

# Comparing and Diffing XML Schemas

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# Introduction

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## The project

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- ◆ Build a tool to identify the differences between two schemas.
- ◆ For each difference, determine whether it is backward compatible.
  - Or, determine whether one schema is a "subset" of another schema.
- ◆ Show the results in as simple/concise a report as possible.

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## OH in the trenches

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### Schema developers on internal project teams:

"The changes were really minor, I think all I did was add element z."

"Don't worry. They shouldn't affect your code."

"The tool was acting kind of strange when I saved the schemas. Hopefully it didn't break anything."

### Designer of XML-based standard:

"Let's hand-compile a list of all the changes we made in version 3.1."

"When we redesigned the schemas from Russian Doll to Venetian Blind, I hope we didn't change what's valid."

"All our changes in version 3.1 *should* be backward compatible with 3.0. We were pretty careful."

### Implementer of XML-based standard:

"Hmmm, I wonder what exactly changed in version 3.1. These release notes are kind of vague."

"To be conformant to this standard I have to use a strict subset. Guess I'll start deleting things from the schema and hope for the best."

"Wish I had a list of all the extensions I added to this standard, so I could communicate it to the Java developers."

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## Simplifying assumptions

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- ◆ XSD 1.0 only
  - Schemas must be a valid, coherent set.
  - No support (yet) for certain XSD features, for example:
    - redefine/override
    - chameleon includes
    - identity constraints
  - No attempt to parse regexes (xs:pattern) or XPath expressions (identity constraints, assertions) to determine backward compatibility.
- ◆ No attempt to compare more than two things at a time.
- ◆ We only care about what is valid in an instance.
  - Documentation, schema constructs and design patterns are ignored.
- ◆ Diffs only need to be shown at one level.
  - A change to a leaf element affects all its ancestors, but it only needs to be shown as a diff once.

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## Note to self

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- ◆ The diffing doesn't have to be perfect!
  - Dramatic changes are unlikely between versions.
  - Cover the most common ~75% of cases.
  - The worst case scenario is to show a complete deletion and insertion of the content model.
- ◆ It doesn't always have to be able to determine backward compatibility.
  - "I don't know" is an acceptable answer.

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## "Data-oriented" example: NIEM

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- ◆ National Information Exchange Model
- ◆ Large (10,000-element) model used mostly by US federal, state and local government
- ◆ Characteristics
  - Highly structured content models
    - No mixed content.
    - Heavy use of type inheritance and substitution groups.
    - All elements and types are global.
    - The outermost model group is always *sequence*.
    - Many, many namespaces.
  - Strict rules for what XSD constructs are allowed/disallowed.
  - Role of an XML Schema Diff tool:
    - Ensure that your NIEM subset is indeed a subset of NIEM.
    - Ensure that your "constraint" schema allows a subset of your base schema.
    - Track changes to your NIEM-based extension schemas over time.
    - Find out what's new in a new version of NIEM.

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## "Document-oriented" example: JATS

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- ◆ Journal Article Tag Suite
- ◆ Characteristics
  - Narrative content
    - Lots of mixed content.
    - Mostly global elements, local types.
    - Slightly more complex content models than NIEM.
    - No namespace (except for incorporating MathML, etc. namespaces).
  - Three tags sets with different levels of strictness (Archiving, Publishing Authoring)
  - Role of an XML Schema Diff tool:
    - Find out what's new in a new version of JATS.
    - Create a restriction of JATS and ensure that it allows a strict subset.
    - Analyze the differences between the three tag sets.
  - Examples in this presentation show the diffs between JATS 1.0 and JATS 1.1d3 MathML2.

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## The approach

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- ◆ Use XSLT. (What else?)
- ◆ Use a pipeline (in Ant) to break it down into several simpler steps.
- ◆ Build it "iteratively". Which means:
  1. Write some code.
  2. Run it.
  3. Bang head against wall.
  4. Reread note to self.
  5. Goto 1.
- ◆ Current status: basic working code, much untested code, long list of future enhancements.

