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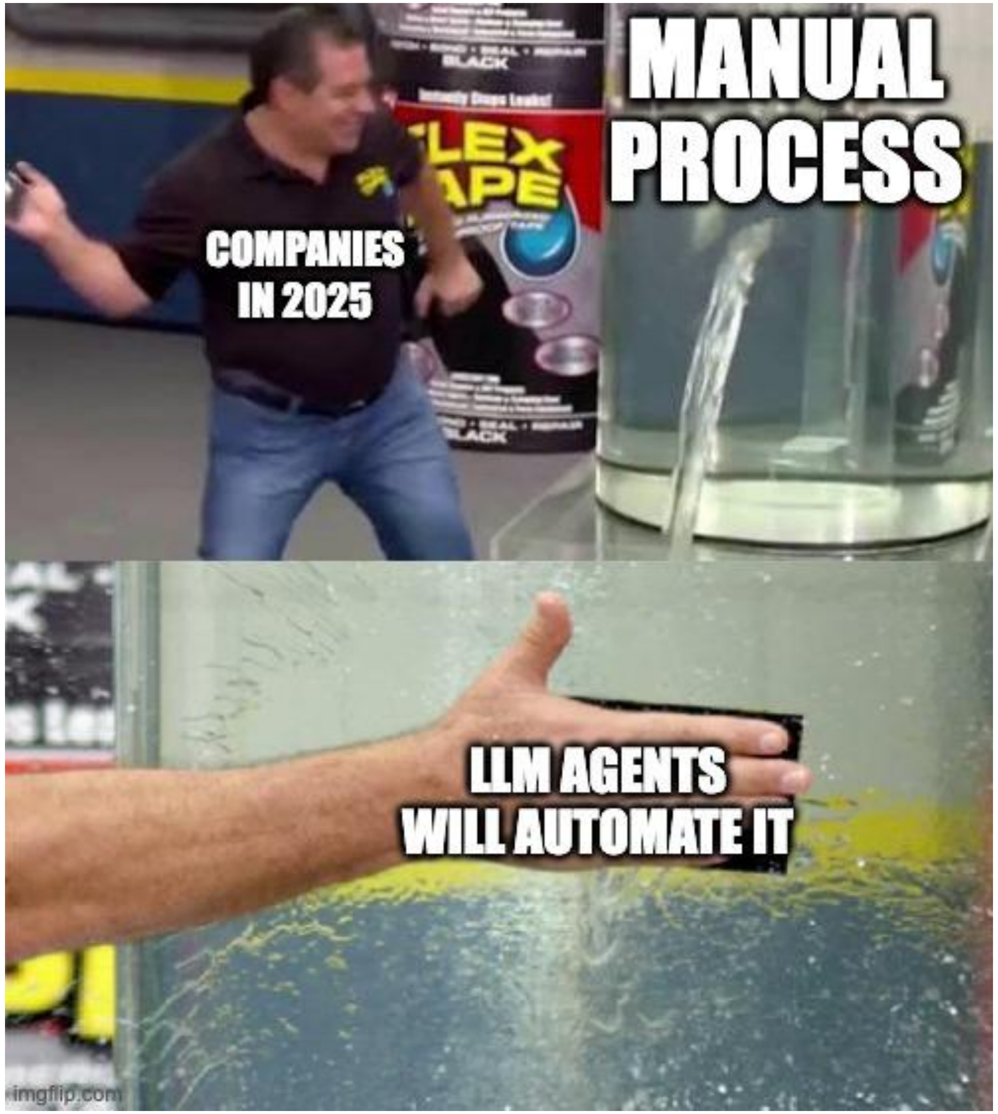
A Step Towards Cognitive Automation

Integrating LLM Agents with Process Rules

Sascha Kaltenpoth, Alexander Skolik, Oliver Müller and Daniel Beverungen

Motivation

1. Business Process Automation in 2025



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2. The Goal of “Cognitive Automation”

- Traditional business process automation:
  - ✚ An important BPM core element[27, 30]

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- Robotic process automation (RPA):
  - ➕ Enables automation of less standardized and mid-frequently occurring processes[24, 29]

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→ LLM agents are promising for automating complex processes with unstructured data: “cognitive automation”[7]

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3. LLM agents and their stochastic nature

- LLM agents:
  ✚ Support multi-process automation of "cognitive" processes (e.g., reasoning, synthesis)[11, 16, 22]

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  - ➖ Their stochastic nature possibly leads to deviations from the predefined process[11,16,33]

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→ LLM agents need to **still support adaptability** to novel, unexpected user requests

→ LLM agents need to **also integrate existing automation** approaches (e.g., RPA, low-/no-code)

Motivation

„RPA is the body and AI is the brain"[22]

