



Technological Challenges of Integrating the ISO 20022 Standard into Payment Systems Using Machine Learning

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Abstract

In the scope of the publication the migration of the worldwide financial industry to the ISO 20022 standard has been analyzed by considering the technical restrictions of ML algorithms applied to process a set of transactional data, the architectural restrictions of common payment systems that do not allow for the integration of smart components, and the use of smart data mapping algorithms to harmonize heterogeneous formats and fields in a single message model. Another aspect is the issue of data quality, which is necessary for reliable training of neural networks in the application areas of money laundering or fraud prevention. The objective is simplified to the construction of a theoretical model, which allows identifying opportunities to optimize the integration processes in the introduction of ISO 20022 and the subsequent use of the machine learning tooling in the transaction circuit. The method includes systems analysis and synthesis of the research results, which enables the comparison of architectural variants and the identification of conditions for adequately trading off interoperability and computational costs. The empirical-analytical part is based on publications of the last few years indexed in Scopus and Web of Science. In addition, this also ensures the topicality of the scientific basis used and the representativeness of the identified trends. The conclusion provides recommendations that reduce the risks of transition to the standard and the potential negative impact on data quality and process control. Our findings are of practical relevance to architects designing payment solutions, Data Science experts, and financial analysts.

Keywords: ISO 20022, Machine Learning, Payment Systems, Financial Messages, Cross-Border Payments, Big Data, Compliance, AML, Interoperability, XML.

INTRODUCTION

One meaningful change in payment processing infrastructure in recent years has been the migration of the global financial industry towards the ISO 20022 messaging standard for financial messages. Compared with older financial messaging formats (such as SWIFT MT), ISO 20022 provides a richer data model that eases the encoding of richer contextual information and semantic description of transactions in financial messages. One of the key technological challenges of moving to this standard is the multiple increase in the volume of processed information, maintaining backward compatibility over the transition horizon and the increased number of compliance checks. It is accompanied by the growing importance of the ease of conducting checks, traceability and interpretability of decisions [1, 2]. Machine learning (ML) under such conditions is a base instrument of the automation of transformations and data quality control. A strictly formalized standard and the adaptive nature of ML algorithms form a new field of engineering contradictions,

which requires systematic and theoretically verified analysis [2, 3].

The aim of the study consists in identifying and classifying the technological challenges arising at the interaction of ISO 20022 and machine learning in order to develop an authorial concept of an adaptive data processing layer aimed at improving the effectiveness of payment systems during and after the transition to the new standard. An analytical generalization of contemporary research on clever processing of ISO 20022 messages is planned within the stated aim. The main challenges to the application of ML in the procedures of mapping and validation of structured financial messages are identified. An architecture for the integration of ML models in the process is designed, aimed at maintaining high levels of performance and accuracy under increasing loads and complexity of message structures.

Scientific novelty has also been the interpretation of technological and organizational problems. These problems are the mismatches between the fixed XML

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format of the messages within the ISO 20022 standard and the probabilistic nature of ML-based techniques regarding statistical generability, feature distributions, and the assumption of an acceptable level of uncertainty in the normalization and interpretation of fields, quality of schemas validation, ambiguity resolution in the alignment of attributes, replication of processes, and formal monitoring of the accuracy of transformations.

Hence, the **author's hypothesis** is that hybrid methods combining graph databases with deep learning methods can be used to reduce the rate of erroneous conversion of the messages and improve the performance of the anomaly detection on payment flows compared to regression methods. The author's hypothesis is reinforced by leveraging the following aspects: on one side, the merits of graph databases for representing complex relationships among message entities and contextual information; on the other side, the merits of deep models for extracting high-level features from heterogeneous structured and semi-structured sources, while retaining sensitivity to sporadic signs of anomalous behavior.

MATERIALS AND METHODS

The study was based on the systems approach to the analysis of financial technologies that allows presenting the payment infrastructure as a system consisting of a combination of elements, including links, constraints, and control loops.

The articles were selected in stages, first scanning the title and abstract if the article concerned a technical problem. Articles that discussed only economic or legal aspects without addressing their computational mechanisms were excluded. The following characteristics of the systems remained for the second stage of the review: processing latencies, indicators of algorithms' quality, scalability. Great interest has been devoted to the documentation of practical cases of use and application of Big Data and ML in the migration contour to convert XML messages of the MX format. Practical experience can make it possible to compare the declarative advantages of the standard with real implementation constraints.