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## Steps

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1. Canonicalize
2. Flatten
3. Simplify
4. Sort
5. Find Diffs
6. Determine Backward Compatibility
7. Report

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# Part 1: Simplification

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## Step 1: Canonicalize

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Purpose: Make schema documents more similar to make comparison easier.

- ◆ fill in default values for attributes
- ◆ normalize attribute values
- ◆ eliminate anything not relevant to validation (documentation, schema-only features like `final`)

Output is valid XSD schema documents with the same meaning.

```
<xs:element name="foo" minOccurs="01" maxOccurs=" 12" id="foo" dty:doc="foo"/>
```

```
<xs:element name="foo" minOccurs="1" maxOccurs="12" nillable="false" type="xs:anyType" form="qualified"/>
```

### Gory details:

- ◆ fill in default values (canonical representation) for all attributes.
- ◆ normalize space in attribute values (except where it could be significant, e.g. `pattern` or `enumeration`).
- ◆ normalize attribute values based on type, e.g. `@minOccurs` is an integer, so use canonical representation of integer.
- ◆ move schema document-level defaults (e.g. `@elementFormDefault`, `@blockDefault`) down to individual components.
- ◆ eliminate anything not relevant to validation (`@id`, `@version`, `@final`, `annotation`, **non-native** attributes).
- ◆ add generic types to declarations that have none.
- ◆ `@mixed` goes on `complexType`, **not** `complexContent`.
- ◆ all `complexType`s have `simpleContent` **or** `complexContent`.
- ◆ convert `length` into `minLength` and `maxLength`.

## Step 2: Flatten

Purpose: Normalize out all the XSD constructs to get down to the essential properties and content model.

- ◆ resolve all complex type extensions and restrictions
- ◆ resolve all groups and attribute groups
- ◆ turn substitution groups into choices
- ◆ resolve all simple type restrictions (merging facets), back to primitive type

Output is a single "schema document" that is not valid XSD.

```
<xs:sequence minOccurs="1" maxOccurs="1">
  <xs:element name-ns="ns1" name="a"/>
  <xs:element name-ns="ns1" name="b"/>
  <xs:element name-ns="ns2" name="c"/>
  <xs:element name-ns="ns2" name="d"/>
</xs:sequence>
```

```
<xs:simpleType>
  <union xmlns="">
    <atomic primitive="string">
      <xs:pattern value="-?([0-9]+|[0-9]*\.[0-9]+)*(em|ex|px|in|cm|mm|pt|pc|%)?" />
    </atomic>
    <atomic primitive="string">
      <xs:enumeration value="medium" />
      <xs:enumeration value="thick" />
      <xs:enumeration value="thin" />
    </atomic>
  </union>
</xs:simpleType>
```

## Step 3: Simplify

Purpose: further simplify the content models by eliminating unnecessary model groups (sequence, choice, all)

<pre>&lt;xs:sequence&gt;   &lt;xs:sequence&gt;     &lt;xs:element name="a"/&gt;     &lt;xs:element name="b"/&gt;   &lt;/xs:sequence&gt;   &lt;xs:sequence minOccurs="0"&gt;     &lt;xs:element name="c" minOccurs="0"/&gt;     &lt;xs:element name="d" minOccurs="0"/&gt;   &lt;/xs:sequence&gt;   &lt;xs:choice minOccurs="0"     maxOccurs="unbounded"&gt;     &lt;xs:element name="e"/&gt;   &lt;/xs:choice&gt;   &lt;xs:choice maxOccurs="2"&gt;     &lt;xs:element name="f" maxOccurs="3"/&gt;   &lt;/xs:choice&gt;   &lt;xs:choice&gt;     &lt;xs:element name="g"/&gt;     &lt;xs:choice&gt;       &lt;xs:element name="h"/&gt;       &lt;xs:element name="i"/&gt;     &lt;/xs:choice&gt;   &lt;/xs:choice&gt;   &lt;xs:sequence/&gt;   &lt;xs:sequence maxOccurs="0"&gt;     &lt;xs:element name="j"/&gt;     &lt;xs:element name="k"/&gt;   &lt;/xs:sequence&gt;   &lt;xs:element name="l" abstract="true"     minOccurs="0"/&gt; &lt;/xs:sequence&gt;</pre>	<pre>&lt;xs:sequence&gt;   &lt;xs:element name="a"/&gt;   &lt;xs:element name="b"/&gt;   &lt;xs:element name="c" minOccurs="0"/&gt;   &lt;xs:element name="d" minOccurs="0"/&gt;   &lt;xs:element name="e" minOccurs="0"     maxOccurs="unbounded"/&gt;   &lt;xs:element name="f" maxOccurs="6"/&gt;   &lt;xs:choice&gt;     &lt;xs:element name="g"/&gt;     &lt;xs:element name="h"/&gt;     &lt;xs:element name="i"/&gt;   &lt;/xs:choice&gt; &lt;/xs:sequence&gt;</pre>
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### Gory details:

