

Institution: University College London		
Unit of Assessment: 11- Computer Science and Informatics		
Title of case study: xlinkit for fast, cheap, reliable and automated verification of over-the-counter derivatives trading		
Period when the underpinning research was undertaken: 2000 – 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Wolfgang Emmerich Anthony Finkelstein	Role(s) (e.g. job title): Professor of Distributed Computing Professor of Software Systems Engineering	Period(s) employed by submitting HEI: 1997 – 2020 1997 - 2020
Period when the claimed impact occurred: 2013 - 2020		
Is this case study continued from a case study submitted in 2014? Y		
1. Summary of the impact <p>The Software Systems Engineering Group at UCL developed and patented xlinkit, an approach that supports the validation of XML documents in general and over-the-counter (OTC) derivative transactions expressed in the Financial Products Markup Language (FpML). The widespread adoption of FpML—also adopted by JP Morgan Chase's Extensions for securities, repos and security lending (95% of financial market participants now use it for OTC transactions)—has brought about a substantial reduction in market and credit risk for financial institutions, by reducing the time required to confirm derivative transactions from up to ten days to at most one day. About 500 validation rules have been defined for FpML using xlinkit. They define, for example, the constraints that check that the cashflows in an order for a derivative instrument match those held by a counterparty in a confirmation or that payment periods of the agreed cashflows equally divide the contract period. This reduction critically relies on very high straight-through-processing rates, which cannot be achieved if manual interventions are required. High straight-through-processing rates are critically reliant upon a high level of consistency within the OTC contracts, which xlinkit crucially provides. These consistency rules are formally defined in xlinkit and can be automatically checked by FpML validation products. This innovation is especially important given the high value of OTC derivatives, which rose to USD640,400,000,000,000 per annum at the end of June 2019. Message Automation (which markets a product called Message Automation Validator, based on xlinkit patent) has received GBP3,000,000 revenue in that same period. Following the acquisition of Message Automation by Broadridge in 2017, xlinkit remains an essential part of Broadridge Financial Solutions software platform, among others, now in use by over 50 financial institutions globally.</p>		
2. Underpinning research <p>The background of the research that led to xlinkit was Professor Wolfgang Emmerich and Professor Anthony Finkelstein's work on consistency management of structured and semi-structured software engineering artefacts, usually source-code documents. The consistency management of such documents required three elements: 1) the representation of abstract syntax trees and graphs; 2) the definition of validation rules to define static semantics and inter-document consistency constraints; and 3) the construction of validation engines that can execute these rules.</p> <p>The adoption of the Internet standards for managing semi-structured documents—most notably XML—created the possibility of applying similar techniques to documents other than source codes. Similar in nature to abstract syntax trees, representation of such semi-</p>		

structured XML documents is governed by the Document Object Model (DOM). Thus, the UCL Software Systems Engineering Research Group explored whether the principles, methods and techniques for consistency management of software engineering artefacts could be realised more elegantly using the emerging family of standards on XML that were being defined at the same time by the World Wide Web Consortium (W3C)—thereby making them applicable to a broader application area and semi-structured documents that are managed in a decentralised manner. A decentralised setting necessitated managing the consistency relationships out of bounds from the documents being related. The XLink standard of the W3C enabled the management of such out-of-bound relationships and the research focused on how such XLink relationships could be defined and created in an effective and efficient manner.

Xlinkit defines a first order rule language, which combines universal and existential quantification with Boolean logic operators over path expressions defined using the XPath standard. Through further work, researchers under the supervision of Professors Emmerich and Finkelstein then developed three different interpretations for the xlinkit language. The first interpretation showed how the language determines whether two distributed semi-structured documents are consistent with each other (**R1**). A second interpretation defines how out-of-bound links that capture consistency relationships between elements in two semi-structured distributed documents (**R1**) are inferred. And the third interpretation defines how the language determines for two distributed documents that are inconsistent with each other all possible modifications that render them consistent again (**R3**). The initial application of this research was to demonstrate how to manage the consistency of software engineering documents (**R2**, **R4**).

Once the wide applicability of the basic research on consistency management using XML technologies became evident, UCL protected the IP of the underlying research by patenting it in the US and UK. UCL then created a spin-out company called Systemwire, appointed a CEO to run the company and moved to develop a commercial application of the research results. This application has been available since early 2002.

During Spring 2002, UBS, UCL and Systemwire proposed the creation of the FpML Validation Working Group to the International Swaps and Derivatives Association (ISDA), which was submitted in June 2002 (**R6**). ISDA accepted the proposal and the FpML Validation working group was created in autumn 2003. It was chaired by Christian Nentwich, Wolfgang Emmerich's PhD student and had wide industry participation from BNP Paribas, Deutsche Bank, Barclays Capital, UBS and JP Morgan. The Validation working group then used the xlinkit language called Constraint Language in XML (clix) to formulate consistency rules for derivative transactions defined using the FpML standard (**R5**).

