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The Deliberate Practice of Software Testing

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EXACTPRO AT A GLANCE

Exactpro is an independent provider of AI-enabled software testing services for financial sector organisations. Our clients are exchanges, post-trade platform operators, and banks across 20 countries. Our area of expertise comprises protocol-based testing of matching engines, market data, market surveillance, clearing and settlement systems, payments APIs. We help our clients to decrease time to market, maintain regulatory compliance, improve scalability, latency and operational resiliency. Exactpro is involved in a variety of transformation programmes related to large-scale cloud and DLT implementations at systemically important organisations.

Founded in 2009, the Exactpro Group is headquartered in the UK and operates delivery centres in Georgia, Sri Lanka, Armenia, and the UK and representative offices in the US, Canada, and Italy.

Exactpro was part of the London Stock Exchange Group (LSEG) from May 2015 until January 2018, when the Exactpro management went through the buyout of the company from LSEG.

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MEET THE GLOBAL TEAM

Iosif Itkin
CEO, Exactpro Group, Malta

Alexey Zverev
CEO, Exactpro Group, UK

Natia Sirbiladze
CEO, Exactpro Georgia, Georgia

Kirill Zagorouiko
Chief Operating Officer, Canada

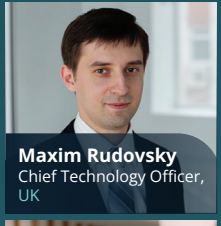
Alyona Lamash
Director, Head of Risk Management Practice, UK

Thomas Toller
Managing Director, USA

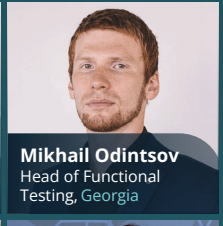
Marina Kudryavtseva
Head of DLT & Corda, SVP, Technology, UK

Ian Salmon
Business Development, UK

Michael Smith
Head of Sales, UK

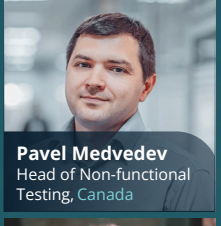


Maxim Rudovsky
Chief Technology Officer, UK



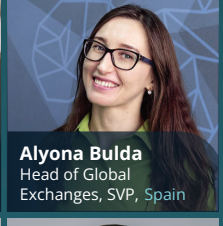
Mikhail Odintsov
Head of Functional Testing, Georgia

Victoria Leonchik
Technology, Data Warehouse, UK

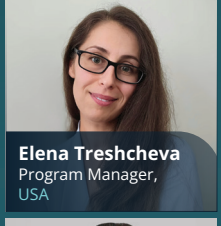


Pavel Medvedev
Head of Non-functional Testing, Canada

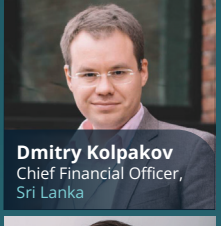
Anna-Maria Lukina
Marketing Director, Portugal



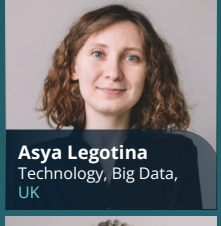
Alyona Bulda
Head of Global Exchanges, SVP, Spain



Elena Treshcheva
Program Manager, USA

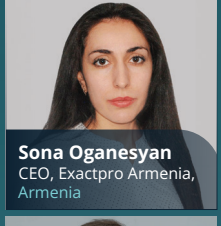


Dmitry Kolpakov
Chief Financial Officer, Sri Lanka

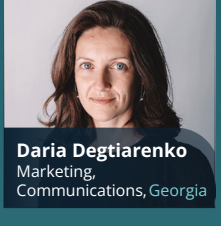


Asya Legotina
Technology, Big Data, UK

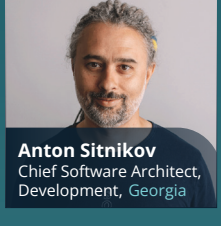
Dmitry Doronichev
Head of Post Trade Division, Sri Lanka



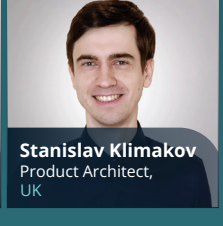
Sona Oganesyan
CEO, Exactpro Armenia, Armenia



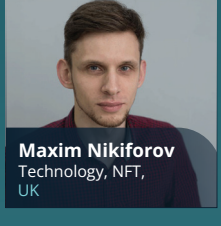
Daria Degtiarenko
Marketing, Communications, Georgia



Anton Sitnikov
Chief Software Architect, Development, Georgia



Stanislav Klimakov
Product Architect, UK



Maxim Nikiforov
Technology, NFT, UK

AI TESTING: DELIVER BETTER SOFTWARE, FASTER

Software testing is an information service. Its goal is to provide stakeholders with objective information about the defects persisting in their system. A software defect is anything in the code, configuration, data or specification that can decrease the value of software to its stakeholders. The effectiveness of an information service can be assessed based on its accuracy, relevance and accessibility. Improving software testing implies making it progressively better at detecting and interpreting defects, whilst reducing the timeframes and costs.