Related Work

LLM agent-based automation approaches

- Support UI and API operations like RPA[10, 13, 16, 37]

Framework	Input	Approach	Process Representation	UI / Input operators	API / Service operators	Cognition / Reasoning	Goal	Source
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SmartFlow	Text Description	Prompting, OCR	Workflow	X			RPA	[13]
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- „Cognitive“ decision making[10, 16, 37]

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- „Cognitive“ decision making[10, 16, 37]
- Approaches to align with the process[10, 13, 16, 37]
- Structured process representations to improve process alignment[10, 13, 16, 37]

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- No comparison of structured and unstructured process representations
- No experimental analysis regarding:
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  while simultaneously ensuring

  - Adaptability support for novel, unexpected requests

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Research Question

How can LLM agents be leveraged to effectively **adapt to novel processes** and simultaneously **align with existing, repetitive processes** as a **step towards cognitive automation?**

Research Design

A 2x2 Evaluation of LLM agent-based automation

1. Generate process descriptions:
   - Unstructured descriptions: text descriptions
   - Structured process descriptions: „Process Rules"

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2x2 Evaluation	**Repeatability** (repetitive, known processes)	**Adaptability** (novel, unexpected processes)
Text descriptions (unstructured descriptions)	**Handling SAP errors** with text input	**Fulfilling user requests** with text inputs
Process Rules (structured descriptions)	**Handling SAP errors** with process rules	**Fulfilling user requests** with process rules

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Research Design

0.1 The Repeatability Use Cases – Handling SAP IDoc Errors

- An energy grid provider with mid-frequently occurring SAP IDoc*[1]-errors sent from an external storage system

*[1]SAP IDocs are a structured exchange format for purchase orders or invoices
*[2]External storage system

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→ An LLM agent needs support repeatability of same (error solving) process

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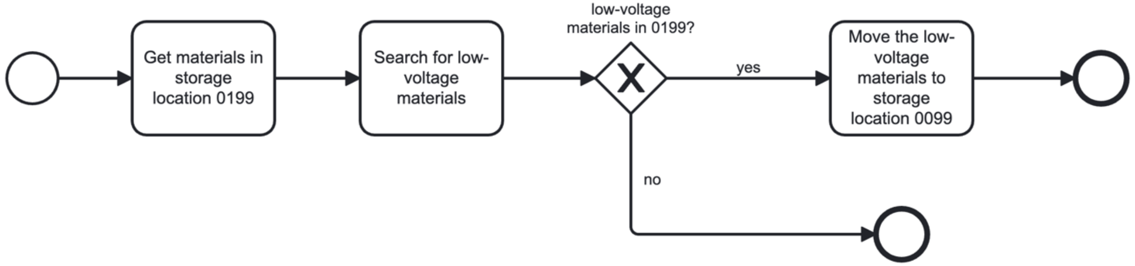
0.2 The Adaptability Use Case – Fulfilling User Requests

- Same energy grid provider has other "cognitive" processes such as inventory audit



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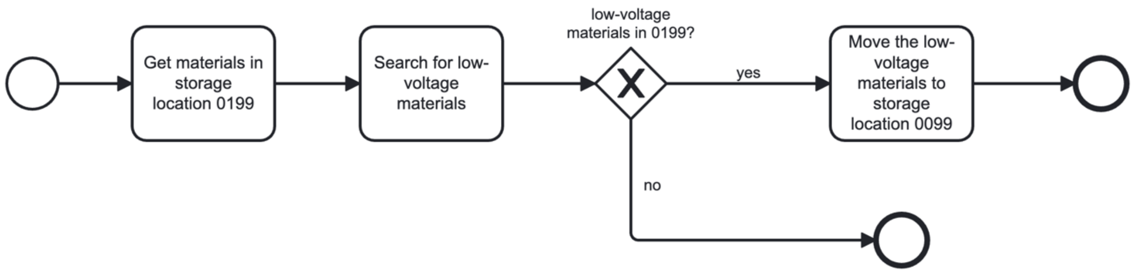

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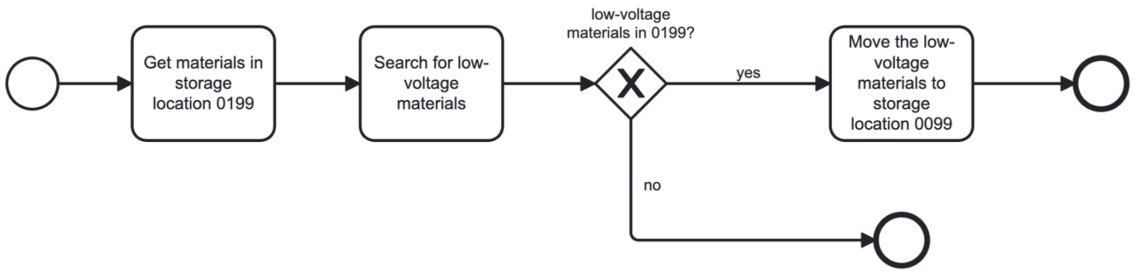

