

# IEEE Standard for Fuzzy Markup Language

IEEE Computational Intelligence Society

Sponsored by the  
Standards Committee

# IEEE Standard for Fuzzy Markup Language

Sponsor

**Standards Committee**  
of the  
**IEEE Computational Intelligence Society**

Approved 29 January 2016

**IEEE-SA Standards Board**

Currently in preview, click buy full version

## Acknowledgments

Grateful acknowledgment is made to Springer Verlag for permission to reprint portions of the following source material:

“Fuzzy Markup Language: A XML Based Language for Enabling Full Interoperability in Fuzzy Systems Design,” in *On the Power of Fuzzy Markup Language* [B1], © 2013.

“An Enhanced Visual Environment for Designing, Testing and Developing FML-based Fuzzy Systems,” in *On the Power of Fuzzy Markup Language* [B2], © 2013.

“Distributing Fuzzy Reasoning through Fuzzy Markup Language: An Application to Ambient Intelligence,” in *On the Power of Fuzzy Markup Language* [B3], © 2013.

“On the Need of a Standard Language for Designing Fuzzy Systems, in *On the Power of Fuzzy Markup Language* [B7], © 2013.

**Abstract:** A new specification language, named Fuzzy Markup Language (FML), is presented in this standard, exploiting the benefits offered by eXtensible Markup Language (XML) specifications and related tools in order to model a fuzzy logic system in a human-readable and hardware independent way. Therefore, designers of industrial fuzzy systems are provided with a unified and high-level methodology for describing interoperable fuzzy systems. The W3C XML Schema definition language is used by this standard to define the syntax and semantics of the FML programs.

**Keywords:** eXtensible markup language, FML, fuzzy logic, fuzzy logic controller, Fuzzy Markup Language, fuzzy system, hardware independence, IEEE 1855™, interoperability, labeled tree, XML, XML Schema

---

The Institute of Electrical and Electronics Engineers, Inc.  
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2016 by The Institute of Electrical and Electronics Engineers, Inc.  
All rights reserved. Published 27 May 2016. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-1-5044-0677-2 STD20790  
Print: ISBN 978-1-5044-0678-9 STDPD20790

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

## **Important Notices and Disclaimers Concerning IEEE Standards Documents**

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

## **Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents**

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE-SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

## Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

## Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

## Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board  
445 Hoes Lane  
Piscataway, NJ 08854 USA

## Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

## Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

## Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

## Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at <http://ieeexplore.ieee.org/xpl/standards.jsp> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at <http://standards.ieee.org>.

## Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

## Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

## Participants

At the time this standard was completed, the IEEE P1855 Working Group had the following membership:

**Giovanni Acampora, *Chair***  
**Bruno Di Stefano, *Vice Chair***

Plamen Angelov  
Sansanee Auephanwiriyakul  
Walter Banks  
Aysenur Bilgin  
Sergio Guadarrama

Kiyota Hashimoto  
Uzay Kaymak  
Vladik Kreinovich  
Chang-Shing Lee  
Chin-Teng Lin  
Trevor Martin

Francisco José Moreno Velo  
Witold Pedrycz  
Marek Reformat  
Autilia Vitiello  
Dongrui Wu

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Giovanni Acampora  
Plamen Angelov  
Kofi Appiah  
Angelo Cangelosi  
S. Claassen  
Alessandro Di Nuovo  
Bruno Di Stefano  
Juan Manuel Escano  
Randall Groves

Christian Guenther  
Kiyota Hashimoto  
Noriyuki Ikeuchi  
Hisao Ishibuchi  
Uzay Kaymak  
Vladik Kreinovich  
Chang-Shing Lee  
Chin Teng Lin  
Pedro Machado  
Alyxander May

Thomas McManis  
Mehmet Fahri Akhavan  
Dmitryeychev  
Marek Reformat  
Thomas Starai  
Wil van der Aalst  
Eric Verbeek  
Autilia Vitiello  
Daidi Zhong

When the IEEE-SA Standards Board approved this standard on 29 January 2016, it had the following membership:

**Jean-Philippe Faure, *Chair***  
**Vicent, *Vice Chair***  
**John D. Kulick, *Past Chair***  
**Georgios Karachalios, *Secretary***

Chuck Adams  
Masayuki Ariyoshi  
Ted Burse  
Stephen Dukes  
Jianbin Fan  
J. Travis Griffith  
Gary Hoffman

Ronald W. Hotchkiss  
Michael Janezic  
Joseph L. Koepfinger\*  
Hung Ling  
Kevin Lu  
Annette D. Reilly

Gary Robinson  
Mehmet Ulema  
Yingli Wen  
Howard Wolfman  
Don Wright  
Yu Yuan  
Daidi Zhong

\*Member Emeritus

## Introduction

This introduction is not part of IEEE Std 1855-2016, IEEE Standard for Fuzzy Markup Language.

