



Eidgenössische Technische Hochschule Zürich  
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## **Master's Thesis Nr. 327**

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A Test Suite for Rumble

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# **DINFK**



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## Abstract

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## Acknowledgements

Write some sad story and then a positive story. Don't forget to mention all the people



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## Chapter 1

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# Introduction

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### 1.1 Motivation

The increasing amount of data available to process, as well as the ever-growing discrepancy between storage capacity, throughput and latency, has forced the database community to come up with new querying paradigms in the last two decades. Data became nested and heterogeneous (JSON), and is increasingly processed in parallel (Spark). In order to make querying more efficient and accessible, Rumble [MFI<sup>+</sup>20] is an engine that automatically runs queries on semi-structured and unstructured documents on top of Spark, using the JSONiq language.

JSONiq [jso20] is a functional and declarative language that addresses these problems with its most useful FLWOR expression which is the more flexible counterpart of SQL's SELECT FROM WHERE. It inherits 95% of its features from XQuery, a W3C standard.

The XQuery/XPath 3.\* Test Suite (QT3TS) [W3C13] provides a set of tests with over 30000 test cases designed to demonstrate the interoperability of W3C XML Query Language, version 3.0 and W3C XML Path Language implementations.

The high level idea of this work is to implement a Test Driver that can directly use QT3TS in order to test and verify Rumble implementation.

Mention Rumble. Mention JSONiq. Mention XQuery test suite. Mention similarity and reusage. Mention Goals.

### 1.2 Related Work

Another section

### 1.3 Contributions

Another section

### 1.4 Outline

Another section



## Chapter 2

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# XQuery/XPath 3.\* Test Suite(QT3TS)

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### 2.1 Analysis

In this chapter, we will discuss design decisions that we have made during the development of Test Driver. The core idea is to develop Test Driver completely independently from Rumble by maintaining the code outside of Rumble.

#### 2.1.1 Programming Language

We view Rumble as black-box and the single point of communication with Rumble should only be via the Rumble Java public API. Therefore, we have decided to implement Test Driver as Java Console Application. Furthermore, Rumble is also written in Java. We decided to setup our Java Console Application project to have two modules - Test Driver and Rumble module. Rumble module is the branch in repository created for the purpose of this work [Mih20]. Making Test Driver module dependent on it, we are allowing possibility to directly use Rumble and its classes in case that not everything is possible to be achieved by treating Rumble as the black-box.

We need to show how Saxon implementation is verified using the test suite. The we need to show the class that we want to reproduce. We need to mention that everything is XML and that we will reuse Saxon for parsing the XML, backwards compatibility with everything except XSLT

#### 2.1.2 Data Format

The XQuery/XPath 3.\* Test Suite (QT3TS) is publicly available at W3C Public CVS Repository under module name 2011/QT3-test-suite [W3C11]. Since April 1st 2019, CVS tree has been discontinued and the repository has been migrated to W3C Public GitHub repository [W3C20]. The tests are published as a set of files - test sets containing in total more than 30000 test cases. The tests are published as a set of files, mostly in XML format. W3C does not supply a Test Driver for executing the tests. Instead, for each implementation a Test Driver should be written. As these test sets are mostly written in XML format, the first component that our Test Driver will require is the XML parser.

### 2.1.3 XML Parser

XML parser is a program that allows our application to read and write XML documents. For our work, we have investigated following possibilities:

