RUTGERS
THE STATE UNIVERSITY
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IDENTIFYING AND PRIORITIZING IRREGULARITIES USING A RULE-BASED MODEL WITH A WEIGHTING SYSTEM DERIVED FROM EXPERTS' KNOWLEDGE

Motivation, Research Questions, & Findings

Motivation:

- Plenty of studies for exception identification, few address processing
- Majority of expert systems assign the same weight to rules
- HOWEVER: business rules, and accordingly their violations, do not have the same importance

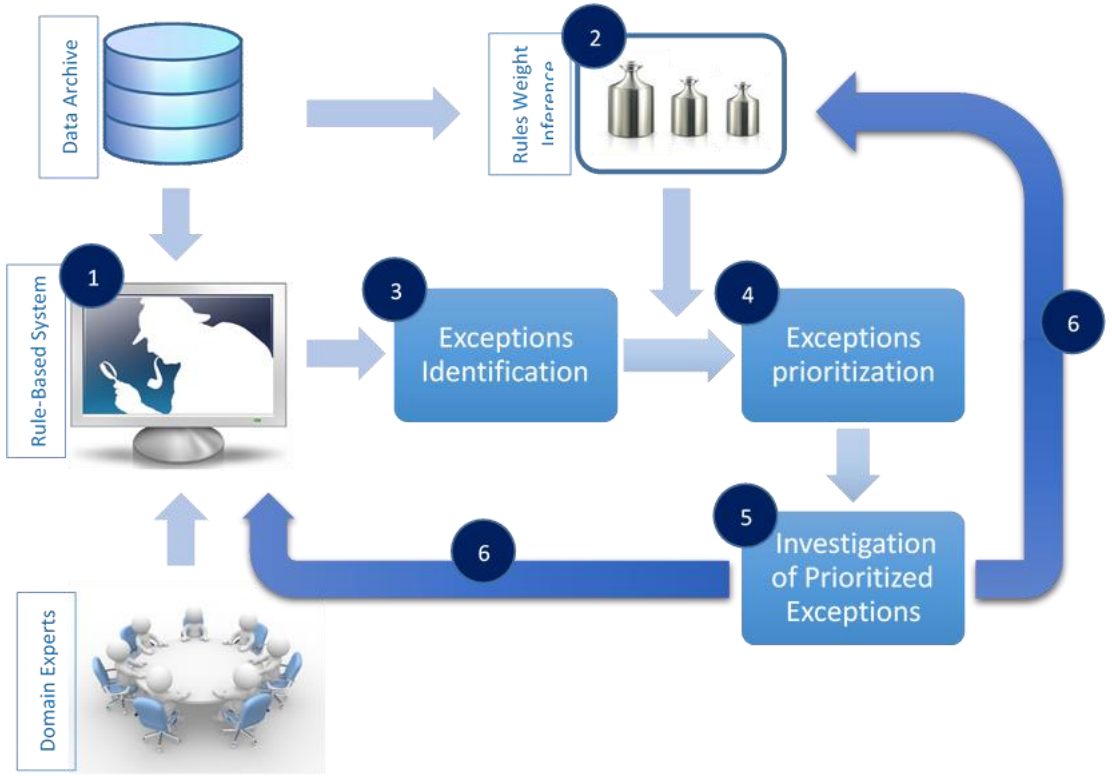
Research Questions:

1. How can we integrate the judgment of the domain experts (in this case the auditors) in a rule-based expert system?
2. How can we develop a weighting system for the various rules in that expert system?
3. How can we use this weighting system to prioritize exceptions?

Main Findings:

- High agreement level among auditors (76.11%)
- High level of correctly identifying violated rule (85%)
- Excessive write-offs ranked highest, SOD rules & operational controls ranked low