With the growth of available digital data and computational capabilities, we are seeing the use of subsymbolic artificial intelligence (AI) deliver improvements in autonomy and efficiency across many industries. In software testing, using AI can help harness the power of big data analytics to enhance the generation of test ideas and the interpretation of test results – both tasks traditionally thought to be highly cognitively demanding. These can also be complemented by advanced execution capabilities.

Using AI algorithms introduces new levels of automation and system exploration. At Exactpro, the use of AI algorithms combined with the principles of model-based testing form the ***AI Testing*** approach. It is designed to strengthen the operational resilience of client infrastructures and, by association, the entire financial technology landscape.

Exactpro's AI-enabled cross-asset and technology-agnostic approach is gaining industry adoption. Each instance of the technology transformation facilitated by Exactpro is supported by a custom-made test framework leveraging our corresponding domain expertise, industry-tested system modelling capabilities and test libraries.

AI Testing ensures that a test framework can fully match the complexity of the system under test. Helping account for massive amounts of parameter permutations unique to the system being tested, AI-enabled automation provides increased versatility of the test library, compared to manual or more formal test generation methods.

Leveraging AI and machine learning, Exactpro transforms the quality evaluation service by providing more extensive, highly-performant yet resource-efficient testing of the functional and performance aspects of financial technology platforms. The approach ensures more effective test coverage via better detection of potential vulnerabilities.

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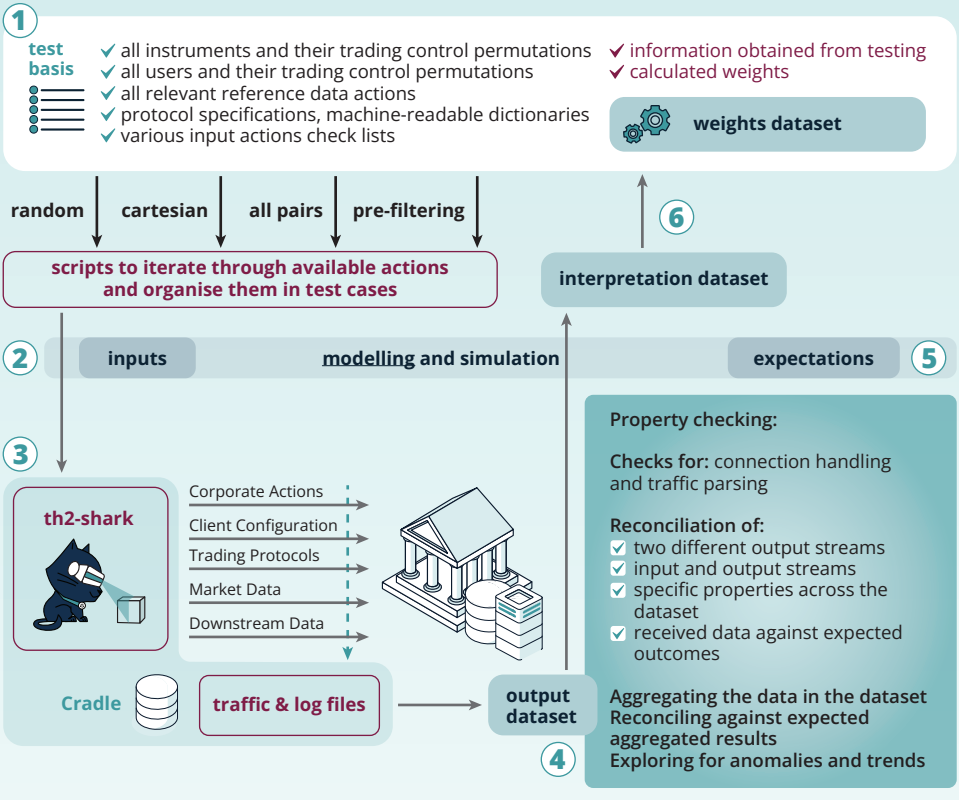
AI TESTING: EXCHANGE SYSTEMS*

CASE STUDY



*To see examples of AI Testing implementations for investment banking and clearing & settlement systems, visit **exactpro.com/ai-testing**.*

TEST LIBRARY GENERATION AND OPTIMISATION

Would you like to see the benefits of AI-enabled test library generation and optimisation for yourself? Watch our latest AI Testing demo by following this QR code.

ENHANCING THE QUALITY OF BANKING TECHNOLOGY PLATFORMS THROUGH A HYBRID AI TESTING APPROACH

Iosif Itkin
CEO & Co-Founder,
Exactpro

Elena Treshcheva
Program Manager,
Exactpro

In the dynamic landscape of the banking sector marked by increased operational complexity and regulatory scrutiny, the pursuit of innovation demands a strategic approach. While offering enhancements in cost, quality and speed, it should mandate a cautious consideration of the risks inherent in the integration of emerging technologies. With the continuous advancement of artificial intelligence (AI), particularly, generative AI (GenAI) – as a method for improving process automation and streamlining dataflows and customer onboarding, among other use cases – its wider adoption in the financial industry demands careful consideration of the associated risk implications.

