TELEMATICS
MOBILE INFORMATION EXCHANGE

3-Axis Accelerometer Orientation Application Note

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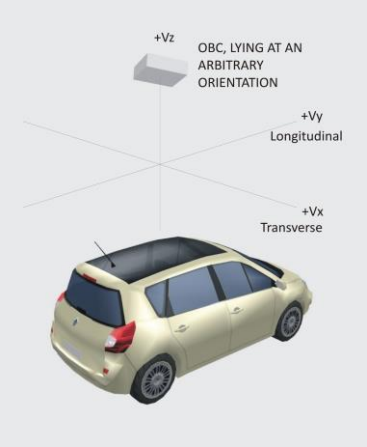
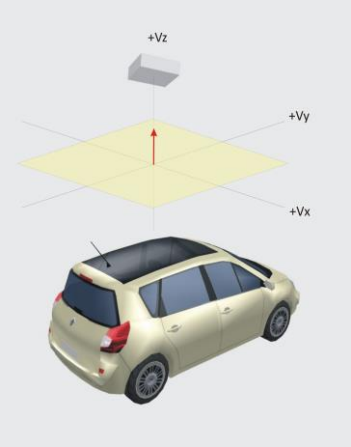
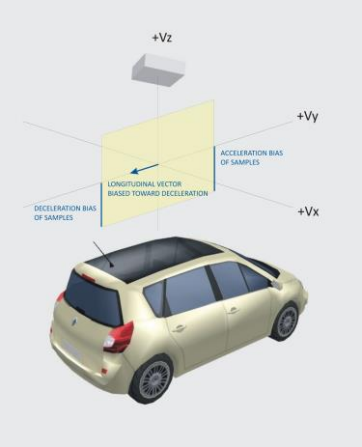
1 Overview

The purpose of this document is to provide a detailed and technical description of how the 3-Axis accelerometer data is used to automatically calibrate the XYZ axis of the unit after installation. The same algorithms are used on the FM3xxx, MiX4000 and MiX6000, so the document will discuss the algorithm without referring to a specific unit type. Also note that the new units might not have all the functionality implemented with the first release.

The problem is depicted in the figures below.

The on-board computer (OBC) is mounted in the vehicle in an arbitrary orientation.	The gravity vector Z can be used to calculate the XY horizontal plane.	The algorithm needs to identify the YZ vertical plane from the accelerometer data and also determine which side is forward (acceleration) or backward (deceleration).
		

The OBC must analyse the input data and decide which results are good or bad for calibration. It is therefore important to note that it will only select data with the highest probability of yielding good results, which is every time the vehicle stops.

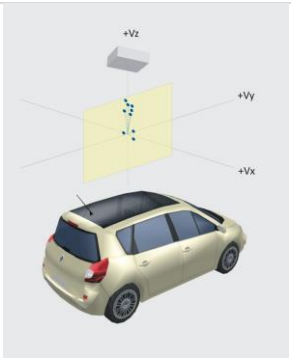
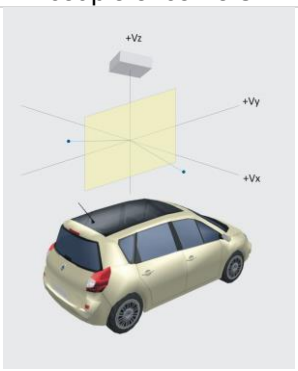
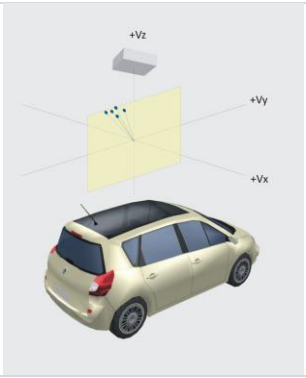
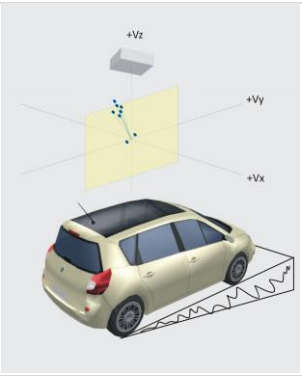
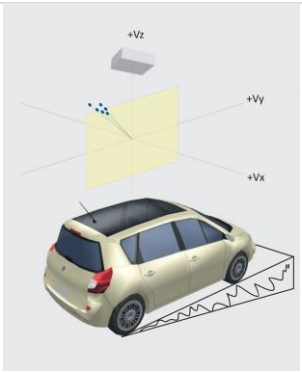
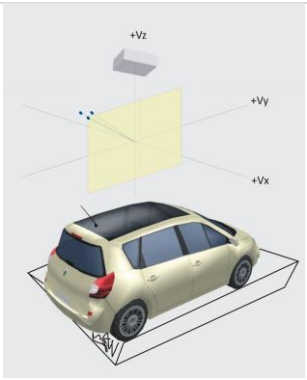
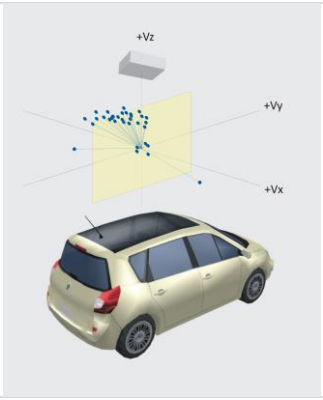
There are 3 possible data collection stages for orientation:

