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TECHNICAL REPORT

colour inside

Safety of machinery – Part 2: Examples of application

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CONTENTS

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FOREWORD

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IEC TR 62998-2, which is a Technical Report, has been prepared by IEC technical committee TC 44: Safety of machinery – Electrotechnical aspects.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
44/849/DTR	44/865A/RVDTR

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

This document is to be used in conjunction with IEC TS 62998-1:2019.

A list of all parts in the IEC 62998 series, published under the general title *Safety of machinery*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

reconfirmed,

withdrawn,

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amended.

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INTRODUCTION

Safety-related sensors are applied to machinery presenting a risk of personal injury. They provide protection by causing the machine to revert to a safe condition before a person can be placed in a hazardous situation.

IEC TS 62998-1:2019 is intended for use by safety-related sensor manufacturers and integrators of safety-related sensors for the design of safety-related sensor systems used for the protection of persons.

This document gives guidance for manufacturers and integrators on the application of IEC TS 62998-1:2019.

SAFETY OF MACHINERY –

Part 2: Examples of application

1 Scope

This document establishes guidance for the application of IEC TS 62998-1:2019.

It provides examples of:

– application for which SRS/SRSS are relevant,
– use of SRS/SRSS information from an application point of view,
– fusion of SRS into SRSS for given applications, and
– appropriate information for use for given applications.

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.

IEC TS 62998-1:2019, *Safety of machinery – Safety-related sensors used for protection of persons*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Terms and definitions

3.1.1
mobile robot
robot able to travel under its own control

[SOURCE: ISO 8373:2012, 2.13, modified – The note has been omitted.]

3.1.2
robot
actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks

[SOURCE: ISO 8373:2012, 2.6, modified – Notes 1 and 2 have been omitted.]

3.2 Abbreviated terms

CHE container-handling equipment
ALARP as low as reasonably practical
LiDAR light detection and ranging
MOR meteorological optical range
TOF time of flight
SLAM Simultaneous Localization and Mapping
SRS safety-related sensor
SRSS safety-related sensor system
SCS safety-related control system

4 Applications for mobile robots

4.1 General

This example covers the integration and installation phase using fusion of three SRSs into an SRSS in accordance with Clause 6 of IEC TS 62998-1:2019 to improve sensing zones and safety-related zones in accordance with requirements for the intended use. The intended uses are 2 different mobile robot types, in accordance with ISO 13482:2014, that operate autonomously in a public area with limited access. The reader should be aware that the following descriptions are not based on comprehensive analysis and are only examples for mobile robotics.

NOTE ISO 13482:2014 covers mobile robots operating in an autonomous manner. For simplification, the term "mobile robot" will be used from now on.

Two different mobile robots operate on a certain university campus with buildings to achieve:

transport of in-house mail items among office buildings of the university, and

cleaning of pavements of the university.

Figure 1 shows the typical outdoor pavement of a university campus. Person(s) being present or approaching the safety related zone(s) of an SRSS should be detected and the safety-related control system should initiate appropriate reaction of the mobile robot.

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Figure 1 – Outdoor scene

4.2 SRSS on mail transport mobile robot

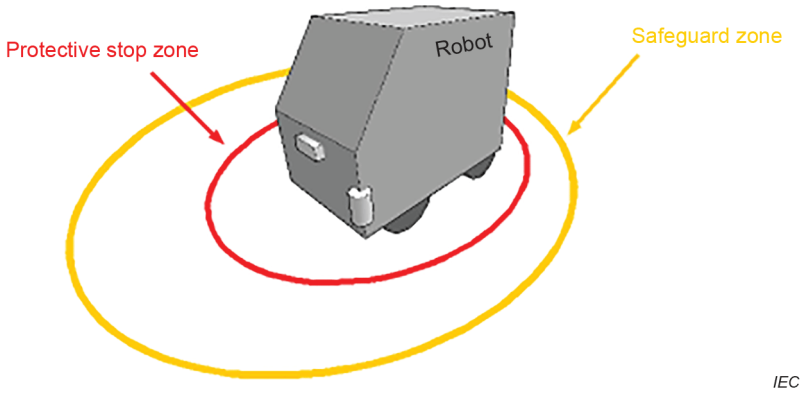
4.2.1 Intended use

The intended use should be determined (see 6.2.1 of IEC TS 62998-1:2019) by the integrator. It is defined by the following selected example items:

