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**OpenGIS© Recommendation Paper —
Units of Measure Use and Definition Recommendations**

OGC 02-007r4

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Contents

i.   Preface

This document is a public OGC Recommendation Paper, providing recommendations for use and definition of the units of measure used for numerical quantities. The recommendations take the form of Best Practices.

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Foreword

This recommendation paper provides recommendations for use and definition of the units of measure used for numerical quantities.

Many of these recommendations are stated using XML and XML Schema. The concepts of use are still valid when not using XML. The implementation, of course, will be different.

This document partially replaces OGC Discussion Paper 01-044r2: Units of Measure and Quantity Datatypes. This document contains a listing of the main recommendations.

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Introduction

The basic information needed to understand a measured value is the value and the unit of measure. Eight different ways, and various options of these ways, to tie these two pieces of information were identified. The goal of this project was to develop a preferred way to implement this information in XML.

In addition, it was noted that a symbol for a unit of measure was not sufficient to identify it. Thus, this recommendation paper also defines a best practice for giving the meaning of a unit of measure.

OpenGIS© Recommendation Paper — Units of Measure Use and Definition Recommendations

1 Scope

This OpenGIS© Recommendation Paper provides recommendations for use and definition of the units of measure used for numerical quantities. These recommendations are more widespread than OpenGIS only, and are being proposed at other organizations, including POSC, W3C, CSIRO, PIDX, and OASIS.

These recommendations are given as best practices, and are not intended to be rigidly followed. However, it is recommended that variations from these practices be considered for their negative effects on interoperability.

The recommendations are stated for a single, measure value. However, many of the same structures apply to arrays and tuples of values. XML Schema and documents that capture arrays of values, and tuples of values, should consider the patterns of these recommendations, and follow them where appropriate.

Many of these recommendations are stated using XML and XML Schema. These recommendations should be followed even when XML is not being used.

2 Conventions

2.1 Symbols (and abbreviated terms)

ISO   International Organization for Standardization

OGC   Open GIS Consortium

UOM   Unit of Measure

W3C   World Wide Web Consortium

XML   eXtended Markup Language

2.2 XML use conventions

This document uses a set of conventions for use of XML and XML Schema, that currently include:

a) Use of xsd prefixes to indicate the XML schema elements, as defined in the W3C proposed recommendation dated 30 March 2001.

b) Snippets of XML being used as examples forgo any use of namespaces.

3   Using a unit of measure

3.1   Introduction

This clause provides recommendations for using a unit of measure. The use of a unit of measure is meant to encompass the means by which a measured value is tied explicitly to its unit of measure.

3.2   Abbreviation for units of measure

Recommendation 1: When an abbreviation for units of measure is to be used in an element or attribute name, the abbreviation should be **uom** or **UOM**.

Comment: The other obvious choice is "unit." Since "unit" can have other meanings, it was felt that "uom" was a better choice than "unit." The important point is to select one, and use it exclusively.

Comment: This recommendation is for abbreviations only. It is still permissible to use the full name, "UnitOfMeasure," where appropriate.

3.3   Measure data type

Recommendation 2: A QuantityType data type should be defined in XML Schema as follows:

```
<xsd:complexType name="QuantityType">
  <xsd:simpleContent>
    <xsd:extension base="xsd:double">
      <xsd:attribute name="uom" type="xsd:anyURI"
          use="optional"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
```

The type for the **uom** attribute may also be IDREF or string, with the understanding that it will be a *keyref* to a value that is contained within the file.

Comment: The type xsd:double is used for the value since it is the most general format available in the XML Schema data types. It is not intended to imply any semantics on the data value, or to imply any special computer representation of the value.

Comment: It is intended that the **uom** attribute be a reference to a unit defintion instance within the same file. Thus, alternative formulations of the QuantityType would allow the **uom** to be of type xsd:IDREF, or of type xsd:string, where string is declared to be a *keyref* to a locally defined *key*. The particular implementation of the MeasrueType is left to the using application. Note that xsd:IDREF is being deprecated by W3C, and its use is discouraged.

Comment: The use of xsd:anyURI for a local reference implies that a "#" is included. Applications should be able to handle a reference with or without the "#" symbol. Below is a XML example of a QuantityType with **uom** of type xsd:anyURI and one of xsd:string:

```
<length uom="#ft">26.62</length>
<width uom="ft">18.3</width>
```

Comment: This Recommendation uses the term, "QuantityType." This is not mandatory. The name of the complexType is local, and is under control of the schema developer. However, the structure of the complexType should be maintained.