3. References to the research

- R1. C. Nentwich, L. Capra, **W. Emmerich** and **A. Finkelstein** (2002). xlinkit: A Consistency Checking and Smart Link Generation Service. ACM Transactions on Internet Technology, 2(2):151-185. <http://doi.org/btnt4z>
- R2. C. Nentwich, **W. Emmerich**, **A. Finkelstein** and E. Ellmer (2003). Flexible Consistency Checking. ACM Transactions on Software Engineering and Methodology, 12(1):28-63. <http://doi.org/bt87v2>
- R3. C. Nentwich, **W. Emmerich** and **A. Finkelstein** (2003). Consistency Management with Repair Actions. In Proc. of the 25th Int. Conference on Software Engineering, Portland, Oregon. pp. 455-464. ACM Press. <http://doi.org/c6z7j3>
- R4. C. Nentwich, **W. Emmerich** and **A. Finkelstein** (2001). Static Consistency Checking for Distributed Specifications. In Proc. of the 16th Automated Software Engineering Conference, Coronado Island, CA. pp. 115-124. IEEE Computer Society. <http://doi.org/fhphxv>
- R5. D. Dui, **W. Emmerich**, C. Nentwich and B. Thal (2003). Consistency Checking of Financial Derivative Transactions. In M. Aksit, M. Menzini and R. Unland (eds), Objects,

Components, Architectures, Services and Applications for a Networked World. Lecture Notes in Computer Science. 2591. pp. 166-183. Springer Verlag. <http://doi.org/bh5m8d>
 R6.B. Thal, **W. Emmerich**, S. Lord, D. Dui, and C. Nentwich, FpML validation proposal by UBS, UCL and Systemwire. June 2003
<http://www.fpml.org/documents/proposals/valid/proposal-fpml-validation-1.0.pdf>

US patent 7,143,103 granted 2006 to UCL for consistency management of distributed documents. UK Patent 9914232.5.

<http://patentscope.wipo.int/search/en/detail.jsf?docId=US41646661>

4. Details of the impact

Financial services institutions who trade in over-the-counter (OTC) derivatives have benefitted significantly from research conducted at the UCL Software Systems Engineering Research Group, as the notional outstanding contract value of OTC derivatives increased during the first half of 2019 to USD640,400,000,000,000, an 18% increase from the first half of 2017 (**S1**). FpML remains an open standard maintained by ISDA for documenting, dealing and processing OTC derivatives (**R5**), and FpML offers a cost-effective alternative for electronic communication of derivative contract information (**S2**). This innovation has reduced the time required to confirm derivative transactions from up to ten days to one day at most, thereby significantly reducing risk and exposure for financial market participants. The FpML validation rules continue to be defined using UCL's xlinkit technology, and the adoption of FpML continues to increase in the financial service sector.

FpML standard version 5.11 and validation rules

The current Version 5.11 of the FpML standard (recently revised in July 2020) was released in December 2019 to continuously support service users. Like previous FpML versions, the latest release is governed by validation rules developed by the UCL team (**R1**, **R6**), which are **“an integral part of the FpML standard providing business logic validation in addition to the schema validation,”** according to the Senior Director and Co-head of Data Reporting and FpML at the International Swaps and Derivatives Association (**S3**). Different parts of the trade cycle therefore benefit from “an additional layer of business logic validation that cannot be enforced through XML schema” (**S3**). The validation architecture written as a result of the underpinning research (**R6**) now defines some 500 validation rules for a large number of equities, interest rates, credit, energy and foreign exchange derivatives.

These rules help clarify the meaning of derivative transactions defined in FpML and provide precise and unambiguous means for market participants using FpML to electronically trade derivatives to validate the correctness of these transactions. The validation rules are included in the normative part of the standard, which means that the financial market participants that have adopted FpML will have to comply with these validation rules in their FpML messages. As such, Message Automation continues to provide a reference implementation of these rules using its xlinkit technology, as it continues to be included in Version 5.11 of the FpML standard. This latest version has informed the continued adoption of electronic processing implemented between August 2013 and December 2020. Thus, the substantial introduction of electronic confirmation with FpML (which can be validated automatically) has reduced manual effort and brought down the time required to confirm derivative transactions from up to 10 days to at most one day. This reduction means **there is also a substantial reduction in the period during which a financial market participant is subject to market and credit risk because a contract is not yet confirmed**. Given the value of these transactions confirmed by the FpML surveys, this risk reduction is very significant. Some financial market participants have stated these benefits publicly.