1) The mobile robot is a Type 1.1 robot specified in ISO 13482:2014 with a weight of 30 kg and size of length: 500mm × width: 500mm × height: 600mm.
2) The mobile robot automatically navigates the pavement connecting the university office buildings. The path of the robot is predetermined according to the map created by SLAM technology [1][1] and physical constraints. The map includes position information for objects that are fixed along the pavement, such as guardrails, building walls, trees, etc. By referring to the map, the robot determines its own restricted space (ISO 13482:2014, 3.18.2) while moving.
3) The mobile robot moves during daytime on non-carriageways where:
   a) light vehicles such as bicycles are not allowed to enter;
   b) wheelchairs can enter;
   c) pavements are smooth paved with slopes of up to 5 degrees in some areas, as shown in Figure 1;
   d) standing or walking people on the pavements are adults and/or children. Children under and including 3 years are assumed to be controlled and children from 4 years up to including 10 years are assumed to be accompanied by adults. An adult might not accompany children over 10 years up to 14. For the purpose of this example, the speed of a person towards the mobile robot is assumed to be between 0 mm/s and 800 mm/s if the person enters into the safeguarded zone.

   NOTE The speed in this example deviates from ISO 13855:2010 under the assumption of different human behaviour in this application. For other applications, faster or slower speeds might be more appropriate. On the campus, people are informed by organizational measures and warning signals that running is not allowed in the areas where mobile robots are present. Other examples of properties are given in 4.2.4.
4) The mobile robot:
   a) is intended to make a protective stop when a standing or walking person comes into the protective stop zone (see Figure 2);
   b) is intended to reduce the speed when a standing or walking person moves into the safeguarded zone (see Figure 2);
   c) is driven with a speed up to 700 mm/s reduced by the safety related speed control function down to 300 mm/s;
   d) can reduce speed within 0,5 s from 700 mm/s to 300 mm/s, and another 0,2 s to reduce to zero speed;
   e) is intended to be used in the daytime.
5) The outdoor environmental conditions during operation:
   a) can be up to 10 mm/h precipitation;
   b) can have light interference representing daytime.

1 Numbers in square brackets refer to the Bibliography.



The mobile robot has two distinctive zones, in accordance with ISO 13482:2014. The protective stop zone, where the mobile robot performs a protective stop, and the safeguarded zone, where a safety-related speed control function is performed when a safety-related object is detected. In accordance with IEC TS 62998-1:2019, the protective stop zone and safeguarded zone would be safety-related zone(s).

Figure 2 – Mobile robot with 2 distinctive safety-related zones

4.2.2 SRSS performance class determination

In the chosen approach using ISO 13482:2014 the required performance level of the safety functions of a Type 1.1 mobile robot is PL b, in accordance with ISO 13849-1:2015. The safety functions include the protective stop function, the safety-related speed control function, the hazardous collision avoidance function, and the travel surface detection function in accordance with ISO 13482:2014, which will be initiated by the SRSS.

The required performance class of the SRSS corresponding to PL b is the sensor performance class B specified in IEC TS 62998-1:2019.

4.2.3 SRS limits of use and SRSS function

The SRSS consists of three SRSs defined by the manufacturer as follows (see Figure 3).

1. SRS1: a 2D LiDAR suitable to be used up to PL b, in accordance with ISO 13849-1:2015, which allows the detection of persons and other safety-related objects and the measurement of their positions and velocities with high accuracy. The systematic capabilities are assessed in accordance with IEC TS 62998-1:2019. The sensing zone is up to a radius of 7 000 mm, and a viewing angle of 270°. The detection capability is given for safety-related objects with the properties: minimum size 40 mm × 40mm; minimum object reflectivity 5 %; maximum object speed 1 600 mm/s. The response time is 0,05 s. Use in indoor and outdoor environmental conditions is possible within defined limits.
2. SRS2: a TOF camera suitable to be used up to PL b, in accordance with ISO 13849-1:2015, which allows detecting parts of 3D volumes of persons, road surface, and other safety-related objects using 3D imaging technology. The systematic capabilities are assessed in accordance with IEC TS 62998-1:2019. SRS2 is capable of measuring the position and velocity of objects within the 3D sensor coordinate system. The sensing zone is up to 4 000 mm and vertical and horizontal field of views angle of 60° and 70°, respectively. The detection capability is given for safety-related objects with properties: minimum size 40 mm × 40 mm × 40 mm; minimum object reflectivity 5 %; maximum object speed 1 600 mm/s. The response time is 0,05 s. It is possible to distinguish a paved road surface and other objects three-dimensionally. Use in indoor and outdoor environmental conditions is possible within defined limits.
3. SRS3: the same specification as SRS1.

