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Artificial Intelligence (AI) — Assessment of the robustness of neural networks

Part 1: Overview

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Foreword

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Introduction

When designing an AI system, several properties are often considered desirable, such as robustness, resiliency, reliability, accuracy, safety, security, privacy. A definition of robustness is provided in 3.6. Robustness is a crucial property that poses new challenges in the context of AI systems. For example, in AI systems there are some risks specifically tied to the robustness of AI systems. Understanding these risks is essential for the adoption of AI in many contexts. This document aims at providing an overview of the approaches available to assess these risks, with a particular focus on neural networks, which are heavily used in industry, government and academia.

In many organizations, software validation is an essential part of putting software into production. The objective is to ensure various properties including safety and performance of the software used in all parts of the system. In some domains, the software validation and verification process is also an important part of system certification. For example, in the automotive or aeronautic fields, existing standards, such as ISO 26262 or Reference [2], require some specific actions to justify the design, the implementation and the testing of any piece of embedded software.

The techniques used in AI systems are also subject to validation. However, common techniques used in AI systems pose new challenges that require specific approaches in order to ensure adequate testing and validation.

AI technologies are designed to fulfil various tasks, including interpolation/regression, classification and other tasks.

While many methods exist for validating non-AI systems, they are not always directly applicable to AI systems, and neural networks in particular. Neural network systems represent a specific challenge as they are both hard to explain and sometimes have unexpected behaviour due to their non-linear nature. As a result, alternative approaches are needed.

Methods are categorized into three groups: statistical methods, formal methods and empirical methods. This document provides background on these methods to assess the robustness of neural networks.

It is noted that characterizing the robustness of neural networks is an open area of research, and there are limitations to both testing and validation approaches.

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Artificial Intelligence (AI) — Assessment of the robustness of neural networks —

Part 1: Overview

1 Scope

This document provides background about existing methods to assess the robustness of neural networks.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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:

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

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

3.1
artificial intelligence
AI
<system>capability of an engineered system to acquire, process and apply knowledge and skills

3.2
field trial
trial of a new system in actual situations for which it is intended (potentially with a restricted user group)

Note 1 to entry: Situation encompasses environment and process of usage.

3.3
input data
data for which a deployed machine learning model calculates a predicted output or inference

Note 1 to entry: Input data is also referred to by machine learning practitioners as out-of-sample data, new data and production data.

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3.4
neural network
neural net
NN
artificial neural network
ANN
network of primitive processing elements connected by weighted links with adjustable weights, in which each element produces a value by applying a non-linear function to its input values, and transmits it to other elements or presents it as an output value

Note 1 to entry: Whereas some neural networks are intended to simulate the functioning of neurons in the nervous system, most neural networks are used in artificial intelligence as realizations of the connectionist model.

Note 2 to entry: Examples of non-linear functions are a threshold function, a sigmoid function and a polynomial function.

[SOURCE: ISO/IEC 2382:2015, 2120625, modified — Abbreviated terms have been added under the terms and Notes 3 to 5 to entry have been removed.]

3.5
requirement
statement which translates or expresses a need and its associated constraints and conditions

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.37]

3.6
robustness
ability of an AI system to maintain its level of performance under any circumstances

Note 1 to entry: This document mainly describes data input circumstances such as domain change but the definition is broader not to exclude hardware failure and other types of circumstances.

3.7
testing
activity in which a system or component is executed under specified conditions, the results are observed or recorded, and an evaluation is made of some aspect of the system or component

[SOURCE: ISO/IEC/IEEE 26513:2017, 3.42]

3.8
test data
subset of *input data* (3.3) samples used to assess the generalization error of a final machine learning (ML) model selected from a set of candidate ML models

[SOURCE: Reference [2]]

3.9
training dataset
set of samples used to fit a machine learning model

3.10
validation
confirmation, through the provision of objective evidence, that the *requirements* (3.5) for a specific intended use or application have been fulfilled

[SOURCE: ISO/IEC 25000:2014, 4.41, modified — Note 1 to entry has been removed.]

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3.11
validation data
subset of *input data* (3.3) samples used to assess the prediction error of a candidate machine learning model

Note 1 to entry: Machine learning (ML) model *validation* (3.10) can be used for ML model selection.

[SOURCE: Reference [2]]

3.12
verification
confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

[SOURCE: ISO/IEC 25000:2014, 4.43, modified — Note 1 to entry has been removed.]