On top of regulatory compliance, aspects such as ethical considerations, potential biases, and the need for human oversight remain critical in AI-driven product development and testing. This paper* advocates for a software testing approach capable of addressing the complexities of banking technology platforms. Rooted in the principles of model-based testing, the proposed approach leverages GenAI algorithms to achieve extensive test coverage of the distributed systems and simultaneously employs rule-based analytics to refine the generated datasets, optimising coverage for faster test library execution and efficient resource utilisation. Such an approach is in line with a risk-averse innovation strategy, as it balances the smart creativity with more deterministic discriminative mechanisms.

Following the proposed approach, banking technology operators get to innovate, while learning about potential issues persisting in their systems faster and mitigating risks better, making timely and informed release decisions.

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WELCOME TO OUR PoC PROGRAMME

Exactpro has been successfully applying its AI Testing approach across capital markets use cases for two years. It has helped enhance protocol-based testing of matching engines, market data, market surveillance, clearing and settlement systems worldwide. In addition to helping improve the quality of their systems, the approach has helped our clients decrease time to market, maintain regulatory compliance, improve scalability, latency and operational resiliency.

We are now looking to expand the scope of the approach beyond capital markets. We kindly invite participants from the banking industry to join our Proof-of-Concept (PoC) Programme to partner on exploring innovative ways to improve quality assurance processes across a variety of banking use cases.

PROGRAMME OBJECTIVES

- Helping banks and banking organisations benefit from cutting-edge software testing technology solutions and having them assessed for applicability and comprehensiveness against the existing bank infrastructure setup;
- Advancing the development and testing of innovative Machine Learning (ML), Artificial Intelligence (AI) and Generative AI (GenAI)-based solutions in the banking sector;
- Exploring use cases of ML, AI, and GenAI implementation in the banking space, while maintaining full regulatory compliance.

APPLICATION PROCEDURE

To submit your PoC Programme application, please fill out the short form on the Exactpro website (via the QR code on this page). A member of the Exactpro PoC Programme team will get in touch with you within 1-2 business days.

Feel free to contact our team via *info@exactpro.com* with any additional questions.

GLOBAL IMPACT OF THE EU ARTIFICIAL INTELLIGENCE (AI) ACT

Among the first articles of the **EU AI Act** to take effect is the **"AI Literacy" obligation** that entered into force on 2 February this year. The Act defines "AI Literacy" as "skills, knowledge and understanding that allow providers, deployers and affected persons, taking into account their respective rights and obligations in the context of this Regulation, to make an **informed deployment of AI systems**, as well as to gain awareness about the **opportunities** and **risks** of AI and **possible harm** it can cause." Both providers and deployers of AI systems are obliged to "ensure, to their best extent, a sufficient level of AI literacy of their staff and other persons dealing with the operation and use of AI systems on their behalf," taking into account both the current technical knowledge of the said staff and the context in which the AI solution will be used.

It is worth noting that, whilst the "Regulation does not apply to AI systems released under free and open-source licences," it still applies to those free or non-commercial models that are "placed on the market or put into service as **high-risk AI systems** or as an AI system that falls under Articles 5 or 50." **Article 5** – already in effect – describes a set of practices prohibited for AI systems. **Article 50** – to be enforced on 2 August 2026 – focuses on AI systems that create synthetic content (like deepfakes and other visual, audio or textual artefacts) and the importance of labelling their outputs as artificially generated. The same applies to AI used for emotion recognition or biometric categorisation, unless used in law enforcement or for national security purposes.

Main takeaways for the financial industry:

- AI system providers, deployers, and manufacturers deploying third-party AI solutions under their own trademark are already subject to a **rigorous set of obligations**, the number of which is expected to incrementally expand;
- One such obligation is for providers and deployers of AI technology to establish a sufficient level of **AI Literacy** of their staff – and others dealing with or operating the system on their behalf – by means of training specific to their use case;
- Even providing a free (non-commercial-use) AI solution does not absolve a given provider of the abovementioned **accountability**;
- The EU AI Act has a **global impact**, affecting both EU-based and non-EU-based businesses who export their AI solutions to Member States or plan to do so in the future.

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AI & SOFTWARE TESTING TRAINING: LEARN TO TRAIN AI MODELS AND HANDLE BIG DATA

As a technology vendor supporting FMI transformations, we hold our clients and ourselves to increasingly high standards. In early 2024, Exactpro received accreditation from ISTQB®, a globally recognised body for software testing certification, for our innovative AI Testing training course curriculum, developed for individual and corporate clients. Over the last year, we have been successfully sharing **AI Literacy** practices within the broader fintech community. The course helps understand the complexities involved in:

- using the AI toolkit to automate workflows and everyday project tasks, enhancing their efficiency, and
- testing AI-based systems – including self-learning functionalities – from the functional and performance perspectives, mitigating issues such as biases, ethics, non-determinism, and the challenges related to transparency and explainability.

The course follows the ISTQB® CT-AI syllabus structure and features both theory and practice materials on topics including:

- Machine Learning (ML)
- Neural Networks and Testing
- Testing AI-based Systems
- Test Environments for AI-based Systems
- AI for Testing

ARE YOU LIMITED ON TIME OR HAVE SPECIFIC REQUESTS BASED ON YOUR CURRENT PROJECT?