- DOM (Document Object Model) - This parser loads entire XML document in memory and uses interfaces to access the information. It can access couple of item elements at same time. It can be used for both reading and writing.
- SAX (Simple API for XML parsing) - This parser doesn't load XML document in memory. Instead, it allows us to register a handler with SAX parser. When parser goes through file it keeps invoking methods on the handler class for each item. It process it in sequence one at a time. For each new item it reads, it forgets state of previous items. Therefore, on each read we need to take appropriate action in our application. It is read only and also known as push parser. There is no handler on XML document side, only in our application.
- STAX (Streaming API for XML parsing) - This parser allows us to both read and write multiple documents at same time. Unlike SAX that reads one item at a time, STAX can be explicitly asked to get a certain item from XML document without loading it in memory. Therefore, we can look at it as mixture of DOM and SAX. It is pull parser and has handler on XML document as well
- JAXP (JAVA API for XML parsing) - Since JDK 1.5, the JAXP API has been available as a standard part of the Java platform, and it provides access to XSLT transformation, schema validation, and XPath processing services.
- Saxon [Kay20] - Open Source XSLT & XQuery processor developed by Saxonica Limited. The Saxon package is a collection of tools for processing XML documents. The main components accessible via API are:
  1. XSLT processor. Saxon implements the XSLT 3.0 Recommendation. The product can also be used to run XSLT 2.0 stylesheets, or XSLT 1.0 stylesheets in backwards compatibility mode.
  2. XPath processor. This supports XPath 2.0 and XPath 3.1. It can also be used in backwards-compatibility mode to evaluate XPath 1.0 expressions.
  3. XQuery processor. This supports XQuery 3.1, which also allows XQuery 1.0 or 3.0 queries to be executed.
  4. XML Schema Processor. This supports both XSD 1.0 and XSD 1.1. It can be used to support the schema-aware functionality of the XSLT and XQuery processors.

For parsing XML, we have decided to use Saxon. One may argue that for all 4 listed components, Java also has its own API – JAXP for 1st, 2nd and 4th together with XQJ for 3rd. However, in practice, Saxon is easier to use and more flexible than JAXP. Apart from that, main arguments are:

1. Saxon itself is one of the implementations for which Test Driver was also implemented. Based on Results Report [Kay16], it passes more than 99,9% of the QT3TS tests.
2. Saxons implementation of the Test Driver can be used as a baseline for developing our own Test Driver.

## 2.2 Phase 1 Implementation

### 2.2.1 Description

In the first phase of the implementation we have analyzed the structure of QT3TS. We had to understand the under-laying structure of each and every test case. We had to see under which tags the information is stored in order to obtain it using Saxon API. Example test case in XML format:

```
<test-case name="fn-absint1args-1">
  <description>
    Test: absint1args-1 The "abs" function
    with the arguments set as follows:
    $arg = xs:int(lower bound)
  </description>
  <created by="Carmelo Montanez" on="2004-12-13"/>
  <environment ref="empty"/>
  <test>fn:abs(xs:int("-2147483648"))</test>
  <result>
    <all-of>
      <assert-eq>2147483648</assert-eq>
      <assert-type>xs:integer</assert-type>
    </all-of>
  </result>
</test-case>
```

The two most important tags in each test case are:

- Test - this is the test that should be executed on Rumble. It can be XSLT, XPath or XQuery expression.
- Result - this is the expected result outcome of the test tag. As it can be seen in the provided example, there are several types of assertions that we need to verify.

Test Driver's Test Case Handling Logic is supposed to iterate over catalog.xml using the Saxon API. This XML document contains list of all test-sets. Again, using the Saxon API, we iterate over test-cases in each of the test-sets. For each test-case, we are asking explicitly Saxon XML parser to get items under Test and Result tags. To use Saxon API, we need to know the structure. But, once Test Case Handling Logic obtains information under Test tag, it passes it down "as is" to Rumble API in order to execute the query. Rumble API returns the result which is then passed down to Test Result Handling Logic.