Comment: The Recommendation is that the **uom** attribute be optional. This is not mandatory. The schema developer may make it required. The optionality is given because many users felt that a unit of measure can be defined within a context, and should not be given with every, individual value.

Comment: The string value of the **uom** attribute does not contain any semantic meaning. It is strictly defined as a key reference to another instance within the document. The use of "ft" in the above example does not necessarily imply that the unit of measure is a foot. However, in practice, it would probably be useful to have a meaningful value. See also Recommendation 4a.

3.4   Unit of measure reference type

Recommendation 3: A unit of measure reference type should be defined in XML Schema as follows:

```
<xsd:complexType name="unitref">
  <xsd:attribute name="uom" type="xsd:anyURI" use="required"/>
</xsd:complexType>
```

Comment: The comments for Recommendation 2 apply to Recommendation 3.

Comment: This data type differs from the QuantityType only in that there is no value. Its usage is to set a unit of measure within a context, rather than to assign a unit of measure to a value.

4   Defining a unit of measure

The **uom** attribute given above is intended to be a reference to a definition of the unit of measure instance within the same document. The definition may either be contained at that point in the document, or be a reference to a definition in another document. This latter case is here referred to as a "remote reference."

4.1   UOM value reference

Recommendation 4: Every **uom** value in a document should reference a unit definition instance with an **id** or equivalent attribute within the document.

Comment: This recommendation 4 is a preferred practice. There are two exceptions to this practice. The first is that the **uom** attribute directly reference an instance in another document. This alternative puts a burden on the reader, and may degrade interoperability.

Comment: The second exception is that the reference be implied, rather than explicit. In particular, using the example above, the "ft" used as a reference is intended to imply that there is meaning to "ft" that is known to the reading application. This puts a burden on the reader to understand all **uom** references, since they are implicitly defined. While this

practice is acceptable in a tightly controlled environment, it is not interoperable in a general environment, and its use is highly discouraged. This comment leads to the following variation on Recommendation 4:

4.2 UOM reference by symbol

Recommendation 4a: Within a tightly controlled environment, it is acceptable for the **uom** value to be a symbol that represents a unit of measure. When this is the case, there must be a specification that lists all the acceptable symbols and their meanings.

Comment: When using Recommendation 4a – reference by symbol – compliant applications must understand all the symbols in the listed set. It should also be understood that extensions to new units of measure require a change to the specification, rather than a simple extension, since the new unit of measure will break all existing applications.

4.3 Remote reference data type

Recommendation 5: A remote reference data type should be defined in XML Schema as follows:

```
<xsd:complexType name="remoteRefType">
  <xsd:attribute name="id" type="xsd:ID" use="required"/>
  <xsd:attribute name="href" type="xsd:anyURI"
     use="required"/>
</xsd:complexType>
```

with exceptions as noted in the comments below.

Comment: The remoteRefType has the property that it contains a referencable key, and references a resource, generally in another document.

Comment: The datatype name is not part of the recommendation. Schema developers may use any datatype name, since this is strictly internal.

Comment: The value of the **id** attribute is a key that may be referenced by a **uom** attribute. The semantic meaning of the xsd:ID data type in this definition is that it be unique within the document, and serve as a key for a **uom** *keyref*. Note that this may also be accomplished using the schema elements *uniq, key*, and *keyref*. This latter process is also encouraged within application documents as an alternative to the above.

Comment: The **href** attribute is illustrative. No general agreement has been set for the attribute name. However, such agreement should be a goal of using groups.

Comment: The data type xsd:anyURI is necessary. The purpose of the remote reference is to reference an outside resource.

Comment: A XML example of use of the remote reference follows. This reference takes the local "ft", and skips it to a document which contains the definition of a "foot":

```
<remoteRef id="ft" to="http://www.some.com/unitDef.xml#foot"/>
```

4.4 Defining meaning of a unit of measure

Recommendation 6: In XML Schema, a complexType should be used that defines the meaning of a unit of measure. The meaning is defined in one of two ways – either it is a base unit, or it contains a conversion to a referenced base unit. Beyond these two requirements, this recommendation does not define the information carried in such a definition or the structure of the information. Recommendations 7 and 8 define these two requirements.