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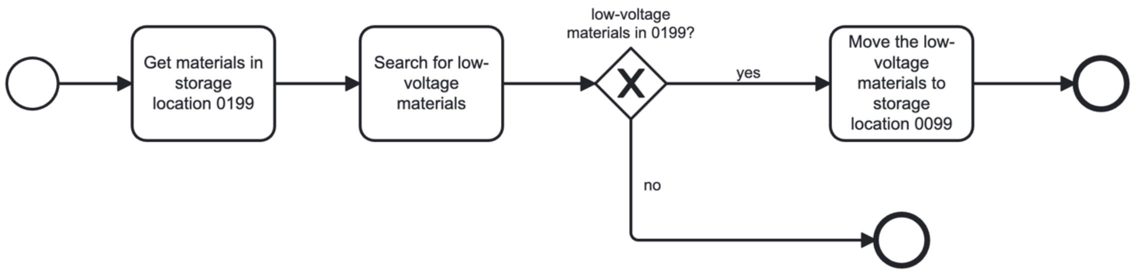
→ The LLM agent needs to be adaptive to completely novel, unknown requests



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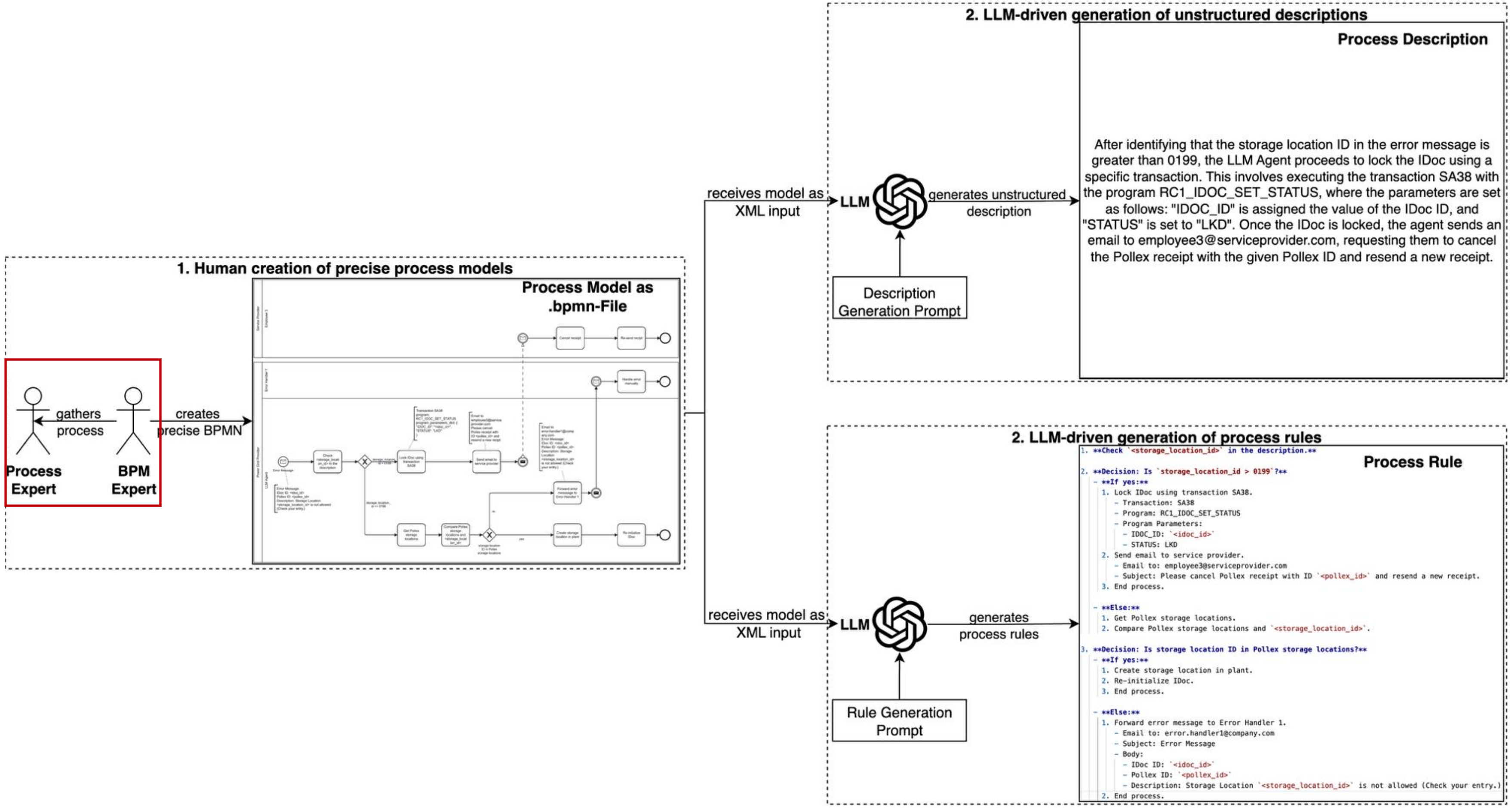
1. Generating Process Descriptions – Unstructured vs Structured Descriptions