Test Driver's Test Result Handling Logic is in charge of determining which assertion needs to be performed. Here we provide the list of possible assertions:

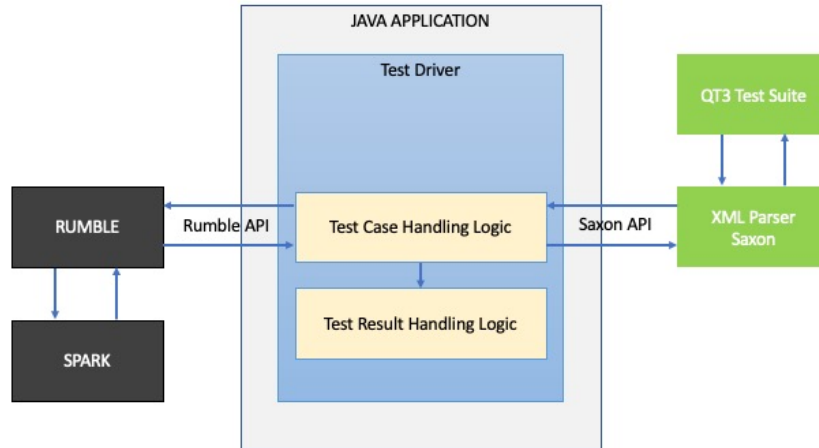
- assert-empty - This assertion requires result to return empty sequence
- assert - This assertion requires us to run another query in which obtained result will be used as parameter of the new query. For example:

```
<test>math:acos(0)</test>
<result>
  <assert>
    abs($result - 1.5707963267948966e0) lt 1e-14
  </assert>
</result>
```
- assert-eq - It requires us to run another query in form of obtained result "eq" value under the assert-eq tag
- assert-deep-eq - Similar to assert-eq but runs "deep-equal" query
- assert-true - It requires result to return single Boolean value True
- assert-false - Opposite of assert-true
- assert-string-value - It requires that each item in the obtained result sequence is type of String and also "eq" to the sequence under this tag
- all-of - It contains multiple different assert tags described in this list and it requires all of them to be fulfilled
- any-of - Similar to all-of but requires only one of them to be fulfilled
- assert-type - Requires to check if obtained result is instance of this tag
- assert-count - It requires obtained result sequence size to be equal to the value under assert-count tag
- not - It requires to execute nested assertion with a negation

After the assertion is performed, we need to classify the results. The idea is to make statistics that are described in 2.2.3. With such a classification we would be able to improve Rumble by reporting bugs in its implementation.

### 2.2.2 Architecture

The overview of scenario described in 2.2.1 can be seen in Figure 2.1



**Figure 2.1:** Phase 1 Architecture Overview

### 2.2.3 Results

As explained in 2.2.1, result obtained via Rumble API was compared with the expected result by applying the correct assertion check. In case assertion passed, test-case was considered a Success and otherwise Fail. The block of code performing these operations was surrounded by try and catch. In case that test failed because the syntax was not completely JSONiq, it would throw a RumbleException or more generally an Exception - Crash. With this implementation, we were to be able to distinguish 3 possible scenarios:

1. Success - Test case succeed
2. Fail - Test case failed because of bug in Rumble
3. Crash - Test case failed because it is not compatible with Rumble

The report is generated as .csv file having test-sets as rows and total number of test-cases per scenario in the columns. In Table 2.1 we will present the aggregated sum over all rows in the .csv file:

Scenario	Total test-cases	% of all test-cases
Success	2330	7.8
Fail	2769	8.8
Crash	26421	83.4

**Table 2.1:** Phase 1 Results Overview

## 2.3 Phase 2 Implementation

### 2.3.1 Description

After generating Phase 1 Implementation report described in Table 2.1, we carefully examined our implementation and identified 4 major pain points:

- Unstable implementation of assertion which resulted in implementing proper way of result binding in Rumble
- Too many crashing tests which resulted in implementing converter
- Insufficient granularity for distinguishing test-cases
- Improving Test Driver implementation resulted in breaking previously implemented features. Therefore, regression tests were introduced