We also offer:

- Custom training programs for your team
- Exclusive workshops on AI testing tools and practices
- Expert consulting for business-specific challenges

To find out more about the training course or register your interest, please visit *exactpro.com/training/ISTQB-AI-Testing-course*

BUILD SOFTWARE TO TEST SOFTWARE

TRADING TECHNOLOGY TESTING

CASE STUDIES

EXACTPRO – JSE COLLABORATION TO TEST THE MILLENNIUM EXCHANGE™ PLATFORM

The case study highlights the Exactpro deliverables in setting up automated functional and non-functional testing of the Millennium Exchange™ trading platform provided to the Johannesburg Stock Exchange (JSE) by LSEG Technology.

ATHENS STOCK EXCHANGE (ATHEX) TRADING SYSTEM FIX MIGRATION

OASIS Upgrade Testing & Coverage Analysis

The case study is a reference use case for supporting trading system migrations to FIX-enabled technology, it also highlights the role of passive testing approaches in performing and automating regression testing and improving test coverage.

MEMX – EXACTPRO COLLABORATION ON EXCHANGE QUALITY ASSURANCE

The case study reviews the extensive functional testing and test automation delivered by the Exactpro team.

MARKET SURVEILLANCE SYSTEMS TESTING

The case study highlights the challenges and the complexity of testing market surveillance systems connected to trading platforms, market data providers, involving various data mining processes, alerting mechanisms, and having different degrees of process distribution complexity. The case study is based on the experience of testing a number of market surveillance systems across different markets and locations.

MARKET DATA SYSTEMS TESTING

Recommended Practices for AI-enabled testing of market data, ticker plant, consolidated tape, Securities Information Processor and direct-feed solutions that handle market data from trading venues.

AI-ENABLED SOFTWARE TESTING FOR ARTEX MTF

The case study highlights Exactpro's AI Testing approach tailored to ARTEX needs and encompassing E2E functional and non-functional testing of the MTF's protocol and matching engine software.

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POST-TRADE TECHNOLOGY TESTING

CASE STUDIES

POST TRADE: FUNCTIONAL AND NON-FUNCTIONAL TESTING

In times of high market volatility, CCPs are one of the finance infrastructure links that are hit the hardest. This case study focuses on the Exactpro approach to testing large-scale post-trade infrastructures with emphasis on enhancing system resilience and increasing the level of process automation. The latter is achieved via leveraging the latest data mining and machine learning techniques.

RISK MANAGEMENT

The case study focuses on the challenges of testing risk management systems and Exactpro's test automation and testing approach developed and implemented for our client, a central counterparty responsible for clearing and risk management of CCP-eligible transactions on a leading European exchange.

COLLATERAL MANAGEMENT

The case study features scenarios for testing of collateral and liquidity management systems for a leading global rates and multi-asset clearinghouse and a multi-national central counterparty.

AUTOMATING CUSTOMER CONFORMANCE CERTIFICATION

Conformance certification (also known as conformance testing) is a mandatory step in ensuring that customer systems comply with the officially declared exchange/broker certification rules. Conformance certification is conducted in order to prevent the occurrence of compatibility issues between the trading platform and the systems of the trading participants connecting to it. The list of parties conducting conformance certification includes but is not limited to exchanges, alternative trading systems (ATSs), multilateral trading facilities (MTFs), Swaps Execution Facilities (SEFs), broker and post-trade systems. The case study describes Exactpro's passive-testing-based solution for streamlining customer conformance testing automation.

THE ROLE OF T+1 IN POST-TRADE SYSTEMS QUALITY ASSESSMENT

First published in
the World Federation of Exchanges Focus Magazine

focus | Monthly insight from the WFE and our member exchanges

As a number of countries have successfully transitioned to the compressed settlement standard, many are still to follow suit. The T+1 transition collaboratively initiated by SIFMA, ICI, and DTCC – backed by the SEC in the US and joined by the CDS and CIRO on the other side of the border – clearly defines the direct impact on business and operations activities. However, it does not formally prescribe how the change influences the configuration of frameworks and processes that ensure the quality of the systems involved. Determining the extent to which software testing operations are affected by T+1, in fact, reveals the strengths and vulnerabilities of the organisation's underlying approach to quality assessment.

The heavily manual quality assurance operations, the ones reliant on specifying tests step-by-step in Excel and their manual execution in the system's user interface, are likely to be affected the most. Continuing to introduce technical changes manually will be incredibly time-consuming. In the context of the compressed clearing and settlement timeframes being a global trend and a systemic shift – it is doubtful that this can be considered a competitive practice.

For venues that have had their automated test libraries (T+2 or longer) previously set up, deployed and functioning as regression testing tools, validating a transition to T+1 will be much less of an effort, but it would still not be as simple as mass-replacing expected result values in test scripts or implementing any other typical change request. Disparate processes would have to be reconfigured and realigned, with the aim of having the test framework match the new lifecycle structure. In this case, test library optimisation would still involve a considerable amount of manual effort.