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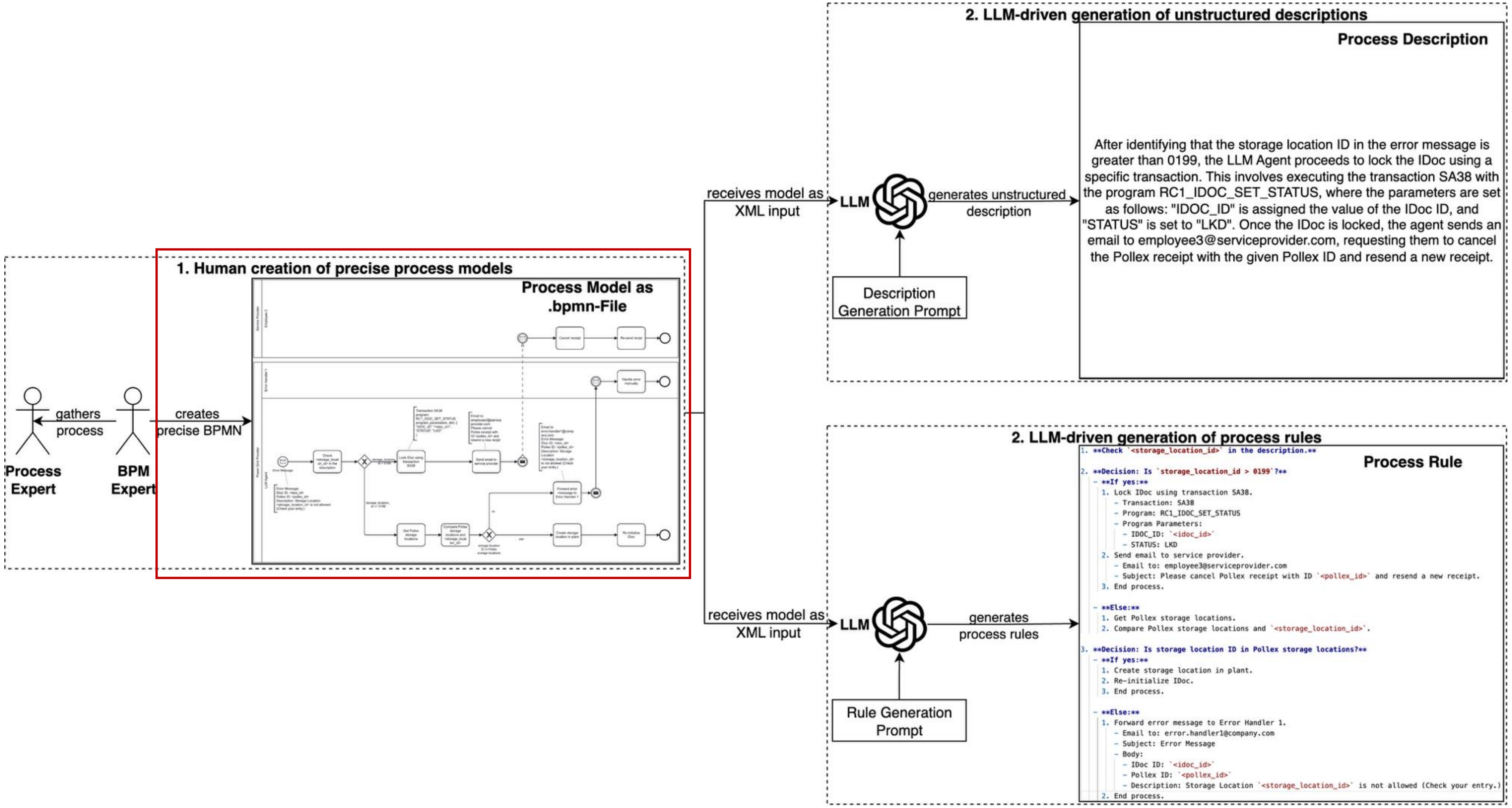

