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English version

Space - Use of GNSS-based positioning for road Intelligent Transport Systems (ITS) - Metrics and Performance levels detailed definition

Espace - Utilisation de la localisation basée sur les GNSS pour les systèmes de transport routiers intelligents - Définition détaillée des mesures et niveaux de performance

Detaillierte Definition von Metriken und Leistungsstufen

This Technical Report was approved by CEN on 13 January 2020. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

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European foreword

This document (CEN/TR 17448:2020) has been prepared by Technical Committee CEN/JTC 5 “Space”, the secretariat of which is held by DIN.

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1 Scope

This document constitutes the main deliverable from WP1.1 of the GP-START project. It is devoted to a thorough review of the metrics defined in EN 16803-1 and proposes a performance classification for GNSS-based positioning terminals within designed for road applications. It will serve as one of the inputs to the elaboration of prEN 16803-2:2019 and prEN 16803-3:2019.

This document should serve as a starting point for discussion within CEN/CENELEC/JTC 5/WG1 on a consolidated set of performance metrics and associated classification logic. The proposals and conclusions appearing in this document are therefore only preliminary.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 16803-1:2016, *Space - Use of GNSS-based positioning for road Intelligent Transport Systems (ITS) - Part 1: Definitions and system engineering procedures for the establishment and assessment of performances*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 16803-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 List of acronyms

ADAS	Advanced Driver Assistance Systems
CAN	Controller Area Network
CDF	Cumulative Distribution Function
CEN	Comité Européen de Normalization — (*European Committee for Standardization*)
CENELEC	Comité Européen de Normalization Électrotechnique — (*European Committee for Electrotechnical Standardization*)
ECEF	Earth Centred Earth Fixed
ETSI	European Telecommunications Standards Institute
GBPT	GNSS-Based Positioning Terminal
GNSS	Global Navigation Satellite Systems
HPA	Horizontal Position Error
HPL	Horizontal Protection Level
IMU	Inertial Measurement Unit
ITS	Intelligent Transport Systems
KOM	Kick-Off Meeting
MEMS	Micro Electro-Mechanical Systems

NMEA	National Marine Electronics Association
PPP	Precise Point Positioning
RTCA	Radio Technical Commission for Aeronautics
RTK	Real Time Kinematics
SPP	Standard Point Positioning
TTFF	Time To First Fix

5 Review of EN 16803-1 Performance Metrics

5.1 Potential Improvements of unstable definitions

5.1.1 Position accuracy metrics

5.1.1.1 Vectors vs their Norms

One thing that draws immediate attention when reviewing the metrics is some degree of ambiguity in some of the definitions. For instance, the first Accuracy metric (EN 16803-1:2016, Table 1) refers to the "3D position error", which has not been explicitly defined anywhere along the document:

3D Position Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of 3D position errors.

There is some discussion in EN 16803-1:2016, 3.2.1 regarding vector and scalar quantities, but no explicit definition of the 3D position error is proposed. The position error (without the "3D" adjective) is defined in EN 16803-1:2016, 4.3 as follows:

Position error: is the difference between the true position and the position provided by the positioning terminal. It shall be understood as a vector expressed in some convenient local reference frame (e.g. local horizontal frame).

This definition explicitly states that the position error shall be understood as a vector quantity. Then, the use of the expression "3D position error" in the definition of the metric seems to emphasize the vector character of the position error, which may be misleading since the metric actually refers to the norm of the position error vector, which is actually a scalar quantity.

The same concern can be raised about the horizontal position error. It is therefore recommended to include explanations on the meaning of expressions such as "3D position error" and "horizontal position error", making it clear that they refer to norms of vectors rather than vectors. Note that footnote 5 on EN 16803-1:2016, A.2.1 of the document contains such a clarification for the case of the horizontal position error, but a footnote in an annex may not be the best place for it (besides, the expression "it is recalled" seems to indicate that the definition was written in some other, more prominent place within the document and later removed).

NOTE The norm of a vector is not uniquely defined. To overcome this problem, it could be further specified that the norm of interest is the Euclidean norm (square root of the sum of squared coordinates) of the vector when expressed in a linear (and orthonormal) coordinate system. Suppose, for instance, that the position is expressed in geodetic coordinates (latitude, longitude and height) and the position error is expressed as a latitude error, a longitude error and a height error. The square root of the sum of the squares of these 3 quantities has no physical meaning, and is not what is meant in the above proposed definition. It could be worth making this sort of considerations in the standard.