To transfer general machine learning regularities to applied transactional data processing, deductive analysis was used. The comparative method was used to select the MT and ISO 20022 standards according to their suitability as a basis for training neural networks. For that, the features were compared according to the aspect of how semantically rich they are, how unambiguous they are, and how easy it is to create the training samples with them. By combining data from heterogeneous sources, we present a cohesive picture of the technologies currently considered state of the art, the stable trends and the major bottleneck in both the architectural and computational loop.

RESULTS

Applying ISO 20022 to its limit in loops of real payment

systems means bringing into question the order of processing the transactional data, from extraction to normalization, verification, analysis and decision control. Our study shows that the richness of information envisaged by the standard, like its implemented functional advantages, is a generator of technological complexity [1]. While most legacy messaging standards are flat structured, ISO 20022 message payloads are hierarchical through the XML schema standard, which may need more processing resources for parsing, serialization and deserialization and feature processing in ML loops [2].

Another challenge in the transition phase is a smart mapping and data transformation during the migration of legacy system data with MT into messages of the MX format. Empirical studies show that rule-based methods are not suitable for the field interpretation ambivalence and the population variability. During the transition phase, there is a loss of up to 40% information or information distorted [3]. In this regard, the means of machine learning, including NLP, allow at least to partially restore the context of unstructured parts of Remittance Information, which is necessary for technologies of automatic reconciliation and matching of payment details [4]. On the other hand, the formation of methodological and engineering problems is associated with the temporary absence of labeled data arrays in the financial industry that can help build such models with minimal overfitting.

In contrast to the requirements for interpretability and explainability, time constraints are also an important aspect in real-time scenarios such as instant payment. Transaction processing should not exceed 500 ms. As ML models are typically the bottleneck of the ISO 20022 processing pipeline, with costly computations required to deserialize large XML messages and produce the representations of the input message [5], lightweight models based on GBM or optimized inference engines (e.g. ONNX) may be required for practical deployment in the ISO 20022 processing context. This will help maintain throughput and reduce latency when the volume of transactions is high [6].

Furthermore, thanks to the increased semantics of the ISO 20022 message, fraud and AML analytics can be improved, as more information regarding the Ultimate Debtor and Ultimate Creditor parties can be used to create more advanced relationship graphs, establishing stable interaction patterns in the payment behavior network structure [7]. According to more recent works, applying a GNN to the ISO 20022 information would reduce the false positive triggering by 15-20% points [8]. In addition to data privacy, another issue if such detailed properties are used for model training is the question of whether and to what extent this data can be used. Federated Learning is one way to resolve this contradiction [9].

Furthermore, achieving semantic interoperability is more complex, as even though the ISO 20022 standard is indeed

unified, each financial institution may still have its own market practices. Therefore, the semantic interpretation of one or more fields, or combinations of fields, will be different from one financial institution to the other. From a combinatorial viewpoint, this means that the fields must be protected by a semantic buffer, allowing a machine learning model to be trained on one bank's data while remaining agnostic to message data from other banks with a different distribution and different semantics [10]. This serves the purpose of ensuring uniformity in the feature vectors passed to the neural module, as well as reducing the dependency on the local properties of the data representation.

Thus, the results confirm the soundness of the multilayer approach where ML elements work not on raw XML, but on aggregated features stored in high-performance data repositories. This results in lower processing costs, better models' versatility and offers a more controllable foundation to satisfy quality, performance and interoperability requirements for XML messages within the ISO 20022 loop.

DISCUSSION

The technical implications of the transition to ISO 20022 should be examined in the context of the information explosion stage. The transition to ISO20022 is not a mechanistic transition of the message format, but a transition to a semantically informative representation of the financial transaction, where the attributes along with their interdependencies have independent analytical value. However, intrinsic limitations remain in the existing literature around the cost of computationally streaming the treatment of millions of messages by means of ML. These include factors around implementation such as a multicluster deployment, inference frequency and schema validation and regulatory compliance conducted in parallel with the data flow [5, 6].

Integration Vision has an Adaptive Smart Gateway as a functional entity, where transactions with a higher transaction uncertainty or risk signal are subjected to more intensive validation, semantic reconciliation, and specialized AML and fraud processes, as illustrated in Figure 1.