### Result Binding

To better understand the issues we have encountered, we will provide following code snippet:

```
private boolean AssertEq(List<Item> resultAsList,
    XdmNode assertion) throws UnsupportedOperationException {
    String assertExpression = assertion.getStringValue();
    List<String> lines = resultAsList.stream()
        .map(x -> x.serialize()).collect(Collectors.toList());
    assertExpression += "=" + lines.get(0);
    List<Item> nestedResult = runQuery(assertExpression);
    return AssertTrue(nestedResult);
}

private boolean AssertStringValue(List<Item> resultAsList,
    XdmNode assertion) throws UnsupportedOperationException{
    String assertExpression = assertion.getStringValue();
    List<String> lines = resultAsList.stream()
        .map(x -> x.serialize()).collect(Collectors.toList());
    return assertExpression.equals(String.join(" ",lines));
}
```

If we examine the AssertEq implementation, we will notice that lines.get(0) assumes that obtained result is a single item and takes first one. It does not handle sequences! Furthermore, handling sequences was only possible for AssertStringEqual in case that our result is sequence of strings by performing string concatenation. All other assertions such as Assert, AssertEq, AssertDeepEq are not possible to be implemented. Finally, if we remember Assert example from Section 2.2.1, we will notice that we had to perform string replace of \$result with actual result obtained from the Rumble API.



Thus, Rumble was extended to support result binding. The change was made in Rumble implementation itself. The only modification it required was to instantiate a new RumbleConfiguration and also new Rumble instance for each test-case that requires result binding. Check code snippet below:

```
private boolean Assert(List<Item> resultAsList,
    XdmNode assertion) throws UnsupportedOperationException {
    String expectedResult = Convert(assertion.getStringValue());
    return runNestedQuery(resultAsList, expectedResult);
}

private boolean runNestedQuery(List<Item> resultAsList, String expectedResult,
    RumbleRuntimeConfiguration configuration = new RumbleRuntimeConfiguration(),
    configuration.setExternalVariableValue(
        Name.createVariableInNoNamespace("result"),
        resultAsList);
    String assertExpression = "declare variable $result external;" + expectedResult;
    Rumble rumbleInstance = new Rumble(configuration);
    List<Item> nestedResult = runQuery(assertExpression, rumbleInstance);
    return AssertTrue(nestedResult);
}
```

The main concern of the new implementation was that performing many instantiations might cause the execution time to increase dramatically. However, after run-time increased only by 15seconds from 2minutes - only 12.5%.

Once the result binding was implemented, it allowed us to run the assert type also as a query instead of calling the publicly exposed methods of the Item class in the Rumble Java API. In Phase 1 implementation, we had a switch case for every possible type that Rumble Java API supports, making code difficult for future maintenance and extension with new supported types. With running assert type as "instance of" query, we managed to have a single point of conversion performed in the beginning and applied for both test case and the expected result. Within conversion we would discover the unsupported type errors without the need of second switch case to check whether Rumble's API Item class supports the type or not. Furthermore, the previously implemented switch case had unsupported type as default therefore hiding some types that were supported but not specified in the documentation. The mentioned conversion will be explained more in detail in Section 2.3.1.

The clean separation that was performed here initialized idea and was a base plan for XQuery to JSONiq conversion logic separation. In Section 2.4.1 we will describe Architecture that has separate application that takes XQuery as input, performs conversion and outputs JSONiq test suite. Such approach would make the Test Driver easily maintainable and extensible!

### Converter

As seen in Table 2.1, we had less than 10% Success test-cases as almost all of them required conversion to JSONiq. Here we will document all the conversions that we have performed on both Test and Result tags in this Phase.

The first conversion that we have performed is between types. Both XQuery and JSONiq have simple(atomic) and complex(non-atomic) types.

The list of atomic types that is currently supported by Rumble was taken from official Rumble documentation [IFM<sup>+</sup>20b] and conversion was implemented accordingly. For all types that are not supported, our code throws `UnsupportedTypeException`.