What is crucial to understand is that it is impossible to just test the T+1 transition in isolation (i.e. as an add-on feature) in any given system, if it is to be done comprehensively and efficiently. This approach would lack an understanding that the quality of the system's functions and all its interconnected processes should be verified in a holistic way. That is why venues that already have an automated test library in place and, thus, the ability to implement its migration to the T+1 lifecycle, are much better-positioned for the transition. Those that do not have a comprehensive test library would have to take a step back and start from developing one from scratch. In a way, T+1 can be thought of as a measure that levels the playing field for quality assessment practices. Clearing and settlement organisations that have not been dedicated to developing a streamlined software testing framework will be inclined to do it now.

An approach where T+1 impact on quality assessment is reduced even further is one where testing is a data-driven practice. This may encompass end-to-end (E2E) model-based testing (MBT) and automated input data generation, execution and results analysis using machine learning (ML, also known as subsymbolic AI) methods.

In this approach, neither the input data nor the expected results are specified manually. They are generated automatically, based on the logic defined in the test input generators and the model of the system under test (SUT), respectively. In case of changes to the system logic of any scale – including the shortening of the settlement cycle – the only place where changes need to be introduced is the corresponding model code. Following the change, new test inputs and expected outcomes aligned with the T+1 cycle are generated as part of the usual test workflow.

The resulting process is less time- and resource-consuming, compared to the other approaches. Instead of engaging large amounts of specialists supporting and changing the test cases and test scripts, the approach requires the involvement of fewer experts that, in turn, are tasked with model maintenance and results analysis.

The result of end-to-end modelling would be an automated test library covering the system's functionality. A comprehensive and efficiently automated test library puts a time limit on how fast E2E testing on a given implementation can start, and how fast it can be completed. Using ML methods enables deeper system exploration and leads to a more extensive test suite accounting for more unique parameter combinations and more versatile edge cases, with faster, more resource-light results triage and analysis.

To best prepare for a T+1 transition, whether it arrives in their location in 2025 or 2027, clearing and settlement technology operators should be concerned with developing an efficient integrated test library and ensuring its comprehensive coverage of their system. In that case, a major part of testing would be taken care of before the transition happens and, once the systems are transition-ready, a limited scope of the test library can be fine-tuned to fit the new schedule.

Follow the QR code on this page to access *the full version of the article*.

Dmitry Doronichev
Head of Post Trade,
Exactpro

CONFIDENT INNOVATION: DIGITAL TWINS FOR OPERATIONAL RESILIENCE IN EXCHANGES AND CCPs

First published in
the World Federation of Exchanges Focus Magazine

focus | Monthly insight from the WFE and our member exchanges

'Digital twins' are known to be a reliable means of system simulation across industries: automotive, space, manufacturing – used to obtain valuable insights about a system's quality, analyse its performance, and even prevent or remediate breakdowns. However, building digital twins for modelling complex transaction-processing systems such as exchanges, payment, clearing and settlement systems for the purpose of assessing their quality is an area explored less extensively. This article aims to shine the well-deserved spotlight on the significance of simulation in fintech systems delivery.

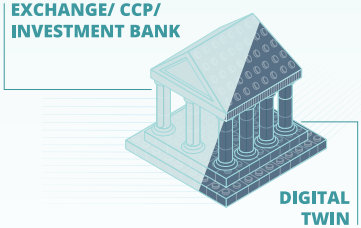
Any given exchange environment can require one to two hundred servers to stay operational. A model of the same environment may require just two servers to run the simulations covering all of the system's quality assessment needs. Significantly optimised resources cut down the associated hardware footprint and costs.

Sufficiently thorough regression testing can require substantial time and effort. Using a model, however, would provide a highly efficient version of the regression test library that leverages computing capabilities to produce and analyse diverse scenarios. Increased testing speed enables faster delivery as well as promotes risk-informed decisions and better delivery strategies.

It is possible for a model to be built as the system matures, which, in line with agile software development methodologies, enables stakeholders to receive objective information about the system early in the development lifecycle and resolve most issues long before they become critical.

Due to its ability to unlock greater control over system components and functions, system modelling provides a fundamentally deeper extent of system analysis, compared to SLA-outlined requirements traceability matrices – more so with the use of AI.

Continue reading about *The Synergy of System Modelling and AI* on our website.



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EXACTPRO WINS
MOST INNOVATIVE PROFESSIONAL DEVELOPMENT INITIATIVE

A-Team Innovation Awards 2024

WINNER

Exactpro

Most Innovative Professional Development Initiative

Many congratulations to Exactpro in winning the Most Innovative Professional Development Initiative award in recognition of their achievement in delivering high levels of innovation to financial institutions. They should be deservedly proud of this accomplishment.

Angela Wilbraham, CEO at A-Team Group,
and host of the 4th annual A-Team Innovation Awards 2024

DIGITAL ASSETS OWNERSHIP
WINNER
RUNNER-UP
SYNTHETIC DATA GENERATION

Swift **HACKATHON** at sibos

PARTNERS AND INDUSTRY ASSOCIATIONS

FIX TRADING COMMUNITY — INDUSTRY-DRIVEN · INDEPENDENT · NEUTRAL

WFE WORLD FEDERATION OF EXCHANGES

Zero Outage INDUSTRY STANDARD

ISTQB Platinum Partner — International Software Testing Qualifications Board

Swift

FIA

r3.corda

DLT AND PAYMENT SYSTEMS TESTING

CASE STUDIES

This November marks the end of the coexistence period for key legacy cross-border bank-to-bank payment instruction messages such as MT103 and MX messages of the ISO 20022 standard. Some MT messages will no longer be supported, while others will become subject to contingency processing fees until their complete retirement. As adoption pressures rise and the industry moves towards global harmonisation, the Exactpro team stays well-equipped to facilitate our clients' transitions with a comprehensive ISO 20022 testing library.