Comment: The element containing the definition must have an **id** attribute of type xsd:ID, where the xsd:ID may be replace by xsd:string with *uniq, key,* and *keyref* definitions as appropriate. This allows the definition to referenced by a **uom** or **to** attribute.

Comment: Recommendations 6, 7, and 8 will require that a unit of measure definition have either a **BaseUnit** subelement or a **ConversionToBaseUnit** subelement.

4.5 Definition of a base unit

Recommendation 7: A definition of a base unit should have a subelement, **BaseUnit**. The content of **BaseUnit**, if any, is not defined by this recommendation.

Comment: A minimal definition of a base unit would look like, for example,

```
<UOMDefinition id="m">
  <BaseUnit/>
</UOMDefinition>
```

Additional information may be contained that would, for example, give a name for the unit (such as metre), the definition of it, how it is annotated, a citation, etc.

4.6 Definition of unit of measure that is not a base unit

Recommendation 8: A definition of a unit of measure that is not a base unit should have a subelement, **ConversionToBaseUnit**, that is of type, *conversionType*, as follows in XML Schema:

```
<xsd:complexType name="conversionType">
  <xsd:sequence>
    <xsd:choice>
      <xsd:element name="factor" type="xsd:double"/>
      <xsd:element name="fraction">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="numerator" type="xsd:double"/>
            <xsd:element name="denominator"
                type="xsd:double"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
      <xsd:element name="formula">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="A" type="xsd:double"
                minOccurs="0"/>
            <xsd:element name="B" type="xsd:double"/>
```

```
                <xsd:element name="C" type="xsd:double"/>
                <xsd:element name="D" type="xsd:double"
                    minOccurs="0"/>
            </xsd:sequence>
          </xsd:complexType>
        </xsd:element>
      </xsd:choice>
    </xsd:sequence>
    <xsd:attribute name="baseUnit" type="xsd:anyURI"
        use="required"/>
  </xsd:complexType>
```

Comment: This definition maps directly to the schema that is output using the XML encoding rules in Subclause A.5.2.2.3 of ISO CD 19118 (N1136). However, it has been modified slightly from the direct output. It has also been modified from the original Units of Measure discussion paper, in order to more closely match the ISO model.

4.7   Angular measure

Angular measures are often given in a sexagesimal format, which is the degrees, minutes, and seconds of the angle. The sexagesimal format is also known as "degrees, minutes, seconds" format, and may be abbreviated as "dms" or "DMS." Note that the units of measure are specified in this particular format. However, there is no agreed upon implementation of this format in XML.

When specifying an angle measure, the XML must always allow for a decimal format – that is, for a QuantityType. However, an implementation may also allow for the angle to be specified in a sexagesimal format. The following three recommendations are made for angular measures.

Recommendation 9: An angular measure must always allow for the angle value to be input as a QuantityType.

Comment: The simplest case of an angular quantity would look no different from any measure value. For example,

```
<bearing uom="deg">15.83</bearing>
```

Recommendation 10: An implementation may allow an angle to be input in sexagesimal format. When this choice is allowed, it should be done using the following AngleChoiceType:

```
<xsd:complexType name="AngleChoiceType">
  <xsd:choice>
    <xsd:element name="angleQuantity"
      type="gml:QuantityType"/>
    <xsd:element name="dms" type="gml:AngleType"/>
  </xsd:choice>
</xsd:complexType>
```

Comment: The choice adds an additional layer to the instance value. For example,

```
<bearing>
  <angleQuantity uom="deg">15.83</angleQuantity>
</bearing>
```

Comment: The recommendation is to use the choice mechanism, and to the element name, angleQuantity and dms.

Comment: In general, and angle needs additional information to be understood. For example, is the angle clockwise or counter-clockwise from the base line? Is the base line a north direction? Which north direction (magnetic, grid, geographic)? This information may be included by using the XML Schema Extension of the AngleChoiceType. Recommendation 10 makes no recommendation about this set of information.

4.7.1 Implementation of the dms element

Recommendation 10 specifies the subelement, **dms**, to be of type, AngleType. There is no present consensus on the exact form of the AngleType. The following recommendation will recommend that that an implementation specify either the format variant or the subelement variant as defined below.