Following 3 complex (non-atomic) types were handled by following conversion:

1. `array(*)` was replaced with `array*`
2. `item()` was replaced with `item`
3. `map(string, atomic)` was replaced with `object`

On the other hand, following 7 complex (non-atomic) types could not be converted and they all throw `UnsupportedTypeException`:

1. `document`
2. `element`
3. `attribute`
4. `text`
5. `comment`
6. `processing-instruction`
7. `xs:QName`

Other conversions that were performed:

1. `true()` was replaced with `true`
2. `false()` was replaced with `false`
3. `INF` was replaced with `Infinity`
4. array access via `.` was replaced with `$$`
5. `'` was replaced with `"`
6. prefixes `fn`, `math`, `map`, `array` were removed

Other items that were unsupported in Phase 2 were `node()`, `empty-sequence()` and `xs:NOTATION` together with all error codes that are not in Table 2.2 that was taken from [IFM<sup>+</sup>20a].

Type	Status	Supported Error Codes
atomic	supported	FOAR0001
anyURI	supported	FOCA0002
base64Binary	supported	FODC0002
boolean	supported	FOFD1340
byte	not supported	FOFD1350
date	supported	JNDY0003
dateTime	supported	JNTY0004
dateTimeStamp	not supported	JNTY0024
dayTimeDuration	supported	JNTY0018
decimal	supported	RBDY0005
double	supported	RBML0001
duration	supported	RBML0002
float	not supported	RBML0003
gDay	not supported	RBML0004
gMonth	not supported	RBML0005
gYear	not supported	RBST0001
gYearMonth	not supported	RBST0002
hexBinary	supported	RBST0003
int	not supported	RBST0004
integer	supported	SENR0001
long	not supported	XPDY0002
negativeInteger	not supported	XPDY0050
nonPositiveInteger	not supported	XPDY0130
nonNegativeInteger	not supported	XPST0003
positiveInteger	not supported	XPST0008
short	not supported	XPST0017
string	supported	XPST0080
time	supported	XPST0081
unsignedByte	not supported	XPTY0004
unsignedInt	not supported	XQDY0054
unsignedLong	not supported	XQST0016
unsignedShort	not supported	XQST0031
yearMonthDuration	supported	XQST0033
		XQST0034
		XQST0038
		XQST0039
		XQST0047
		XQST0048
		XQST0049
		XQST0052
		XQST0059
		XQST0069
		XQST0088
		XQST0089
		XQST0094

Table 2.2: Rumble Supported Types and Error Codes

### Regression Tests

During Phase 1, we were performing iterations with goal to overall improve Test Driver's implementation. The good metric while performing these iterations was total number of test-case Crashes. Our goal was to reduce those numbers as much as possible. This was mainly handled by making following changes: bug fixes, software enhancements, configuration changes. Creating this changes in software development can usually lead to creating new issues that were not present before or re-emergence of old issues. In these cases it is quite common that software development requires regression testing. Regression testing (rarely non-regression testing[1]) is re-running functional and non-functional tests to ensure that previously developed and tested software still performs after a change.[2] If not, that would be called a regression. . During iterations, it was noticed that our approach of fixing and improving the application is highly exposed to changes that require regression testing.

While performing iterations, we had to ensure that any further implementation would not break the test-cases that were passing before. Thus, with every new iteration, we have performed a check that compared whether all the passed tests from the previous implementation were also contained in the new implementation or not. For each iteration we have maintained log files of all Success and Crashed test-cases. In every next iteration we have done two comparison between new and previous log files. By doing so we have created "List of test cases that were passing before but not anymore" and "Tests that were not crashing before, but are now and not in list above".