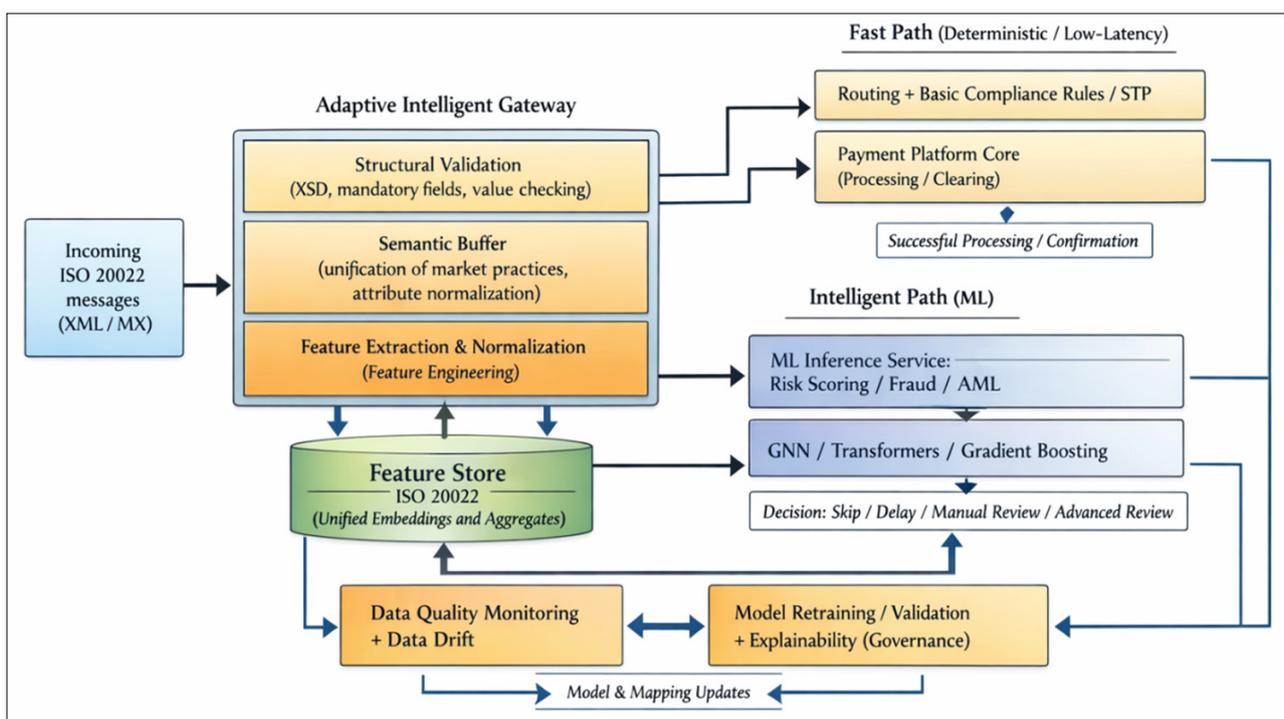


Figure 1. Multilayer architecture for processing ISO 20022 messages with an adaptive intelligent gateway, a semantic buffer, and a feature store [5, 6]

Beyond the conversion and routing functionalities, the gateway includes filtering for predictions to resolve the further admissibility, prioritization and trajectory of message processing as soon as possible. In this way, the gateway is a layer of interpretation that performs the feature selection and normalization required to offload the computational cost and demand for processing in analytical and processor-intensive loops to alternative services later in the processing chain [3, 7].

The gateway will be able to assess risk, check the quality and completeness of the incoming message, detect abnormal and

deficient structures and identify the need for a more detailed verification in a very short time. Due to this, flow separation is achieved. Such an organization ensures not only an increase in the controllability of the transition to ISO 20022, but also forms an economically justified model for operating ML, in which computational resources are concentrated on genuinely significant segments of the flow, and cloud cost becomes a parameter of architectural optimization rather than an external constraint [6, 8].

Table 1 presents the results of comparing data processing parameters.

Table 1. Comparison of data processing parameters: Legacy (MT) vs ISO 20022 + ML [3, 6, 7, 8]

Parameter	Standard MT (Legacy)	ISO 20022 + ML (Forecast)	Impact on the system
Structure	Flat, fixed	Hierarchical (XML)	Requires complex parsers
Automation (STP)	Medium (substantial manual work)	High (predictive reconciliation)	Reduction of operational costs
AML scoring accuracy	Low (high risk of errors)	High (contextual analysis)	Increased security

The interaction of ML components in the payment processing loop is justified by the functional distribution between a fast path and a clever path. The validation of the structural conformance and of the core syntactical properties of the message (e.g. XML schema, mandatory data, admissibility of values, basic integrity of the representation) is part of the assessment of the fast path. This should be deterministic and as predictable as possible in its performance since it is what provides throughput guarantees and stability of transaction execution when the system is under peak load. The so-called clever path is where the analytics take place, with ML models being used for semantic enrichment, feature extraction, risk scoring, anomaly detection and AML/fraud monitoring. This dual-loop organization permits the latency of the most critical operations to be kept very tight, while still being able to do detailed analysis wherever feasible, without suffering undue performance penalties.