Framework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Domain Experts

Rule-Based System

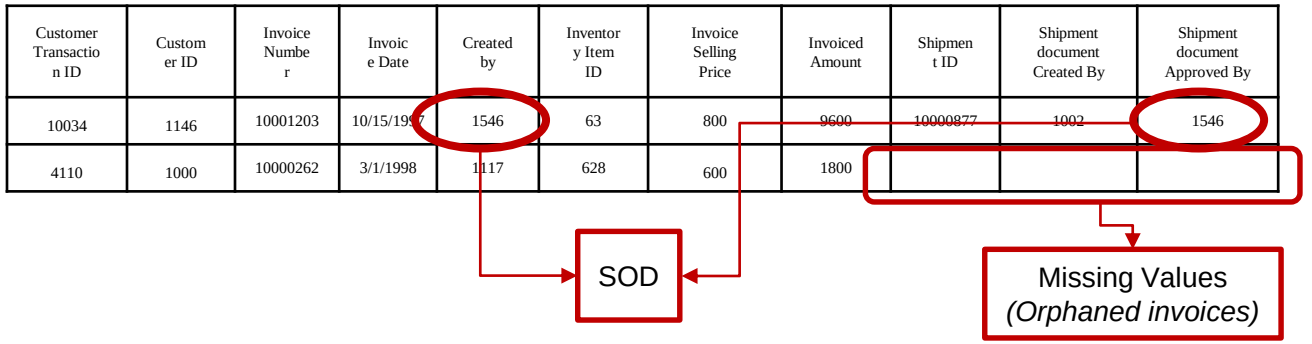
- Set of IF-THEN rules
- Popularity stems from simplicity, interpretability, flexibility
- Data: Simulated Order to Cash data
- Originally 33 analytics, narrowed down to 12 by experienced auditors
- 12 analytics can be categorized as tests for:
  - Segregation of duties
  - Unauthorized transactions
  - Missing documents
  - Non-matching documents.

Rules Weights Inference

- Business rules and accordingly their violations, do not have the same significance

- 17 participants with 3 or more years of experience:
  - Conduct 17 pairwise comparisons
  - Select the transaction they believe to present higher control risk
  - Provide justification of their assessment

Customer Transaction ID	Customer ID	Invoice Number	Invoice Date	Created by	Inventory Item ID	Invoice Selling Price	Invoiced Amount	Shipment ID	Shipment document Created By	Shipment document Approved By
10034	1146	10001203	10/15/1997	1546	63	800	9600	10000877	1002	1546
4110	1000	10000262	3/1/1998	1117	628	600	1800			



Rules Weight Inference-LP1

- Special Case Linear Program

$$Max \sum A_{ij}(W_{Ri} - W_{Rj}) + (M * S) \geq 0$$

Subject to

$$(W_{Ri} - W_{Rj}) \geq A_{ij} * S$$

$$W_{Ri} \geq 1$$

$$W_{Rj} \geq 1$$

$$\sum W_{Ri} = 2 * N$$

$$S \geq 0$$

Where

W_{Ri} and W_{Rj} are the weights of Rules R_i and R_j, respectively.

A_{ij} is the certainty about the ordering of the rules in pair P_{ij}, defined by the proportion of responses showing that transaction T_i presents a risk greater than or equal to that presented by transaction T_j

S is the scaling factor, a non-negative variable

M is a constant following the Big M method (or Big Component method)

N is the number of rules in the expert system.

Rules Weight Inference-LP2

- General Case Linear Program

$$Max \sum A_{ij}(\sum W_{Ri} - \sum W_{Rj}) + M * S \geq 0$$

Subject to

$$\left(\sum W_{Ri} - \sum W_{Rj}\right) \geq A_{ij} * S$$

$$W_{Ri} \geq 1$$

$$W_{Rj} \geq 1$$

$$\sum W_{Ri} = 2 * N$$

$$S \geq 0$$

Where

W_{Ri} and W_{Rj} are the weights of Rules R_i and R_j, respectively.

A_{ij} is the certainty about the ordering of the rules in pair P_{ij}, defined by the proportion of responses showing that transaction T_i presents a risk greater than or equal to that presented by transaction T_j

S is the scaling factor, a non-negative variable

M is a constant following the Big M method (or Big Component method)

N is the number of rules in the expert system.

Exceptions Identification & Prioritization

Identification:

- Apply expert system to the whole population to find all the records that violate one or more rules
- Remaining records are assumed to be normal, thus presenting negligible risk

Prioritization:

- Calculate the Suspicion Score for each exception such that:

$$SS(X_i) = \sum W_{Rj} V_{Rj}$$

Where $SS(X_i)$ is the Suspicion Score of record X_i

W_{Rj} is the weight of rule R_j

V_{Rj} is the binary variable that equals 1 if record X_i violates rule R_j, and 0 otherwise

Exceptions Prioritization-Example

Record	Weight	SOD Customers /Sales Order	Unauthorized Sales Order	Unauthorized price	SOD Credit Adjustment /SO	Match Shipping Docs to SO	Match Invoice to Shipping docs	Missing Sales Orders	Unauthorized Shipments	SOD Invoices / Shipping docs	Orphaned Invoices	SOD Invoices / Receipts	Excessive Write offs	Suspicion Score	Rank
		1.00	2.58	1.23	1.23	1.91	2.36	2.81	2.36	1.91	2.58	1.00	3.04	24	
1001		X				X								2.91	4
1002									X		X			4.94	2
1003								X				X		3.81	3
1004			X					X					X	8.43	1
1005														0	6
1006				X										1.23	5