Payments infrastructure providers are also disrupting the space with emerging technologies, and tokenization continues to play an expanding role in traditional finance. In recent years, our team has successfully tested digital exchanges and helped integrate DLT (Distributed Ledger Technology) networks with Payment Service Providers (PSPs), bridging decentralized finance (DeFi) with mainstream banking systems.

Testing Distributed Ledger Technology Platforms and Infrastructures

The case study discusses the development of new techniques for the functional and non-functional testing of distributed ledger technologies (DLT) such as Corda, Hyperledger and DAML, in particular, for their application to mission-critical financial market infrastructures.

Functional Testing of CBDCs in the R3 Sandbox for Digital Currencies

The case study focuses on the approaches for functional testing of a Corda-based CBDC solution.

DEMOS

Formal Verification of Smart Contracts with the th2 Framework for Automation in Testing

P8 NFT Marketplace Functional Testing with the th2 Framework for Automation in Testing

th2 Implementation for Reconciliation Testing of the P8 Marketplace Built by Yaala Labs

Learn more about our Case Studies and Demos on our ***website***

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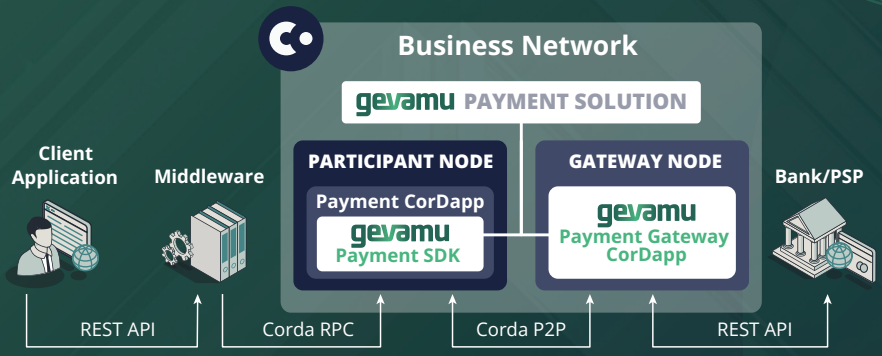
GEVAMU PAYMENT SOLUTION

Enter the age of interoperability, fully equipped to accommodate your customers' technology needs

Enhance your domestic and cross-border payments infrastructure with greater speed and transparency

Connect your payments platform and the blockchains of your choice to set up a frictionless workflow and benefit from full ISO 20022 support

Enable integrated ecosystems where users can send and collect cryptocurrencies, CBDCs and fiat money across technologies



Gevamu Payment Solution is developed as two components – a payment SDK and a payment gateway. The current implementation is to be deployed in a Corda business network managed by a Corda Business Network Operator (BNO). A separate gateway is configured for each bank/PSP.

Implementations for other blockchains are possible upon request.

Watch demo ⟶

HOW COMPLETE IS THE '100% TEST COVERAGE' ?

First published in
the World Federation of Exchanges Focus Magazine

Focus | Monthly insight from the WFE and our member exchanges

A 100%-scale tends to be a common sign of "complete" test coverage or the degree of test automation in assessing the quality of complex fintech platforms. But is it always clear what the "100%" implies and what requirements it actually satisfies? Let's see why this approach is fundamentally at odds with what comprehensive quality assessment is, and why it does not lead to representative test coverage.

The approach to quality assessment that includes "100%" goals is often based on a traceability matrix featuring quality requirements based on user stories. The International Software Testing Qualifications Board (ISTQB) Glossary defines a user story as "a high-level user or business requirement [...] in the everyday or business language capturing what functionality a user needs and the reason behind this [...]." The downside of this approach is that it causes the resulting quality metrics to be driven by high-level static descriptions of user needs that may not communicate the entire context or outline the true depth of the test coverage measure of a given requirement.

For example, if a user expects an order with a negative price to be rejected, then the user story will state that fact, and the resulting test will aim to confirm it. In contrast, what software testing should do is challenge this requirement and try to prove the opposite — check whether there are, in fact, conditions where a negative price is accepted, that would mean detecting an issue (a bug). Covering the "price-result" field combination in-depth would require checking as many value and parameter combinations as possible. This measure would ensure a truly comprehensive quality assessment, as opposed to that derived from directly following the initial requirement to the letter.

We can observe that a failure of a complex system is rarely traced back to an isolated error. It is often a combination of factors, e.g. a large amount of minor individual issues considered non-critical, the common context of which is being ignored, accumulating into a larger problem. That's why it is important for the test framework to encompass all possible relevant conditions and parameters that could in any way affect system behaviour, as well as their combinations.

Access the full article on our *website* for more insights on comprehensive quality assessment.