1) At a start of a trip – this is usually not good, because the vehicle can turn in or out of driveways/roads or initially drive backwards.
2) During a trip – this is also not very good for gathering data because there will usually not be a lot of acceleration and deceleration in the longitudinal plane.
3) When the vehicle stops – this is the best stage to gather data, because the vehicle is least likely to be turning when it is stopping. In addition, the camber on roads is normally flat at braking points.

The speed of the vehicle is also taken into consideration and the calibration algorithm will only consider areas where the speed is decreasing continuously until it is zero (stopping). If the speed does not decrease until it reaches zero, that period will be excluded from consideration, i.e. if the vehicle decelerates but did not come to a complete stop.

2 Why can it take a few trips to calculate the orientation?

Calibration data is only collected when the vehicle is stopping with various different scenarios that will influence the quality of the data (see pictures below for the scenarios).

Driving without braking.	Braking while taking a couple of corners.	Braking in a straight line.	Driving without braking on an incline.
			
Braking on an incline.	Braking on a surface with chamber.	All samples combined.	
			

The algorithm therefore must apply some filtering on the data to discard some samples. This sampled data is persisted between trips and ignition on/off cycles and the calibration is only applied when all the criteria is met.

<u>The following criteria must be met before the orientation can be calculated:</u>

- The unit must first calculate the average of 8 in-trip gravity vectors. These are measured once every 30 seconds while the vehicle is moving faster than 30km/h. If the vehicle isn't moving faster than 30km/h at the 30 second interval, it doesn't measure a gravity vector.

- Immediately after calculating the in-trip gravity vector (this can be during the same trip), the unit will start to record stop vectors. The vehicle needs to have started the deceleration from a speed of greater than 60km/h until it comes to a complete stop for 5 seconds. The stop vector can be rejected for the following reasons:
  - Vehicle started moving before 5 seconds have passed.
  - The vehicle decelerated too fast or too little.
  - The deceleration strength varied too much (e.g. breaking hard and then soft).
  - The unit has not yet measured 8 in-trip gravity vectors.

- The unit will continue to record stop vectors to keep improving the average stop vector, but 10 is the minimal requirement.

- Once the trip is ended the unit will complete the orientation calculations if at least 8 in trip gravity vectors and 10 stop vectors have been recorded. The orientation is then persisted.

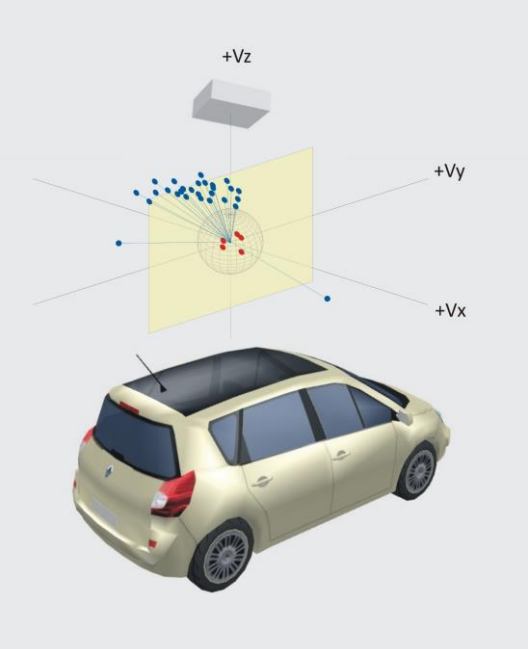
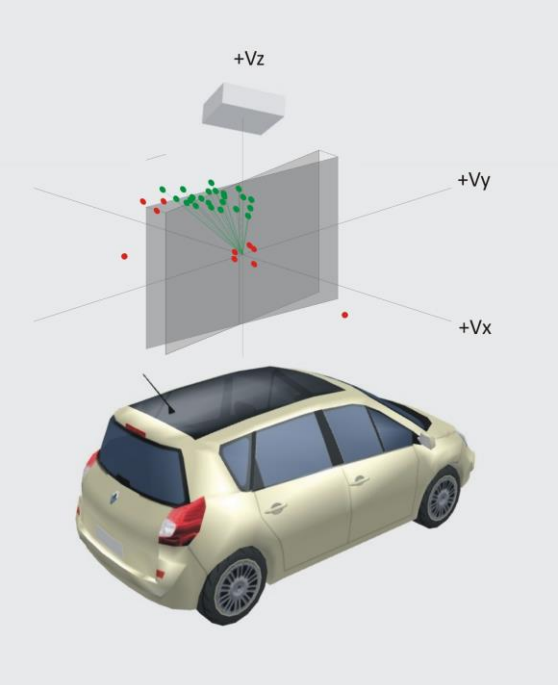
It is therefore quite obvious that orientation can be achieved from just one trip or might take multiple trips. It all depends on how quickly the orientation requirements are met. See section *3 – What filtering is applied* for the summarised requirements in tabular form.