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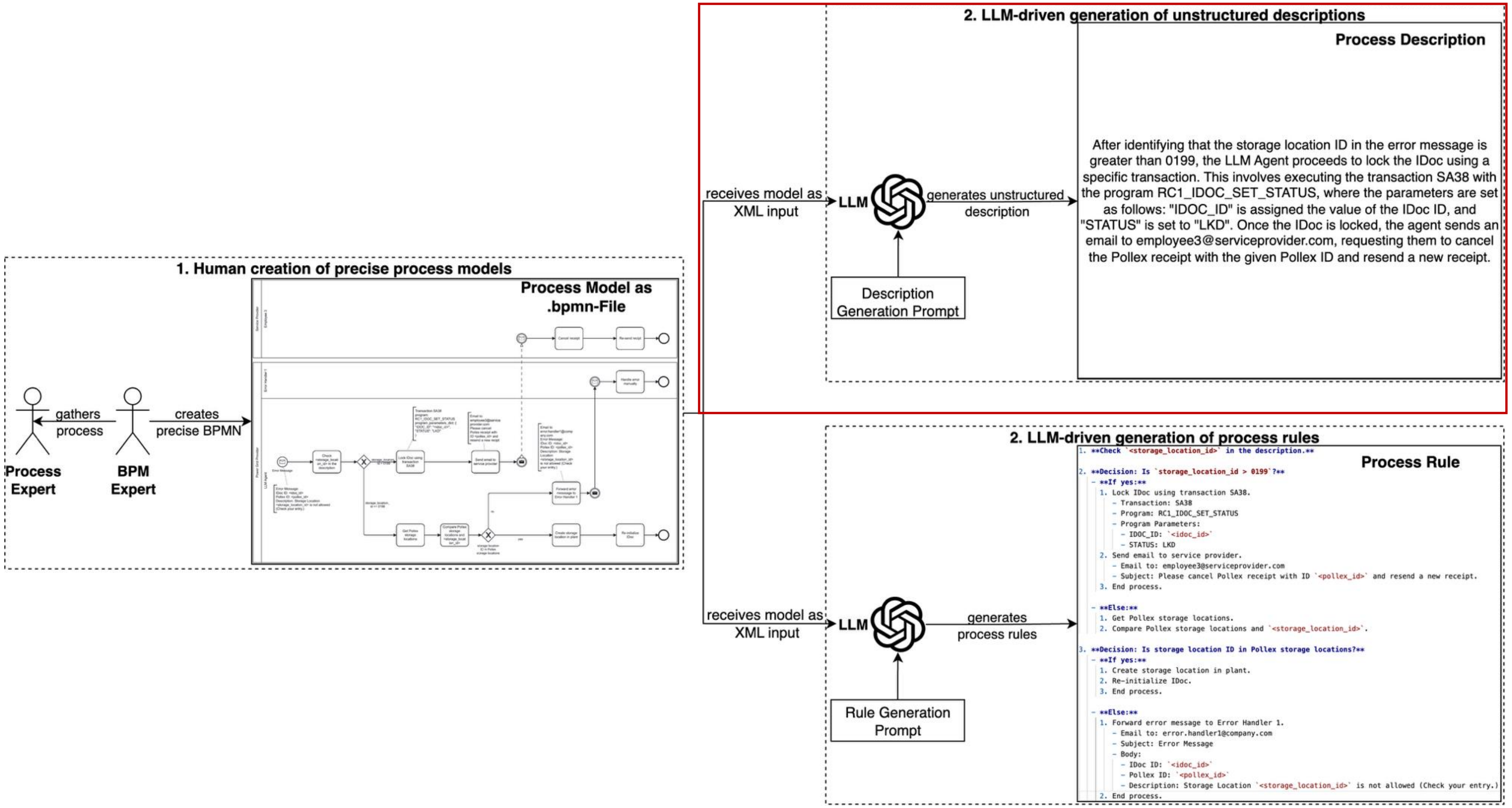