Maxim Nikiforov
Senior Project Manager,
Commodity Exchanges,
Exactpro

exactpro

AI-DRIVEN SYNTHETIC DATA ENGINEERING FOR IMPROVED DIGITAL RESILIENCE

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Focus | Monthly insight from the WFE and our member exchanges

As the rapidly expanding fintech space ventures into innovative transformation initiatives, seeing outages as a "data" problem can set it up for long-term success.

Every transformation has a major impact on various steps of transaction processing across the financial infrastructure, and, at the core of each such transformation, lies thorough testing. It is paramount in helping ensure that the data flows, related functions, and the system's performance characteristics are not adversely affected by the new features.

From being the lifeblood of the financial industry, data becomes its actual fabric, the resource that the digital evolution hinges on. However, for the real client and transactional data to function smoothly within systems and across infrastructures, carefully curated data "stuntmen" have to go further and wider, taking hits from all the bumps in the road first and testing the way for real data to run smoothly in a production environment. These "stuntmen" are none other than synthetically generated datasets that can help shape a high level of digital operational resilience in exchanges, CCPs, CSDs and other financial organisations.

The majority of outages reported in 2018-2022 were caused by "software issues" or a combination of issues including a software issue. A software defect can happen for various reasons including errors in specification, code, configuration, development of a rare race condition or a latency- or throughput-related halt, among others. While the root causes differ, the overarching reason remains the same: an outage is the consequence of occurrence of a scenario that was never tested.

From the perspective of long-term operational resilience, an outage event is much less about the event that caused it and more about the reason why that specific event was not injected into the system at the testing phase. Could the overall approach have been too targeted, too narrow? Did the test tools have limitations of their own? Was the selection of techniques and subsequent scenarios lacking diversity?

Continue reading on our *website* to break the code of higher-quality innovation.

Daria Degtiarenko
Senior Marketing Communications Manager, Exactpro

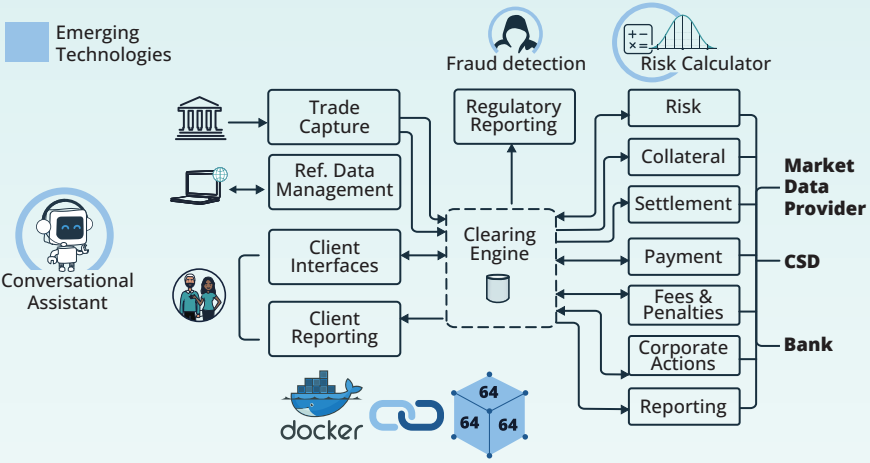
TOWARDS REDUCING THE OPERATIONAL RISK OF EMERGING TECHNOLOGIES ADOPTION IN CENTRAL COUNTERPARTIES THROUGH END-TO-END TESTING

Elena Treshcheva,
Program Manager, Exactpro

Rostislav Yavorsky,
Head of Research, Exactpro

Iosif Itkin,
CEO, Exactpro Group

The research paper was accepted as part of the programme at IOMA: WFE'S 37TH CLEARING & DERIVATIVES CONFERENCE 2020 and published in the conference proceedings via the Journal of Financial Market Infrastructures.



This schema of a generalised architecture of a post-trade platform within a CCP enhanced with emerging technologies illustrates the participant structure complexity. A company may be represented by various entities, and these entities may trade in different markets and in different asset classes. Moreover, their margining can be carried out in a consolidated way or in segregated currencies. The links between non-clearing members and clearing members, their changing roles in different markets, the array of accounts – all of this adds challenges to the software testing process.

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KEY TAKEAWAYS

- Emerging technologies that are widely adopted by financial institutions promise functional efficiency and cost reduction, but also pose a number of risks. Extreme complexity and non-deterministic nature of the existing technology platforms are commonly underestimated and need to be addressed, as they will be imminently inherited by the platforms built with the new technologies.

- Potential risks associated with traditional technology platforms in the financial services industry stem from the challenges posed by their multicomponent structure, large number of endpoints and system interdependencies, participant structure complexity, multitude of asset classes and associated life cycle events and their system schedules, variety of protocols and APIs, complex calculations, and distributed multithreaded architecture.

- The risks induced by the existing complexity of FMIs are amplified by some of the characteristics of the emerging technologies. Infusing traditional CCP technology stack with DLT leads to significant platform transformations and associated interoperability issues at the confluence of traditional technology components and those built with DLT. In its turn, AI transformation, in addition to obvious technical challenges of data collection and preprocessing as well as building a trustworthy model, requires additional attention to avoid biases and ensure regulatory compliance.