3 What filtering is applied?

The following rules and thresholds are applied by default (changeable via settings):

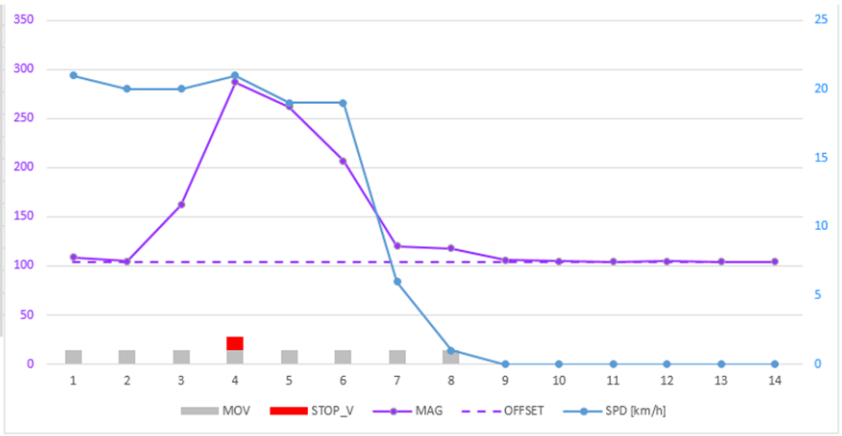
Description	Value
Number of long term in-trip gravity samples to take for the new calibration settings to be accepted.	8 samples
Period in seconds between sampling of long term in-trip gravity samples.	30 seconds
Minimum vehicle speed (km/h) required for a long term in-trip gravity sample to be accepted.	30 km/h
Number of vehicle stops required for the new calibration settings to be accepted (can span over many trips).	10 stops

Below is a graphical example of other filters that are applied to the data.

A sphere filter will filter out the small vectors that occur with normal driving. We are only interested in the larger vectors that are present for longer periods of time.	A corridor filter will consider where the bulk of the samples reside and discard those that lie outside of the corridor. It will exclude the turning samples and samples generated on road sections with chamber. The orientation of the corridor filter is the longitudinal orientation.
	

The following picture shows a sample that were acceptable for calibration since the vehicle came to a complete stop.

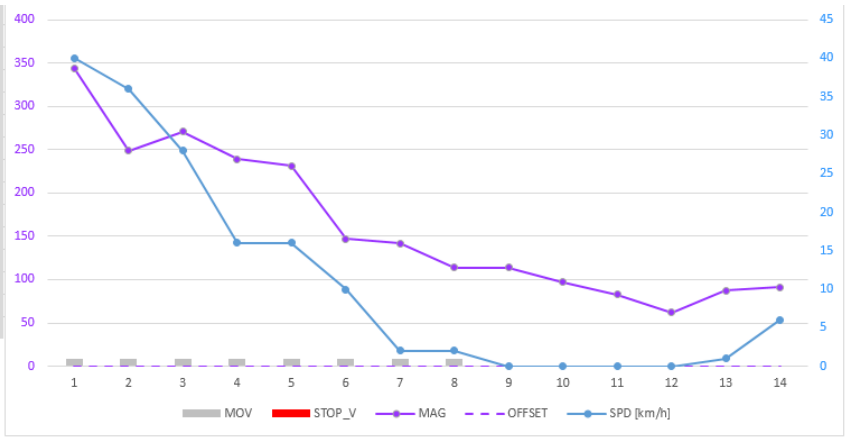
@RAW	SPD [km/h]	X	Y	Z	MOV	MAG	OFFST	STOPV
@RAW	21	77	38	991	1	109	104	0
@RAW	20	81	43	995	1	105	104	0
@RAW	20	37	-9	1000	1	162	104	0
@RAW	21	-36	-114	1017	1	287	104	1
@RAW	19	-23	-92	1016	1	262	104	0
@RAW	19	4	-45	1005	1	207	104	0
@RAW	6	61	28	992	1	120	104	0
@RAW	1	62	31	994	1	118	104	0
@RAW	0	73	42	992	0	106	104	0
@RAW	0	71	42	990	0	105	104	0
@RAW	0	75	43	989	0	104	104	0
@RAW	0	72	42	990	0	105	104	0
@RAW	0	74	43	987	0	104	104	0
@RAW	0	72	43	989	0	104	104	0



stopMagnitude	183	Expect > 50
PostStopVariance	2	Expect <= 15

The following example shows a sample of data that was discarded (not used for calibration) since the vehicle did not come to a complete stop.