A related remark (although not concerned with performance metrics) is on the identification of the GBPT outputs made in EN 16803-1:2016, 4.2, which may require some review and perhaps include attitude parameters (e.g. heading) or make some additional considerations on the reference frame used to represent position and velocity (e.g. horizontal velocity could be represented in polar coordinates as a pair consisting of speed and heading).

5.1.1.2 Along Track and Cross Track Components

Another potential issue that has been detected is the fact that the expressions "along track" and "cross track" are undefined, yielding the definitions of "*along track*" and "*cross track*" position accuracy a little ambiguous. It is recommended to include the definitions of these terms somewhere in the document, especially considering that there is no general agreement as to their meanings. Note that these terms have their roots in aeronautics and astronautics, and have been widely use to describe the motion of space vehicles, such as artificial satellites, especially when in orbit around the Earth. Each satellite is assigned a body-centred orthogonal reference frame with axes pointing:

— in the satellite's direction of motion;

— in the direction orthogonal to the orbital plane;

— in the direction orthogonal to the previous 2.

However, since most orbits are nearly circular, the third direction is roughly pointing to the centre of the Earth, and in some cases, this is how the third axis is defined, implying a slight misalignment of the first with respect to the satellite's direction of motion. Besides, the direction of motion is not well defined unless the satellite's trajectory is referred to an external (not body-centred) reference frame, such as one with origin at the centre of the Earth. Depending on how this external frame is chosen (e.g. an inertial frame vs one which rotates with the Earth), the satellite's direction of motion may be different.

In road applications the situation is also somewhat complicated. It may seem natural to define the along track direction as the one parallel to the vehicle's velocity vector, but caution shall be taken as to the reference frame used to define the vehicle's motion. A natural choice would be an Earth-centred, Earth-fixed (ECEF) frame, such as WGS84. Of course, when the vehicle is standing still, the along track direction is not well defined using the velocity vector (which in this case is the null vector), but still the last along track direction computed before the vehicle stopped could be used (besides, there is no actual "track" when the vehicle is not moving, so the along track and cross track errors may not make much sense in that case either). However, there is still the problem of defining the cross-track direction, and now there is no such thing as an orbital plane. Among all directions orthogonal to the along track axis, a natural choice seems to be the one lying on the horizontal plane (well defined unless the vehicle's motion is purely vertical, which is an extremely unlikely situation in road applications). Another natural option seems to be the one lying on the local road plane, which may differ from the horizontal plane due to road banking. This second option may be of interest when an inertial measurement unit (IMU) is involved in the navigation process, as the local road plane is nearly fixed with respect to the IMU axes. However, the first option seems better for most implementations as it does not require any prior knowledge of the road geometry or of the vehicle's attitude. There's yet a third option to be considered in which the cross-track direction is the one defined by the normal acceleration vector, but this has an important drawback, namely that the normal acceleration is nearly zero when in low-dynamics situations (such as driving along a nearly straight road or a highway). Hence the first option continues to seem the most convenient one. With this in mind, the following definition is proposed:

Along track and cross track components are coordinates in a reference frame whose definition is based on the vehicle's true velocity vector $\vec{v}$ (relative to some ECEF reference frame) and the local upward unit vector $\vec{\eta}$. Namely, the said reference frame is defined by the following 3 orthogonal unit vectors: $\vec{\tau} = \vec{v} / \left\| \vec{v} \right\|$, $\vec{n} = \vec{\eta} \times \vec{v} / \left\| \vec{\eta} \times \vec{v} \right\|$ and $\vec{\mathrm{b}} = \vec{\tau} \times \vec{\mathrm{n}}$. The along track and cross track components of a vector $\vec{\varepsilon}$ attached to the user's position (such as the position error vector) are then defined as the scalar products $\vec{\varepsilon} \cdot \vec{\tau}$ and $\vec{\varepsilon} \cdot \vec{\mathrm{n}}$, respectively.

NOTE 1 The vector $\vec{n}$ as defined above corresponds to the first of the 3 options previously discussed: it is orthogonal to the along track direction (given by $\vec{v}$) and lies on the horizontal plane (as it is orthogonal to $\vec{\eta}$).

NOTE 2 The notation used to define the reference frame is commonly used to denote the so-called Frenet trihedron, although the reference frame defined above and the Frenet trihedron are not exactly the same (rather, the Frenet trihedron would correspond to the third option, which has been readily discarded).