The factor that is most systematically neglected in application is data drift of all kinds, in the statistical distributions of the data features, and also in the semantics of the standards and their application. This applies particularly to ISO 20022 given the growth of the tag vocabulary, the evolution of tags and schemas, and variability in market practice. Under these conditions, however, the initial model trained on the historical data can slowly lose its predictive power not because the algorithm itself is no longer precise, but mainly due to the constantly changing structure and the semantics

of the input stream. Thus, besides applying specific quality measures on a test sample, a general performance criterion for ML components is their adaptability.

This implies additional mechanisms for lifelong learning as an intrinsic property of the target architecture, such as a closed control loop for quality assurance, distribution tracking and model retraining in case of predictive drift and change detection, periodic model updates and validation as well as controlling regulatorily relevant model properties like reproducibility and explainability of predictions [6].

One way to improve the model robustness to changes in the markup schema structure is to adopt an ontologically based approach to instance feature construction. Such an approach would prefer semantic categories, relations and entity types that are invariant with respect to schema changes instead of specific structures of the individual tags. Thus the features are not directly corresponding to the XML fields but are semantically normalized. This allows to avoid influences on the mapping if the schema changes or new tags are added, without limiting the design of the model. In this way, feature vectors live longer, and ML models can be more easily transferred to other schema versions and other implementations of ISO 20022. This is paramount for quality stability under conditions of prolonged standardization evolution [9, 10].

Technology barriers and means to overcome them are described in Table 2.

Table 2. Technological barriers and methods for overcoming them [6, 9, 10]

Technological challenge	Problem description	Recommended method (ML/IT)
Variability of XML tags	Different banks use different optional fields	Use of embeddings for vectorization of structures
Delays (Latency)	ML inference slows down the transaction	Model quantization and edge computing
Data quality	Incomplete completion of rich fields	Generative adversarial networks (GAN) for data imputation

At the center of the approach is the Common ISO 20022 Feature Store, enabling aggregation of heterogeneous tags (from UltmtDbtr to InstrForNxtAgt) by providing a multi-dimensional data space for building complex datasets. This would allow the represented data to be converted into unified embeddings, making it possible to use the same model for credit transfers, debiting, and reporting. This leads to a more consistent decision-making process and reduces dependency on the type of operation being performed. While a lot of focus is on the ISO 20022 standard itself, the main technological gap lies in the lack of standardized data preparation pipelines for machine learning. The clever gateway and the Feature Store

provide the building blocks to address this gap, allowing for better performance and scalability through the separation of heavy feature extraction and normalization from the inference and decision making loops.

CONCLUSION

The study is based on the general conditions and technical possibilities for the implementation of the internationally standardized ISO 20022 format in the new payment architecture, using machine learning methods. The objectives of the research have been met and the correctness of the analytical model has been verified.

The resulting levels of structural and semantic complexity of financial data, in conjunction with the growing volume and variety of financial data being acquired, analyzed and stored, have decreased the effectiveness of customary approaches to processing and quality control, and limited their scalability. Based on this observation, we identify the barriers to implementing the described model as the high cost for parsing XMLs in a streaming fashion, the semantic heterogeneity caused by the market's different practices, and the need for explainable ML models due to regulations and compliance.

Multilayer integration with a clever gateway proved the feasibility of improving STP of payments by separating deterministic procedures of structural validation from computationally expensive loops of smart analysis, and by rational allocation of computational resources. The authorial hypothesis on the context-oriented interpretation of ISO 20022 messages improving the quality of fraud monitoring was also confirmed - it effectively augments the feature space and consequently the capacity of models to discern non-trivial anomalous patterns.

They will allow the transition from a mere compliance with the standard to exploit fully the semantic richness of ISO 20022, creating business benefits and competitive advantages in the medium- to long-term, through a deeper and more accurate analysis of transactional behaviors and profiling of clients' needs and preferences.

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