- ◆ Some can be eliminated outright:
  - maxOccurs="0" (elements, wildcards or groups)
  - Any empty model group
  - An abstract element
- ◆ Some can be eliminated and their children processed:
  - Any model group with cardinality 1..1 that has only one child
  - Any model group with cardinality 1..1 whose parent is the same kind of model group
  - A `sequence` or `all` with cardinality 0..1 whose parent is the same kind of model group and whose children are all optional
- ◆ Some can be eliminated and their cardinalities merged with their children:
  - Any group with one child (minOccurs and maxOccurs are products of group and child)
- ◆ Some min/maxOccurs can be "canonicalized":
  - Sequence group that is optional and all children are optional - minOccurs can be 1
  - Choice, all group that is optional and at least one child is optional - minOccurs can be 1
  - Particle within a choice that is maxOccurs="unbounded" doesn't also need to be repeating
- ◆ Some can be merged
  - Element referenced twice in the same group (consecutively in the case of sequence)
  - Wildcards that appear in the same group (consecutively in the case of sequence)

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## Step 4: Sort

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Purpose: make it easier to compare components line by line.

- ◆ Sort all things where order doesn't matter:
  - values in the namespace attribute of wildcards
  - global components in the schema
  - facets on a simple type
  - particles within a choice or all group

(In retrospect, only the last one was relevant to code further in the pipeline.)

<pre>&lt;xs:choice&gt;   &lt;xs:element name="foo"/&gt;   &lt;xs:any namespace="ns2 ns3 ns1"/&gt;   &lt;xs:element name="bar"/&gt; &lt;/xs:choice&gt;</pre>	<pre>&lt;xs:choice&gt;   &lt;xs:element name="bar"/&gt;   &lt;xs:element name="foo"/&gt;   &lt;xs:any namespace="ns1 ns2 ns3"/&gt; &lt;/xs:choice&gt;</pre>
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## Part 2: Diffing

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### Step 5: Diff

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Purpose: Determine (at a detailed level) what changes were made.

- ◆ Top-level unit of diffing is a global element or attribute declaration.
  - Named types and local elements/attributes are only compared in the context of a particular global declaration.
- ◆ Easy enough to find all the deleted and inserted global declarations.
- ◆ For matching declarations (same qualified name before and after):
  1. Compare basic attributes (nillable, fixed, etc.)
  2. Compare basic attributes of the associated types (mixed, block, etc.)
  3. Compare content
    - Simple content is fairly straightforward comparison of primitive types and facets
    - Complex content - argh. Reread note to self.
  4. Compare attributes

Given two lists of particles:

- ◆ If list1[1] is comparable\* to list2[1], compare them:
  - If they are identical, don't even bother to show them in the output
  - If they have some differences, show them as a "modification" (side-by-side insertion and deletion)
- ◆ Otherwise, if list1[1] is comparable to something anywhere in list2, consider list2[1] an insertion.
- ◆ Otherwise, if list2[1] is comparable to something anywhere in list1, consider list1[1] a deletion.
- ◆ Otherwise, it is a separate deletion AND an insertion (not shown side by side like a modification is).