- To address these challenges, a robust software testing approach is needed. Stochastic processes related to multi-threaded distributed processing across multiple nodes and uncertainties related to machine-learning models require sophisticated testing methods to ensure resilience and trustworthiness of mission-critical software platforms.

- The proposed approach suggests incorporating both active and passive testing techniques reinforced with the statistical analysis of test execution data. High-volume automated testing of distributed clearing systems helps to expand the test coverage and create production-like conditions.

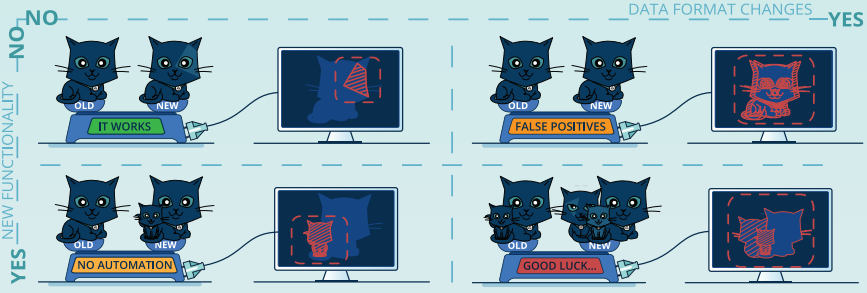
- Test automation framework described in the paper emulates the nodes in CCP infrastructures, generates API calls, and triggers transaction flows. The verification process of bi-directional message flows suggests that the framework stores all the messages sent or received to/from the non-blockchain parts of the hybrid system alongside the data extracted from the ledger to enable passive testing and property-testing over many random cases. The framework provides a platform for building an extensive regression testing library covering functional and non-functional aspects of clearing platforms of any complexity in order to reduce operation risk involved in their implementation and ongoing exploitation in the live service.

TEST AUTOMATION FOR FINANCIAL INFRASTRUCTURES OPERATIONAL DAY REPLAY LIMITATIONS

INTRODUCTION

As regulated entities vital for the financial markets ecosystem, CCPs and exchanges recognise the importance of quality and resilience of their platforms. Thorough software testing is fundamental in identifying problems that can affect system integrity. Software testing encompasses functional testing which ensures that the system works according to specifications and satisfies the compliance requirements, and non-functional testing spanning the assessment of performance, latency, capacity, reliability and operability. Test automation decreases time to market and boosts verification coverage.

A popular verification approach used across the industry – not without some merit – is a parallel run comparing the current production system and a new release, this is also known as 'production data replay.' However, overreliance on this method puts firms at a disadvantage when delivering significant changes into live service.

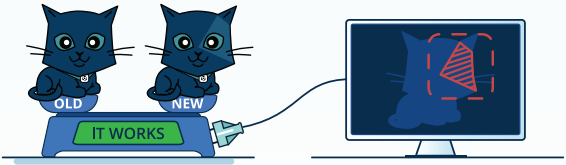


NO/NO QUADRANT – INSIGNIFICANT DATA FORMAT AND FUNCTIONALITY CHANGES

In test automation based on replay, the same set of input data – that can be taken from production or saved for testing purposes – is replayed against the existing and the next versions of the system. Reportedly, the method allows one to identify and analyse the discrepancies between versions. The output data gets compared at the end of such a run.

The data is expected to either have no discrepancies or have so few that a QA analyst will be able to analyse them and determine whether these are expected or regression bugs.

This approach refers to a certain 'old' version of the system as the only test oracle.



Thus, if the system had previously contained outstanding issues, there will be no way to reveal them and expect a different (better) outcome from the comparison. In fact, the correct functioning of the system may be perceived as a bug.

This way, defects can persist in the system for years and not be detected. We can admit, however, that data replay can work well with very limited functional and data format changes.

YES/NO QUADRANT – SIGNIFICANT DATA FORMAT CHANGES AND MINOR FUNCTIONALITY UPDATES

Let's say that the two versions of the system under test are two different images. Every output data element is a pixel in the picture. Using replay and parallel runs is similar to pixel-by-pixel comparison. At times, it works well: the pixels remain where they are and few discrepancies are detected. But what if, instead of changing, the picture has slightly shifted? Despite the absence of significant changes, we will detect major discrepancies between the two pictures.

In software testing based on data replay, a small change in the data format can cause breaks across the perimeter. The team will have to spend time on the manual introduction of adjustments and reviewing all false positives, while overlooking the actual problems. In our ***Trading Day Logs Replay Limitations and Test Tools Applicability*** research (accessible via the QR code in this section), we demonstrate that a non-deterministic outcome can occur even without differences in the input data, due to the distributed nature of the systems used in trading and clearing.

Read the full research paper on our ***website***

NO/YES QUADRANT – EXTENSIVE FUNCTIONALITY CHANGES AND MINOR DATA FORMAT UPDATES

When the system's business-as-usual behaviour serves as the only test oracle, it is impossible to apply test automation to new functionality. Since data replay only allows us to check the existing functionality, verification for the new functionality is mostly manual and the testing scope is very limited.

The data replay approach also fails when the new functionality is outside the testing scope. There is no way to detect it or test it.

Read the full white paper on our ***website***

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