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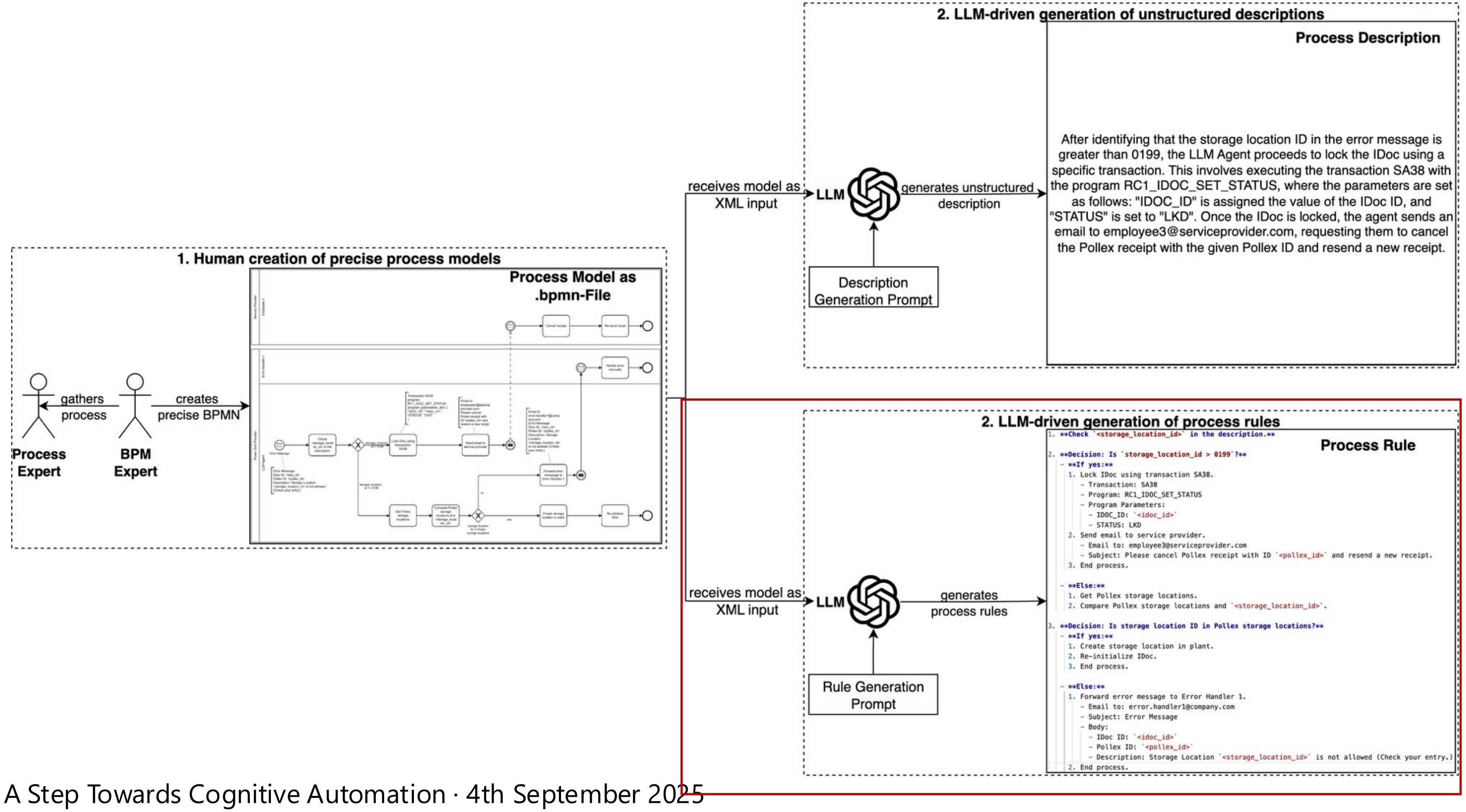