4 Overview of the existing methods to assess the robustness of neural networks

4.1 General

4.1.1 Robustness concept

Robustness goals aim at answering the question "To what degree is the system required to be robust?" or "What are the robustness properties of interest?". Robustness properties demonstrate the degree to which the system performs with atypical data as opposed to the data expected in typical operations.

4.1.2 Typical workflow to assess robustness

This subclause explains how the robustness of neural networks is assessed for different classes of AI applications such as classification, interpolation and other complex tasks.

There are different ways to assess the robustness of neural networks using objective information. A typical workflow for determining neural network (or other technique) robustness is as shown in Figure 1.

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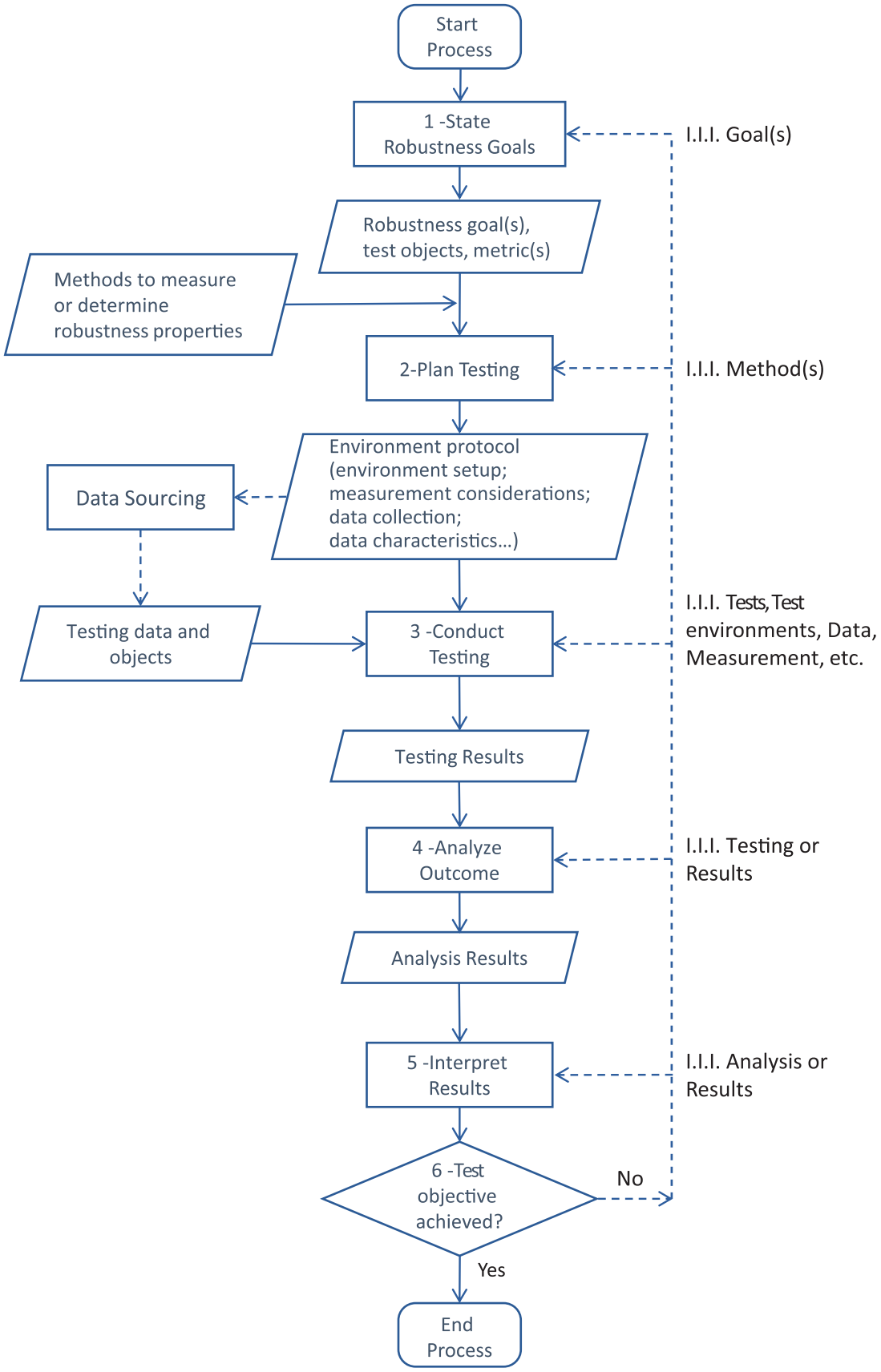

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