Currently, engineers and scientists developing a fuzzy system progress, iteratively, by alternating design, modeling, and simulation of their system. Depending on several design parameters, parts of this process are better handled by some software tools, while some others are better handled by other software tools. As a consequence and unfortunately, designers often have to enter various versions of their model into several software packages manually, slowing down the entire design phase of the system. The Fuzzy Logic (FL) Standard IEC 1131-7 was meant to address this issue, allow interoperability of various software packages, and allow engineers and scientists to use a single, well-defined specification language of fuzzy systems during all design activities. This has not happened mainly because of the lack of power of the abstractions of IEC 1131-7. In order to address this need, this standard defines an eXtensible Markup Language (XML)-based language, named Fuzzy Markup Language (FML), aimed at representing Fuzzy Logic Systems (FLSs) in an interoperable way. Considering the benefits offered by XML specifications and related tools, FML successfully allows FLSs to be implementable on different hardware platforms with a minimal effort, without additional design and implementation steps. Since FML was introduced by Giacomo Acampora, this markup language is contributing to the development and evolution of fuzzy-based intelligent decision systems belonging to different application fields such as healthcare, computer games, malware behavioral analysis, and many more [B4], [B13], [B22]. This standard uses the W3C XML Schema definition language to define the syntax and semantics of FML programs. In order to ensure wide acceptance throughout the user community, the XML Schema has been designed to encompass the most known FLSs: Mamdani [B16], Tsukamoto [B21], Takagi-Sugeno-Kang [B20], and AnYa [B5]. However, to accommodate all design needs, the language can be easily extended. This standard enables the generation of so-called FML drivers, i.e., software systems, based on XML technologies such as eXtensible Stylesheet Language Transformation (XSLT) and Document Object Model (DOM), capable of translating a system description based on FML to a runnable version.

This standardization project provides designers of industrial controllers and intelligent decision-making systems with a unified and high-level methodology for describing systems' behaviors by means of rules based on FL.

## Contents

1. Overview .....	9
2. Normative references.....	12
3. Definitions, acronyms, and abbreviations .....	12
4. A fuzzy system model for enabling a standard FML-based representation.....	14
5. FML Schema definition.....	1
6. FML Synthesis: XSLT Documents and DOM API .....	53
7. Compatibility with IEC 61131-7 .....	54
8. Conformance .....	56
9. Extensibility.....	57
Annex A (normative) Fuzzy logic theory .....	59
Annex B (normative) XML Schema.....	67
Annex C (normative) Examples .....	80
C.1 Mamdani and TSK versions.....	80
C.2 Japanese diet assessment system.....	83
Annex D (informative) Bibliography .....	86

# IEEE Standard for Fuzzy Markup Language

**IMPORTANT NOTICE:** IEEE Standards documents are not intended to ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

## 1. Overview

### 1.1 Scope

This standard defines an eXtensible Markup Language (XML)-based language, named Fuzzy Markup Language (FML), aimed at providing a unified and well-defined representation of Fuzzy Logic Systems (FLSs). This standard includes an extensible schema that natively defines the basic components of an FLS and enables the modeling of different categories of fuzzy inference engines, including Mamdani [B16], Tsukamoto [B21], Takagi-Sugeno-Kang (TSK) [B20], and AnYa [B5].

### 1.2 Purpose

The purpose of this standard is to allow the creation of interoperable FLSs. This standard uses the W3C XML Schema definition (XSD) language as the encoder, which allows for interoperability and the exchange of XML-based FLS instances between various systems. Different from other approaches used to describe fuzzy systems such as Fuzzy Control Language (FCL), FML allows fuzzy designers to simply code their ideas on heterogeneous hardware without need for a deep understanding of details related to the different platforms. This approach enables fuzzy systems designers to achieve *design transparency*. It means that, by using FML, it is possible to implement the same FLS on different hardware architectures with minimal effort and without additional design and implementation steps. In short, FML makes it possible to model an FLS in a human-readable and hardware-independent way.