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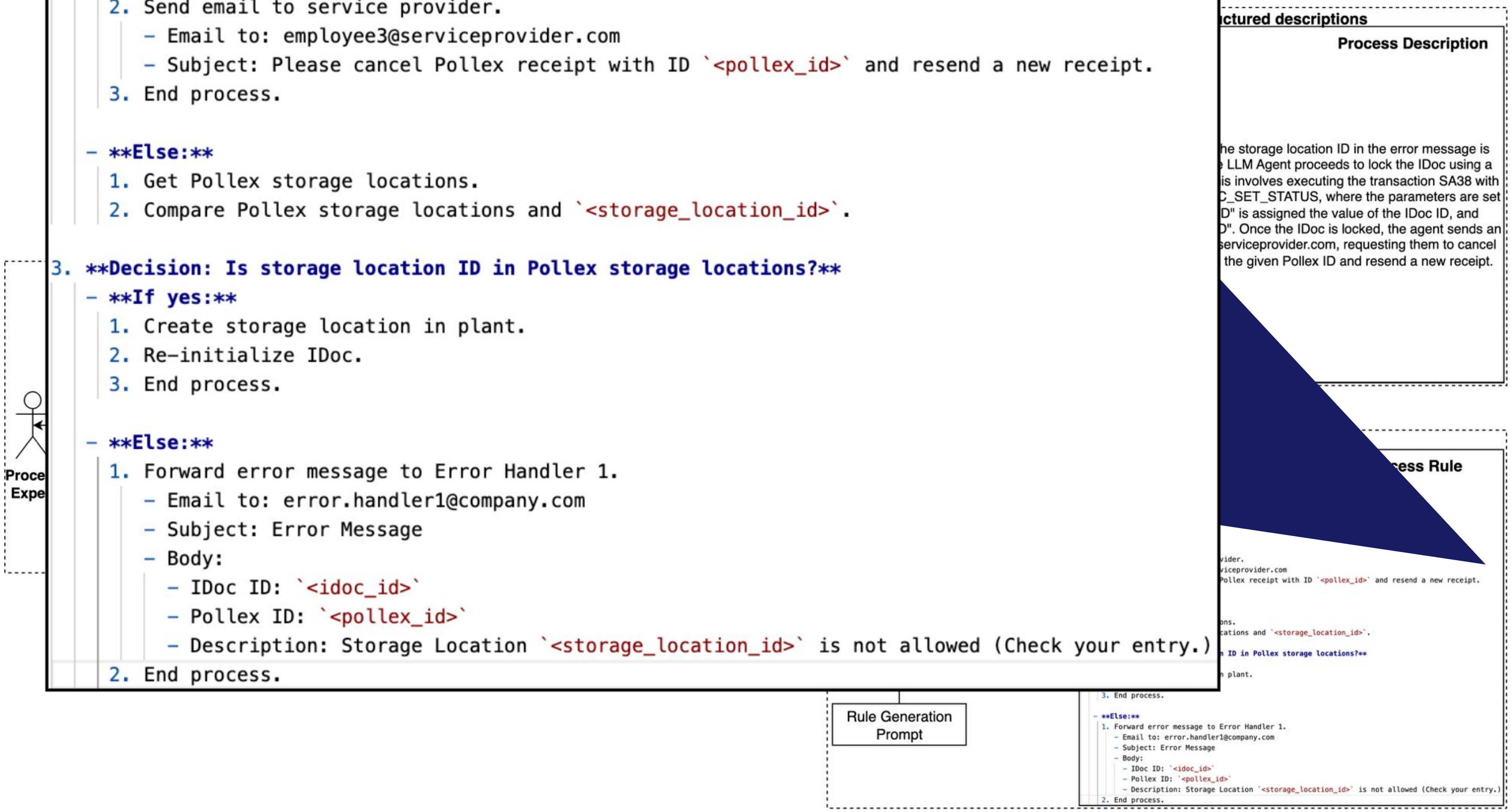
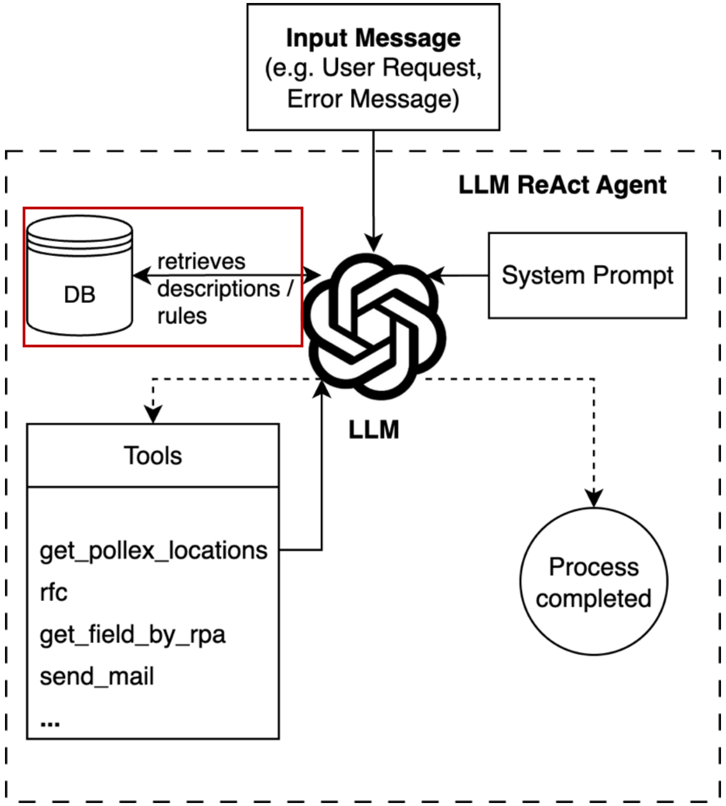



```
1. **Check `<storage_location_id>` in the description.**

2. **Decision: Is `storage_location_id > 0199`?**
 - **If yes:**
   1. Lock IDoc using transaction SA38.
     - Transaction: SA38
     - Program: RC1_IDOC_SET_STATUS
     - Program Parameters:
       - IDOC_ID: `<idoc_id>`
       - STATUS: LKD
   2. Send email to service provider.
     - Email to: employee3@serviceprovider.com
     - Subject: Please cancel Pollex receipt with ID `<pollex_id>` and resend a new receipt.
   3. End process.

 - **Else:**
   1. Get Pollex storage locations.
   2. Compare Pollex storage locations and `<storage_location_id>`.

3. **Decision: Is storage location ID in Pollex storage locations?**
 - **If yes:**
   1. Create storage location in plant.
   2. Re-initialize IDoc.
   3. End process.

 - **Else:**
   1. Forward error message to Error Handler 1.
     - Email to: error.handler1@company.com
     - Subject: Error Message
     - Body:
       - IDoc ID: `<idoc_id>`
       - Pollex ID: `<pollex_id>`
       - Description: Storage Location `<storage_location_id>` is not allowed (Check your entry.)
   2. End process.
```

