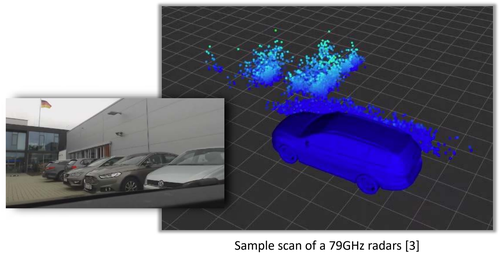
A series of major crashes of semi-autonomous *Level 2 and 3* systems in trivial ACC-oriented scenarios demonstrated deficiencies of the modern radar systems.

HIGH-RESOLUTION RADARS





Comparison of low-bandwidth 77GHz and high-bandwidth 79GHz radars [2]

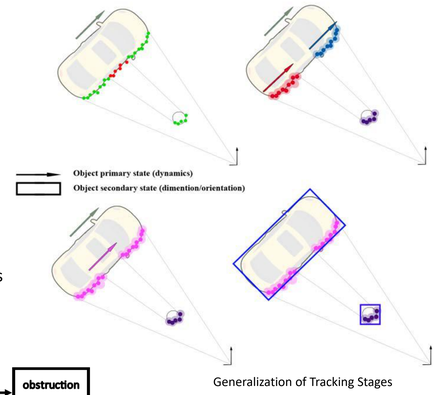


Sample scan of a 79GHz radars [3]

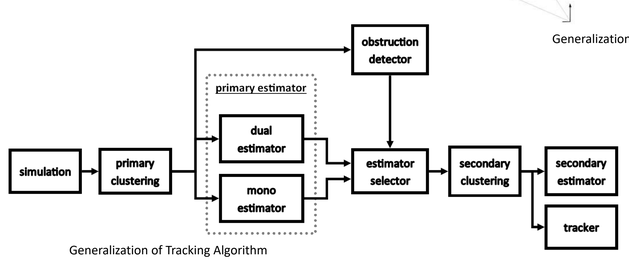
- Modern electronics allow operation at a higher frequency range of 79 GHz and an increased bandwidth of 4 GHz
- Higher amount of detail allows a more deterministic approach to state estimation
- High resolution provided by sub-meter object separation allows extraction of more states at less time

RESEARCH GOALS

- Instantaneous state extraction and track initialization of targets
- Extraction of complete vehicle dynamics states
- Handling of momentarily target obstructions by utilizing multi-state, multi-stage clustering
- Extraction of secondary states such as target's geometry for further classification

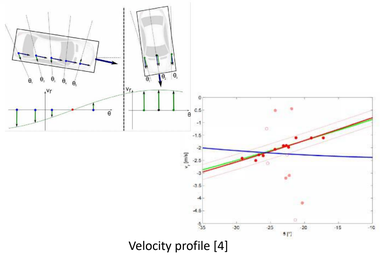


Generalization of Tracking Stages



Generalization of Tracking Algorithm

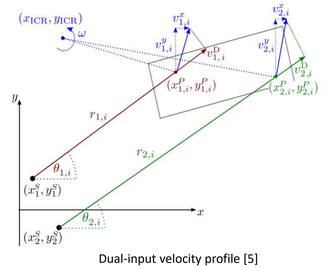
VELOCITY PROFILE



Velocity profile [4]

Collection of points associated with a single target allows for extraction of a sinusoid by means of ***O**rthogonal **D**istance **R**egression* (**ODR**). The resulting sinusoid is a representation of the **instantaneous velocity** vector relative to the radar (*velocity profile*).

Additional radars allow for expansion of the estimation algorithm, that now can be used to extract **full dynamics** of the vehicle such as velocity and center of rotation within the same frame the data was received.



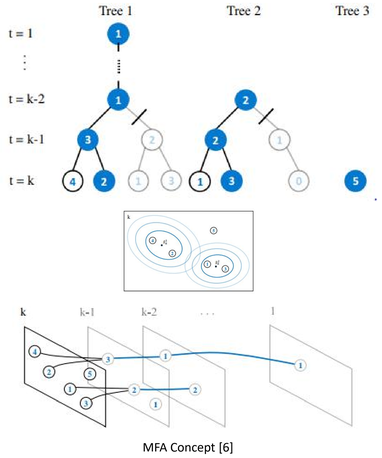
Dual-input velocity profile [5]

MFA TRACKING

***M**ultiple **F**rame **A**ssignment* (**MFA**) algorithms keep history of detections and utilize it for re-evaluation of validity of possible tracks, potentially generating a completely new set of tracks.

The algorithm effectively is a tree path minimization problem, the solution of which leads to the optimal track. While computationally intensive, this algorithm has been proven to be implementable on modern ECUs.

Utilization of MFA approach may reduce the effects of momentary complete target obstructions, as the algorithm inherently keeps the history of detections and will reconstruct proper track even if a detection for that particular object is missing or incorrect.



MFA Concept [6]

FUTURE WORK

Classification: Primary and Secondary States estimated by the algorithm can be used for target classification. Fuzzy Classifiers or Neural-Networks algorithms such as RCNN or YOLO may be utilized for this purpose.

Real-Time Implementation: Further work is required to study more efficient state estimation algorithms that can perform. The importance of this task grows as radars with more detailed scans become available.

On-Road Application: As the 79 GHz radar hardware becomes widely available and financially attractive, the idea of application of the algorithm in a real-world scenario becomes more feasible. This may involve a custom designed sensor array, or a 3rd party solution available on the market.

[1] Gillbert R L, Zoratti P K, Becker R; *Characterization and Evaluation of a Prototype Forward-Looking Automotive Radar (FLAR)*; FCC, Sep 1997
[2] Ohguchi K, Masayoshi S, Masayoki K; *79GHz Band Ultra-Wideband Automotive Radar;* Fujitsu Ten Tech. J. #39, 2013
[3] Smartmicro GmbH; *4D/HD Promotional Material*; 2019
[4] Kellner D, Barjenbrunch M; *Instantaneous Lateral Velocity Estimation of a Vehicle Using Doppler Radar*; IEEE, 21 Oct 2013
[5] Kellner D, Barjenbrunch M; *Instantaneous Full-Motion Estimation of Arbitrary Objects using Dual Doppler Radar*; IEEE, June 8-11 2014
[6] Kim C, Li F, Ciptadi A; *Multiple Hypothesis Tracking Revisited*; ICCV, 2015

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