### 2.3.2 Architecture

The overview of scenario described in 2.3.1 can be seen in Figure 2.2

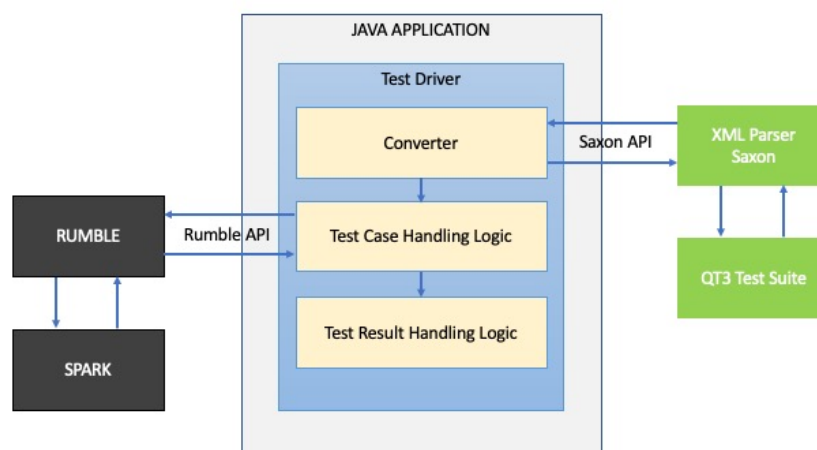


Figure 2.2: Phase 1 Architecture Overview

### 2.3.3 Results

As we have seen in Section 2.3.1, Crashes were not only capturing tests that are not JSONiq and needed conversion. They were also including the tests that could not succeed simply because Rumble does not support that feature, type or error code. In Table 2.2 we can see the limited amount of supported types and error codes compared to XQuery w3 specification for which we are able to verify assertion. All others would then be ignored and classified differently. Furthermore, some of them were introducing dependencies. For example, in dependency tag it was possible to have request for particular version of XPath, XQuery or XSLT. While Rumble is backwards compatible with all versions of XPath and XQuery, it does not support XSLT. We have therefore created and divided test cases into 7 groups:

1. Success – Test that is passing the assertion and does not need Converter
2. Managed – Tests that would have failed assertion, but they were modified with hard-coded conversion into JSONiq using Converter
3. Skipped – Test that is not JSONiq and thus expectedly fails assertion. These tests should not be converted to JSONiq
4. Failed – Tests that are failing because there is a bug in Rumble API or Test Driver implementation.
5. Dependency – Tests that are failing because dependency is not supported
6. Unsupported – Tests that are failing because type, feature or error code is not supported yet
7. Crash – Any other exception

After introduction of the 7 above mentioned cases, together with small adjustments and bug changes, we were able to obtain:

Scenario	Total test-cases	% of all test-cases
Success	2686	8.52
Managed	4211	13.36
Fail	2554	8.10
Skipped	5	0.02
Dependency	1481	4.70
Crash	13171	41.79
Unsupported	7412	23.52

**Table 2.3:** Phase 2 Results Overview

Managed category was introduced as it was identified that with simple hard-coded conversion we are able to obtain around 4200 passed tests increasing

total percentage of passed tests by roughly 12%. At first, it seems that Success and Managed should be grouped into single category, but we decided to keep them separated. The reason behind is that while fixing bugs in both Rumble and Test Driver, we will increase the number of Success test cases. At the same time, we want to keep the track of Managed ones, because in Phase 3 Implementation we are planning to generalize the hard-coded conversion and create pure JSONiq Test Suite based on given XML ones.

For Skipped tests, these are the ones that it would not make sense to try to convert them to JSONiq. One example is XSLT tests and those should be skipped. We are keeping them in separate list as in Phase 3 Implementation we will skip from output and not include them in pure JSONiq Test Suite.

The main goal of performing iterations was to go through all the crashes and try to completely eliminate them. By doing so we would also improve the statistics by classifying them into other categories. At the same time, we were manually investigating test cases and trying to find the root cause. For some of them, our Test Driver implementation was improved. For some it was identified that the XQuery function was not yet supported by Rumble or it was having bugs so Rumble implementation was also improved. List of dependencies that were found in Test Suite were documented and classified according to Rumble documentation. The list is presented in Table 2.3.3 .

Final goal was to identify test-cases that fail but can be converted to JSONiq. They could not be included into the automatic distinction of 7 above mentioned cases and had to be handled manually. They also helped with identifying what Phase 3 conversion also had to support.

maybe some reference here, ask Fourny

Converter we separate. Create a new architecture diagram where Converter outputs the JSONiq test suite. Emphasize that language is not converted. Emphasize that for Converter itself we need a plugin architecture. So that you can include and exclude some conversion. Also we will introduce

## 2.4 Phase 3 implementation

### 2.4.1 Description

The main issue of Converter described in Section 2.3.1 was that it was performed via Java String.replace method.