Investigation & Feedback

Investigation:

- Auditors are provided with Prioritized exceptions
- Scope of investigation depends on their time/budget constraints

Feedback:

- Helps adjust the rules that make up the expert system
- Enables us to modify the weights of the rules according to the audit teams' findings
  - incorporated as a new set of constraints in the general case Model
- Effect of the original experiment will decrease over time with more feedback from auditors

Expert Panel Statistics

Demographics:

- 11 Internal auditors, 6 external auditors
- Median years of experience: 12.5 years
- Median years of experience in control risk assessment: 8 years
- Average 3.18 years of experience in IT audit
- Average 6.53 years of experience in auditing financial statements

Agreement & Correctness:

- 76.11% overall agreement on the same transaction on average
- 85% overall correct identification of rationale on average
  - 86% for the transaction voted to present highest risk
  - 83% for the other one

Weights –Special vs. General Models

- Excessive Write offs ranked highest
- SOD in general ranked low
- Rules with direct impact on financial numbers ranked high
- Operational controls ranked low

Analytic	Rules Weights (Special case Model)	Rules Weights (General case model)
Analytic_12_Excessive_Write_Offs	2.91	2.83
Analytic_7_Missing_Sales_Orders	2.39	2.82
Analytic_2_Unauthorized_Sales_Order	2.67	2.6
Analytic_10_Orphaned_Invoices	2.63	2.56
Analytic_8_Unauthorized_Shipments	2.32	2.27
Analytic_6_Match_Invoice_to_Ship	2.3	2.25
Analytic_9_SOD_Ship_Invoice	2	1.96
Analytic_5_Match_Shipping_to_SO	1.96	1.92
Analytic_3_Unathorized_Price	1.53	1.51
Analytic_4_SOD_Credit_Adjustment	1.3	1.29
Analytic_1_SOD_Customers	1	1
Analytic_11_SOD_Invoice_Receipt	1	1

Weights – Internal vs. External Auditors

	Internal Auditors		External Auditors		All Responses	
Order	**Analytic**	**Weight**	**Analytic**	**Weight**	**Analytic**	**Weight**
1	Analytic 7 Missing Sales Orders	3.07	Analytic 12 Excessive Write Offs	2.71	Analytic 12 Excessive Write Offs	2.83
2	Analytic 12 Excessive Write Offs	2.93	Analytic 4 SOD Credit Adjustment	2.42	Analytic 7 Missing Sales Orders	2.82
3	Analytic 10 Orphaned Invoices	2.75	Analytic 7 Missing Sales Orders	2.36	Analytic 2 Unauthorized Sales Order	2.60
4	Analytic 2 Unauthorized Sales Order	2.65	Analytic 11 SOD Invoice Receipt	2.30	Analytic 10 Orphaned Invoices	2.56
5	Analytic 8 Unauthorized Shipments	2.36	Analytic 2 Unauthorized Sales Order	2.22	Analytic 8 Unauthorized Shipments	2.27
6	Analytic 6 Match Invoice to Ship	2.30	Analytic 10 Orphaned Invoices	2.22	Analytic 6 Match Invoice to Ship	2.25
7	Analytic 5 Match Shipping to SO	1.98	Analytic 6 Match Invoice to Ship	1.95	Analytic 9 SOD Ship Invoice	1.96
8	Analytic 3 Unauthorized Price	1.51	Analytic 8 Unauthorized Shipments	1.92	Analytic 5 Match Shipping to SO	1.92
9	Analytic 4 SOD Credit Adjustment	1.45	Analytic 9 SOD Ship Invoice	1.81	Analytic 3 Unauthorized Price	1.51
10	Analytic 1 SOD Customers	1.00	Analytic 5 Match Shipping to SO	1.68	Analytic 4 SOD Credit Adjustment	1.29
11	Analytic 9 SOD Ship Invoice	1.00	Analytic 3 Unauthorized Price	1.41	Analytic 1 SOD Customers	1.00
12	Analytic 11 SOD Invoice Receipt	1.00	Analytic 1 SOD Customers	1.00	Analytic 11 SOD Invoice Receipt	1.00

Conclusion

Contribution:

Developed a framework to identify and prioritize exceptions

- Used O2C simulated data
- Expert panel of 17 auditors
- Pairwise comparisons to infer rules weights
- Calculated the Suspicion Scores and prioritized exceptions accordingly

Limitations:

- Small expert panel (effect on statistics)
- Did not test the framework on a real business dataset
- Used subset of rules

Future Research:

- Larger expert panel
- More comprehensive set of rules
- Test on real dataset