\*definition on next slide

<pre>&lt;xs:element name="a" /&gt; &lt;xs:element name="b" /&gt; &lt;xs:element name="c" /&gt;</pre>	<pre>&lt;xs:element name="a" /&gt; &lt;xs:element name="c" /&gt; &lt;xs:element name="d" /&gt;</pre>
--	--

...

- element b

...

+ element d

# Defining what is "comparable"

The following particles are "comparable":

- ◆ Two element declarations with the same qualified name.
- ◆ Two element wildcards.
- ◆ Two groups of the same kind (sequence, choice or all) that have at least one descendant element declaration in common.
- ◆ Two groups of different kinds that have ALL element declarations in common.
- ◆ An element and a group that has that element as a descendant.

Why bother with the concept of "comparable"?

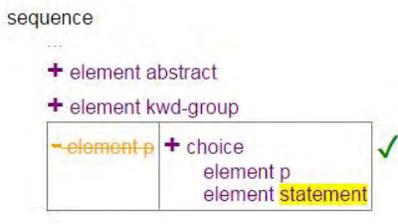
```
<xs:sequence minOccurs="1" maxOccurs="1">
  <xs:element ref="label" minOccurs="0"
               maxOccurs="1" />
  <xs:element ref="title" minOccurs="0"
               maxOccurs="1" />

  <xs:element ref="p" minOccurs="1"
               maxOccurs="unbounded" />
</xs:sequence>
```

```
<xsd:sequence minOccurs="1" maxOccurs="1">
  <xs:element ref="label" minOccurs="0"
               maxOccurs="1" />
  <xs:element ref="title" minOccurs="0"
               maxOccurs="1" />
  <xs:element ref="abstract" minOccurs="0"
               maxOccurs="unbounded" />
  <xs:element ref="kwd-group" minOccurs="0"
               maxOccurs="unbounded" />
  <xsd:choice minOccurs="1"
               maxOccurs="unbounded">
    <xs:element ref="p" minOccurs="1"
                 maxOccurs="1" />
    <xs:element ref="statement" minOccurs="1"
                  maxOccurs="1" />
  </xsd:choice>
</xsd:sequence>
```

## Δ element statement B A

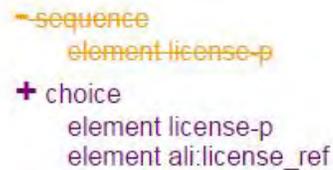
Content changes



Where my definition breaks down:

## Δ element license B A

Content changes



## Step 6: Determine backward compatibility

Four possible outcomes:

1. # "true": there is no impact on validation, and no significant differences in the PSVI
2. ! "true-val": there is no impact on validation, but the PSVI might be different
  - ◆ change simple type from `decimal` to `float`
  - ◆ change simple type from `anySimpleType` to `string`
  - ◆ change the order of member types in a union type from `integer string` to `string integer`
  - ◆ add a default or fixed value
  - ◆ change `whiteSpace` facet
3. X "false": validation is impacted in some or all cases
4. "": unknown; cannot be determined by the current code

"Subset" is the other side of the same coin?

- ◆ If Schema A is backward compatible with Schema B, then Schema B is a strict subset of Schema A. True?

## Backward compatible changes: Examples

### Declaration Properties

- ◆ Changing `nillable` from false to true
- ◆ Changing `abstract` from true to false

### Type Properties

- ◆ Changing `mixed` from false to true
- ◆ Changing `block` from `extension restriction` to `just restriction`

### Complex Content

- ◆ Making occurrence constraints less restrictive.
- ◆ Replacing a sequence with a choice (with all the same declarations).
- ◆ Replacing an element with a choice that contains that element.
- ◆ Replacing an element with a wildcard.

### Simple Content

- ◆ Making facets less restrictive.
- ◆ Changing an atomic or union type into a list or union of that atomic type

### Attributes

- ◆ Adding optional attributes.
- ◆ Making attributes' types or attributes less restrictive.