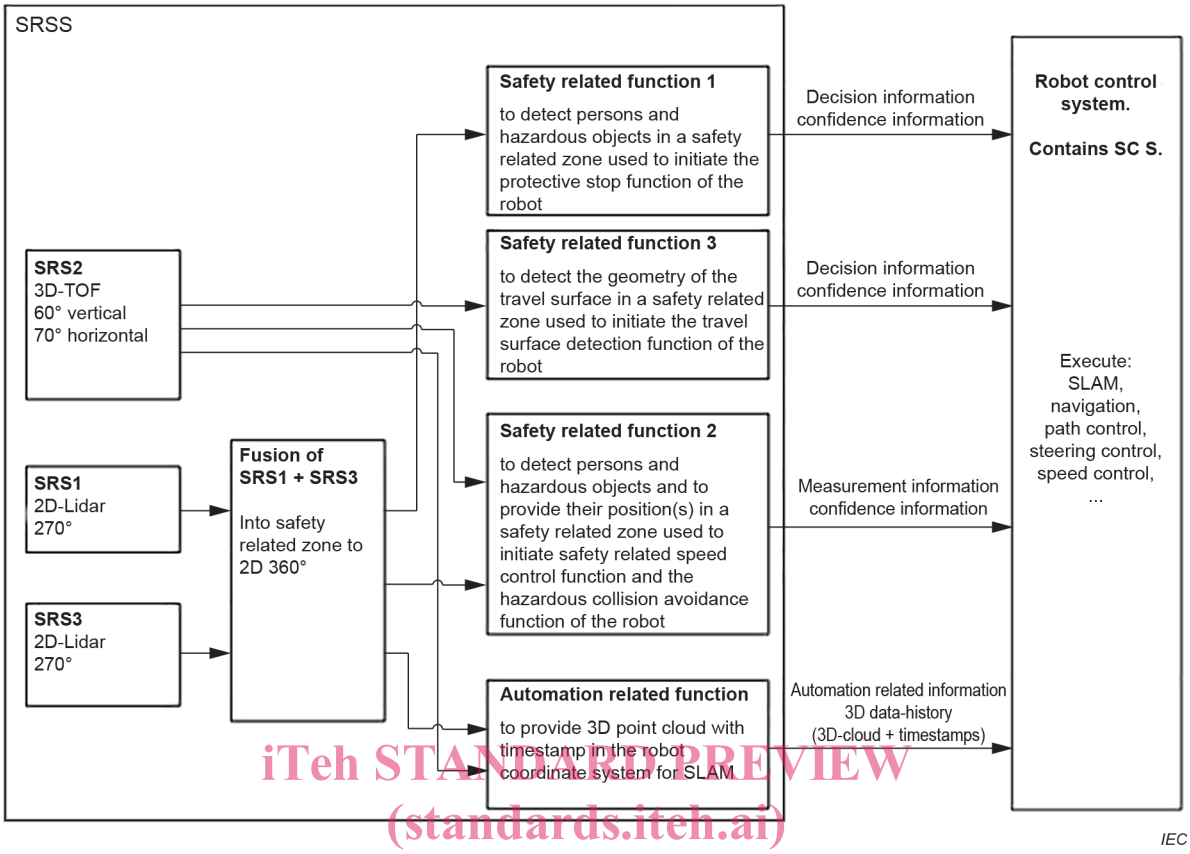


Figure 3 – Combination of three SRSs into an SRSS and SRSS functions

The target applications require four SRSS functions (see Figure 3):

- Safety-related function 1: to detect persons and hazardous objects in the protective stop zone for initiating the protective stop function specified in ISO 13482:2014, 6.2.2.3.
- Safety-related function 2: to detect persons and hazardous objects and to provide their positions and velocities as safety-related information for the safety-related speed control function and/or the hazardous collision avoidance function specified in ISO 13482:2014, 6.4 and 6.5.2.1.
- Safety-related function 3: to detect the geometry of the travel surface of the robot as specified in ISO 13482:2014, 6.5.3. When a travelable surface is observed in the travelling direction of the robot, the robot can move forwards. If the robot moves backwards, the road surface that it has already travelled is definitely present, so this function is not required.
- Automation related function: to provide 3D point cloud with timestamp in the robot coordinate system for SLAM.

4.2.4 Safety-related requirements

The SRSS safety-related requirements should be specified by the integrator (see 6.2.1 of IEC TS 62998-1:2019) based on the intended use. For example, see the requirements defined in Table 1.