### 2.4.2 Architecture

The overview of scenario described in 2.4.1 can be seen in Figure 2.3

## 2.5 JSONiq and Test Converter Data Format

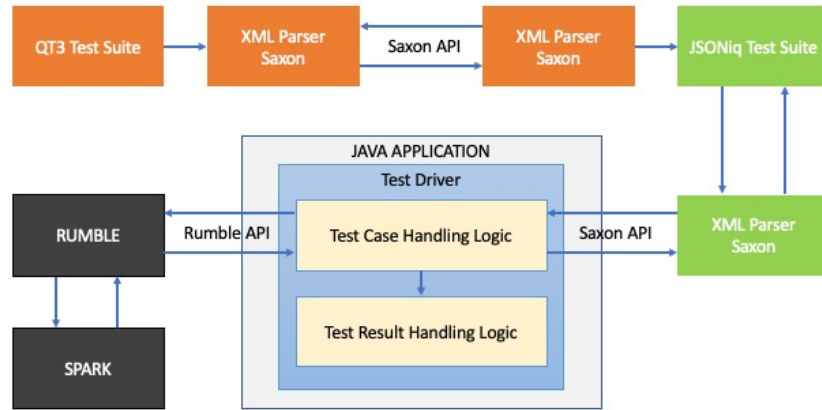
The JSONiq extension to XQuery allows processing XML and JSON natively and with a single language. This extension is based on the same data model as the core JSONiq and is based on the same logical concepts. Because of the complexity of the XQuery grammar, the JSONiq extension to XQuery

Dependency name	Status	
higherOrderFunctions	supported	
moduleImport	supported	
arbitraryPrecisionDecimal	supported	
schemaValidation	not supported (XML specific)	
schemaImport	not supported (XML specific)	
advanced-uca-fallback	not supported	
non_empty_sequence_collection	not supported yet	
collection-stability	not supported yet	
directory-as-collection-uri	not supported yet	
non_unicode_codepoint_collation	not supported	
staticTyping	not supported yet	
simple-uca-fallback	not supported	
olson-timezone	not supported yet	
fn-format-integer-CLDR	not supported yet	
xpath-1.0-compatibility	not supported (XML specific)	
fn-load-xquery-module	not supported yet	
fn-transform-XSLT	not supported yet	caption-
namespace-axis	not supported (XML specific)	
infoset-dtd	not supported (XML specific)	
serialization	not supported yet	
fn-transform-XSLT30	not supported yet	
remote.http	not supported	
typedData	not supported	
schema-location-hint	not supported (XML specific)	
calendar	not supported yet	
unicode-version	supported	
unicode-normalization-form	supported	
format-integer-sequence	not supported yet	
xsd-version	supported	
xml-version	supported	
default-language	only "en" supported	
language	only "en" supported	
spec	only "XT30+" not supported	
limits	not supported yet	

Supported Dependency List

## 2. XQUERY/XPATH 3.\* TEST SUITE(QT3TS)

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**Figure 2.3:** Phase 1 Architecture Overview

has a less pleasant syntax than the JSONiq core. When designing the Test Converter, we could have decided to use either XML or JSON as the underlying language. However, as our Test Driver was already implemented in the previous phase and was expecting XML as input and using the before mentioned Saxon for parsing it, we have decided to keep the same language for output of the Test Converter.



## Chapter 3

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# Concluding Remarks

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### 3.1 Overall Summary

sum up the results

### 3.2 Open Problems

further research here -  
maybe web html page  
of summary of the  
results. Maybe auto  
opening and closing  
issues on Git



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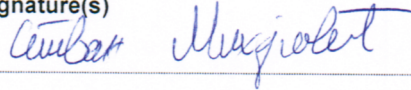
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