The subelement will capture the information as subelements, as the following example will show:

```
<bearing>
  <dms>
    <degrees direction="E">15</degrees>

    <minutes>50</minutes>
    <seconds>0.00</seconds>
  </dms>
</bearing>
```

So that the specific form of the dms is known within an implementation, it must not allow for both for a given element, and should not allow for both within a document.

Recommendation 11: The dms element must be as defined below:

```
. . .Format variant. . .
<. .
<xsd:complexType name="AngleType">
 <xsd:sequence>
  <xsd:element ref="degrees"/>
  <xsd:sequence minOccurs="0">
    <xsd:element ref="gml:minutes"/>
    <xsd:element ref="gml:seconds" minOccurs="0"/>
  </xsd:sequence>
 </xsd:sequence>
</xsd:complexType>

<xsd:element name="degrees">
 <xsd:complexType>
  <xsd:simpleContent>
   <xsd:extension base="gml:degval">
    <xsd:attribute name="direction" use="optional">
     <xsd:simpleType>
     <xsd:restriction base="xsd:string">
       <xsd:enumeration value="N"/>
       <xsd:enumeration value="E"/>
       <xsd:enumeration value="S"/>
       <xsd:enumeration value="W"/>
```

```
            <xsd:enumeration value="+"/>
            <xsd:enumeration value="-"/>
         </xsd:restriction>
        </xsd:simpleType>
       </xsd:attribute>
      </xsd:extension>
    </xsd:simpleContent>
   </xsd:complexType>
 </xsd:element>

 <xsd:simpleType name="degval">
    <xsd:restriction base="xsd:nonNegativeInteger">
       <xsd:maxInclusive value="360"/>
    </xsd:restriction>
 </xsd:simpleType>

 <xsd:element name="minutes">
  <xsd:simpleType>
   <xsd:restriction base="xsd:nonNegativeInteger">
    <xsd:maxExclusive value="60"/>
   </xsd:restriction>
  </xsd:simpleType>
 </xsd:element>

 <xsd:element name="seconds">
  <xsd:simpleType>
   <xsd:restriction base="xsd:decimal">
    <xsd:minInclusive value="0.00"/>
    <xsd:maxExclusive value="60.00"/>
   </xsd:restriction>
  </xsd:simpleType>
 </xsd:element>
```

Comment: Recommendation 11 is intentionally not choosing between the two variants at this time. It is expected that one or the other will dominate in the future. At that time, the recommendation should be altered to choose the dominant one.

Comment: The NESW are intentionally made optional. There are many contexts in which these do not make sense. (For example, an inclination measurment). A particular usage of the AngleType could make these mandatory, if it is appropriate.

5   Terms and definitions

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

5.1
Measured value
Any value which requires a unit of measure to be fully understood.

5.2
Use of a Unit of Measure
The implementation method that declares the unit of measure that is assigned to a particular value.

5.3

Definition of a Unit of Measure

The meaning of a unit of measure. A unit of measure can be defined as a base unit, or by giving a conversion formula to a base unit.

5.4

Base Unit

A unit of measure that is understood by a well-defined physical process. Most base units are defined by ISO 1000. In this paper, a base unit consists of the ISO base units, the ISO derived units, and additional units that are defined for measurement types that are not covered by the ISO defined units.

Comment: In ISO terminology, a second, a metre, and a kilogram are base units. A metre per second and a Newton (= metre kilogram per second per second) are called derived units. This paper refers to all of these as Base Units.

5.5

Conventional Unit of Measure

A unit of measure for which there is a conversion to a Base Unit, using the formula $y = (A + Bx) / (C + Dx)$, where x is value in the conventional unit, and y is the value in the Base Unit.

Comment: A centimetre is a conventional unit. It is defined by setting $A = D = 0$, $B = .01$, and $C = 1.0$, where the base unit is the metre.

5.6

Symbol

An abbreviation or code that represents the unit of measure.

Comment: A symbol can mean different things in different code spaces. For example, the symbol, ft, can mean US Survey foot, or International foot, depending on which set of symbols are being referenced.

Bibliography

[1]   XML, http://www.w3.org/XML/

[2]   XML Schema, http://www.w3.org/XML/Schema

[3]   ISO CD 19118 (N1136), Geographic information — Encoding

[4]   OGC 01-044r2, Units of Measure and Quantity Datatypes