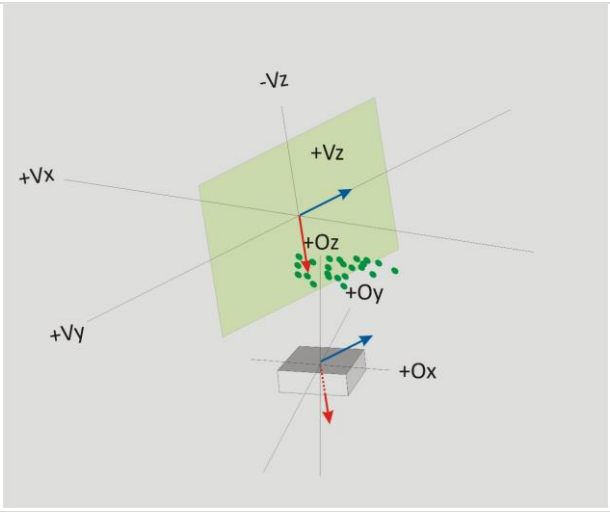
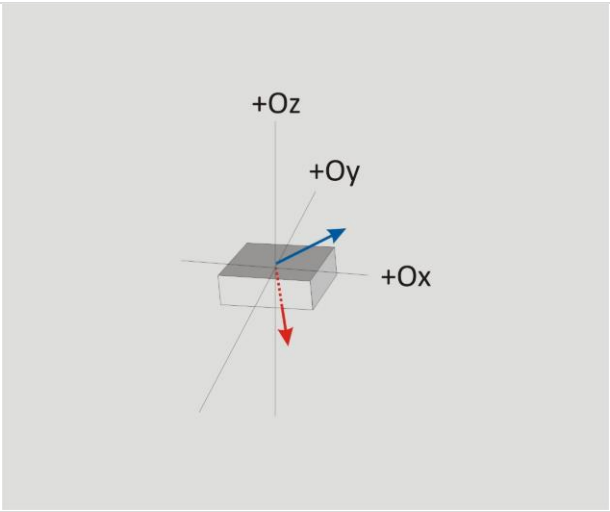
@RAW	SPD [km/h]	X	Y	Z	MOV	MAG	OFFST	STOPV
@RAW	40	-95	-147	1025	1	344	0	0
@RAW	36	-37	-71	1016	1	249	0	0
@RAW	28	-51	-90	1014	1	271	0	0
@RAW	16	-34	-62	1014	1	239	0	0
@RAW	16	-28	-56	1011	1	231	0	0
@RAW	10	16	14	998	1	147	0	0
@RAW	2	19	19	1000	1	142	0	0
@RAW	2	37	41	994	1	114	0	0
@RAW	0	35	42	993	0	114	0	0
@RAW	0	48	55	991	0	97	0	0
@RAW	0	57	67	988	0	83	0	0
@RAW	0	133	174	977	0	62	0	0
@RAW	1	146	199	976	0	87	0	0
@RAW	6	145	207	974	0	91	0	0



stopMagnitude	N/A	Expect > 50
PostStopVariance	52	Expect <= 15

4 How is data transformed after auto calibration?

The XYZ axis is transformed in real time to the axis of the vehicle and the output data is fed into a statistical engine to produce the same values and event thresholds as the old impact sensor.

Looking at it from the OBS's perspective the gravity vector (red) and the longitudinal vector (blue) are shown below.	These vectors are persisted and the OBC's axis is transformed in real time to the vehicle axis. The output data (XYZ) are then fed into the same statistical engine that are used to report the impact sensor.
	

5 When is re-calibration done?

During the first 5 seconds of a trip (after Ignition ON) the unit will compare the orientation of the "gravity vector" with a saved value – if the difference between these values are greater than the threshold, the unit will assume that it has been moved to a different vehicle or that the installation has changed, and it will start a new calibration process (re-calibrate)

It is therefore possible that the unit can re-calibrate in the following scenarios:

1) If you start driving within the first 5 seconds and ends-up at a location that is on a sharp incline or decline or sideways angle.
2) If you move the vehicle while ignition is off into a position with a sharp incline or decline or sideways angle.

Re-calibration will affect the various parameters as follows:

- Road Roughness – no impact
- Impact Detection – no impact
- Harsh acceleration – needs to be re-calibrated
- Harsh braking – needs to be re-calibrated
- Harsh cornering - needs to be re-calibrated
- Lift-off - needs to be re-calibrated