Continued use of xlinkit language for financial services

A recent survey on progress made by firms incorporating the FpML standard gathered data from 33 participating firms including dealers, asset managers, technology companies, assets and fund managers, trade repositories, clearing houses and execution facilities (**S4**). These

vendors benefit from **the clarity and unambiguity introduced through the validation rules defined using UCL's consistency-checking technology with xlinkit**. FpML continues to be used for regulatory reporting in major jurisdictions and reporting systems in Asia, Europe and in the USA. As such, participating vendors reported **10,000,000 daily FpML messages**, showing a **"large increase in message volume compared to the last survey"** and continuous implementation of UCL technology (**S4**). All messages recorded abide by the validation rules defined in the xlinkit underpinning research (**R6**).

The ISDA found a significant level of adoption of electronic confirmations for different classes of OTC derivatives. The adoption rate of electronic confirmations for all market participants was 81% for interest rates derivatives, 16% foreign exchange and 3% distributed among credit derivatives, commodities, equity and other derivatives (**S1**). The adoption of FpML by the financial services sector has become widespread, with **76% of the financial market participants** dealing with recordkeeping view and **62% dealing with confirmation view** (**S4**). Moreover, **39% of dealers and 30% of technology and asset management** participants implement the FpML validation rules defined with xlinkit (**S4**). In addition, 64% of the firms that responded to the survey use tools to convert or translate FpML to other formats or from other formats to FpML depending on firms' needs, while 45% specified using binding tools for FpML application development. This has provided an opportunity for technology firms to develop tools related to FpML: of the technology firms surveyed, 50% provide tools to create, transform or parse FpML, while 40% provide interfaces to and from systems and 20% offer system integration and/or validation services.

Xlinkit technology through Message Automation (Broadridge Financials)

The ability to check whether a trade meets all relevant constraints automatically, and therefore with minimal cost, significantly reduces the time it takes to confirm these transactions (**R1, R2**), with fewer operations staff required. This advantage highlights the flexibility of the xlinkit solution through Message Automation, where there is a **"proven track record - 100% of clients happy,"** in turn building "long-term relationships with a wide range of clients inducing Tier 1 and Tier 2 banks and buy-side organisations" (**S5**). By using Message Automation, financial market participants are therefore exposed to market and credit risk during a shorter period between a trade being agreed and its confirmation.

In 2017, Message Automation was acquired by Broadridge (**S6**) for about **GBP45,000,000**, attesting to the technology's value for the financial services sector. The most recent revenue sharing report from 17 December 2019 states that UCL Business has received royalty income from this patent in the amount of GBP462,838.95 since 2003. Between May 2017 and December 2019, **GBP150,000** of this income was received from Broadridge, suggesting the continuous impact from the licenced UCL patent. The President of Global Technology and Operations International for Broadridge, said that **"Message Automation's leading technology and expertise on derivatives processing models"** was the key driver behind this acquisition, and acquiring this technology has "helped Broadridge establish a comprehensive suite of capabilities across asset classes globally" (**S7**).

The General Manager, BRMA Head of Capital Markets Data & Regulatory Solutions, Broadridge Financial Solutions stated, "Xlinkit, or as we describe it 'Message Automation Validator' remains an intrinsic part of our software platform. It is one of the four core engines we use in all of our business solutions, and is used for much more than just its original purpose of FpML validation, it is the decisioning engine that our orchestration engine uses for [applying] routing rules" (**S8**). Through Broadridge Financials, he said, xlinkit "is now in use by **over 50 financial institutions** globally for various business purposes" (**S8**).

5. Sources to corroborate the impact

S1. ISDA (2018) Key Trends in the Size and Composition of OTC Derivatives Markets 1H 2019 available from <https://www.isda.org/2019/11/27/key-trends-in-the-size-and-composition-of-otc-derivatives-markets-1h-2019/>

- S2. Kolby, M. (2016) Markit acquires syndicated loan technology from J.P. Morgan.
https://news.ihsmarkit.com/prviewer/release_only/slug/financial-markets-markit-acquires-syndicated-loan-technology-jp-morgan
- S3. Karel Engelen, Senior Director at ISDA
- S4. ISDA FpML Survey (2018) available from <https://www.fpml.org/docs/surveys/ISDA-FpML-survey-201802.pdf>
- S5. Message Automation (2014) <https://derivsource.com/2014/08/07/message-automation-2/>
- S6. Broadridge (2020) Message Automation is Now a Broadridge Business.
<https://www.broadridge.com/intl/article/message-automation-a-broadridge-business>
- S7. Broadridge Acquires Message Automation (2017)
<https://www.finextra.com/pressarticle/68380/broadridge-acquires-message-automation>
- S8. Testimonial by The General Manager, BRMA Head of Capital Markets Data & Regulatory Solutions, Broadridge Financial Solutions