### Δ element article B A

- Δ Attribute `article-type`
  - Δ primitive type `anySimpleType string` !
- Δ Attribute `dtd-version`
  - ~~~default 1.0~~ !
  - Δ fixed `1.1d3` X
  - Δ enumeration `1.0` ✓
- Δ Attribute `specific-use`
  - Δ primitive type `anySimpleType string` !
- + Attribute `xml:base`
- + Attribute `id`

### Δ element front-stub B A

#### Content changes

- sequence
  - ...
    - element `volume`
      - Δ maxOccurs `+` unbounded ✓
    - ...
      - element `issue`
        - Δ maxOccurs `+` unbounded ✓
      - ...
        - + element `volume-issue-group`
      - ...
    - + Attribute `xml:base`
    - + Attribute `id`

Previous steps generate a diffs.xml file that can be turned into a report.

```
<global-decl type="element" chgtype="Changed" name="statement">
  <content>
    <sequence name="">
      <skip/>
      <skip/>
      <change type="ContentModel" chgtype="Added" bc="true">
        <element name="abstract"/>
      </change>
      <change type="ContentModel" chgtype="Added" bc="true">
        <element name="kwd-group"/>
      </change>
      <change type="ContentModel" chgtype="Changed" bc="true">
        <change type="ContentModel" chgtype="Deleted">
          <element name="p"/>
        </change>
        <change type="ContentModel" chgtype="Added">
          <choice>
            <element name="p"/>
            <element name="statement"/>
          </choice>
        </change>
      </change>
      <skip/>
    </sequence>
  </content>
  <change type="Attribute" name="content-type" chgtype="Changed">
    <content>
      <change type="Property" name="primitive type" before-value="anySimpleType" after-
value="string" chgtype="Changed" bc="true-val"/>
    </content>
  </change>
  <change type="Attribute" name="specific-use" chgtype="Changed">
    <content>
      <change type="Property" name="primitive type" before-value="anySimpleType" after-
value="string" chgtype="Changed" bc="true-val"/>
    </content>
  </change>
  <change type="Attribute" name="xml:base" chgtype="Added"/>
</global-decl>
```

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## Reporting approach

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One HTML document with all diffs for a schema.

Default approach (versioning focus):

- ◆ Identical parts of content model are omitted for brevity.
- ◆ Diffs are shown like change markup, strikethrough and +/-/#- imply "before" and "after".
- ◆ Backward compatibility icons are shown.
- ◆ Example (JATS 1.0 vs. JATS 1.1d3): <http://www.datypic.com/events/diffs.html>

Alternate view:

- ◆ Entire content model is shown for clarity.
- ◆ Diffs are shown with colors (blue/red) to take away versioning implication.
- ◆ Backward compatibility icons are not shown.
- ◆ Example (JATS 1.0 vs. JATS 1.1d3): <http://www.datypic.com/events/diffs2.html>

Integrated with Schema Central: [JATS 1.0](#), [JATS 1.1d3](#).

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## Conclusions

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### Conclusions

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- ◆ The diffing is not perfect but works well enough for my purposes.
- ◆ The backward compatibility of content models needs to be reworked, to be evaluated on the type as a whole rather than individual "compares".
- ◆ Flattening has pros and cons:
  - Pro: Less complex, requires less knowledge of XSD structure.
  - Con: Repetitive, e.g. if a change is made to a base type and shows up in 15 different places.

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### Future directions

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- ◆ Change algorithm for determining backward compatibility of content models.
- ◆ Rethink diffs.xml structure/vocabulary.
- ◆ Improve readability of report.
- ◆ Fix known bugs, unsupported corner cases.
- ◆ Support other schema languages: similar concepts apply.
- ◆ Support more XSD features, or at least ignore them more gracefully.
- ◆ Improve efficiency.

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## Thank you

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Questions? Let's discuss.

...and you can contact me at [pwalmsley@datypic.com](mailto:pwalmsley@datypic.com) to ask questions or request the code.