On the fly localization and mapping using a 360° Field-of-View Microwave Radar Sensor

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Outline

1. Motivation
2. Radar Sensor & Radar Scan
3. Radar SLAM
4. Experiments
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1. **Motivation**
2. Radar Sensor & Radar Scan
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Why SLAM using a microwave radar sensor?

Benefits of Radar sensor

1. Objective: environment mapping in large outdoor environment.
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**Benefits of Radar sensor**

1. **Objective**: environment mapping in large outdoor environment.
2. **Needs of a high range sensor**: which overcomes the shortcomings of laser, video and sonar sensors.
3. **Antenna opening allows**: "penetrating" signal.
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1. Objective: environment mapping in large outdoor environment.
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4. Radar is robust to atmospheric conditions.
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Characteristics of the K2Pi FMCW radar

The K2Pi radar:

- called K2Pi (2π for panoramic - in K band).
- developed by a Cemagref team.
- on board the R-Trooper of THALES.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier frequency $F_0$</td>
<td>24 GHz</td>
</tr>
<tr>
<td>Transmitter power $P_t$</td>
<td>20 dBm</td>
</tr>
<tr>
<td>Antenna gain $G$</td>
<td>20 dB</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>250 MHz</td>
</tr>
<tr>
<td>Scanning rate</td>
<td>1 Hz</td>
</tr>
<tr>
<td>Angular resolution</td>
<td>3°</td>
</tr>
<tr>
<td>Angular precision</td>
<td>0.1°</td>
</tr>
<tr>
<td>Range Min/Max</td>
<td>3 m/100 m</td>
</tr>
<tr>
<td>Distance resolution</td>
<td>0.6 m</td>
</tr>
<tr>
<td>Distance precision</td>
<td>0.05 m</td>
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K2Pi radar is based on FMCW technology.
Radar data

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2. For each radar beam, a complex temporal received signal is obtained.

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3. Each radar beam is treated by a frequency analysis and represented by a power spectrum which carries information about the environment.
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How to do SLAM with these radar data?

1. A view-based SLAM approach: scan-matching
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2. Some results of radar-scan-matching approach (IROS 09)
How to do SLAM with these radar data?

1. A sparse SLAM approach: objects extraction and tracking

[Images of power spectrum, power spectrum interpretation, and map of extracted objects]
How to do SLAM with these radar data?

1. A sparse SLAM approach: objects extraction and tracking
   - Power spectrum
   - Power spectrum interpretation
   - Map of extracted objects

2. Extraction of entities for a future SLAMMOT extension
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   - Data complexity, multi-travelling, ground noise.
   - Radar phenomena:
     - Doppler effect due to radar and object movement,
     - Speckle effect (interference).
On the fly SLAM with radar data: Principle

Why a "On the fly SLAM"?

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6. Extraction of object which can be localized and tracked,
7. On the fly observation are sent to SLAM process.
Acquisition & processing of a single radar beam

Interpretation of each radar beam: extraction of relevant amplitudes,
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1. Interpretation of each radar beam: extraction of relevant amplitudes,
2. Doppler effect due to target and radar movement is taken into account in measurement formulation:

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   (2)
3. Pose of punctual impacts obtained in radar frame.
On the fly SLAM: Interpretation

1. Extraction of *N punctual objects* on each radar beam,
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**Punctual measurement evolution**  
**Object construction**  
**Object interpretation**
On the fly SLAM: Interpretation

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   - which are not easily re-observable due to Speckle effect and radar displacement,
   - Punctual detections are aggregated into objects,
   - Extraction of more easily detectable geometric feature from objects.

![Punctual measurement evolution](image1)

![Object construction](image2)

![Object interpretation](image3)
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On the fly SLAM: experiments on simulated data

1. Static and dynamic environments can be used.
2. Radar data are modeled thanks to a radar simulator provided by Cemagref.
3. Odometric, gyroscopic and GPS measurements are generated.
On the fly SLAM: experiments on simulated data

1. A 400 meter simulated trajectory at the speed of $10m.s^{-1}$.
2. **Continuous** geometric landmarks detection and use during the vehicle motion to improve the localization and build a map.
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![Graph](image1.png)

![Graph](image2.png)
On the fly SLAM: first results on real data

1. Punctual extraction
2. Aggregation into objects
3. Object interpretation: geometric feature extraction
On the fly SLAM: first results on real data

Detection, Aggregation and interpretation on 8 consecutive scans:

1. **SLAM not robust** on real data for significant distance,
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Detection, Aggregation and interpretation on 8 consecutive scans:

1. SLAM not robust on real data for significative distance,
2. Data Association problem due to high noised and instable data.
Summary

1. This approach is a preliminary work to use radar data on the fly in order to do SLAM/SLAMMOT.

2. A complete radar image is not required to do localization.

3. We presented objects and features extraction taking into account Doppler effect due to radar movement on simulated and real data.

4. Next generation of radar, called IMPALA, will give the measurement of Doppler frequency to take the relative velocity of mobile targets into account. So a classification of object (static / dynamic) will be possible.

5. Once the classification done, integration of SLAM with Mobile Object Tracking (SLAMMOT) will be considered.
Thank you for your attention

Any questions?

Acknowledgements

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