Research Design

2. Implementing the LLM Agent – A Reason-and-Act Approach



- **DB:** Database, returns the solution to the most similar error message when called (repeatability)

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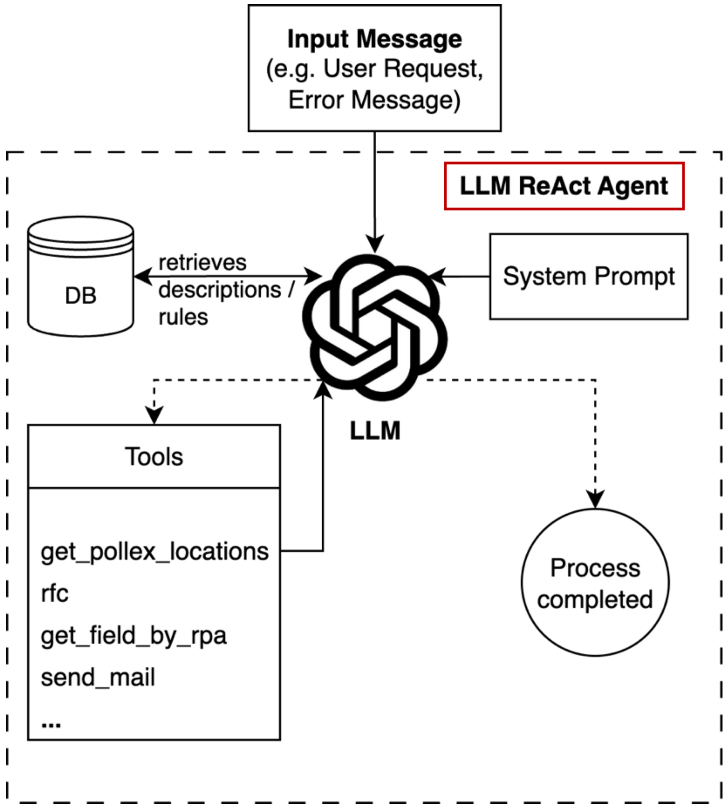

- **DB:** Database, returns the solution to the most similar error message when called (repeatability)
- **ReAct:** Agent receives input and iteratively thinks, acts, and observes using tools (adaptability)
- **Tool:** Function callable by LLM agent using a text command, returns response in text form

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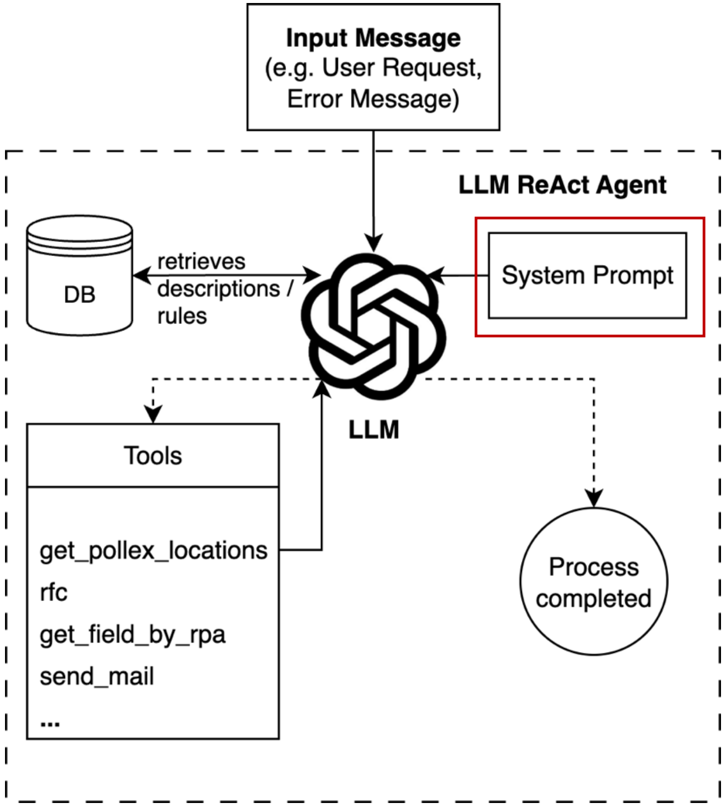

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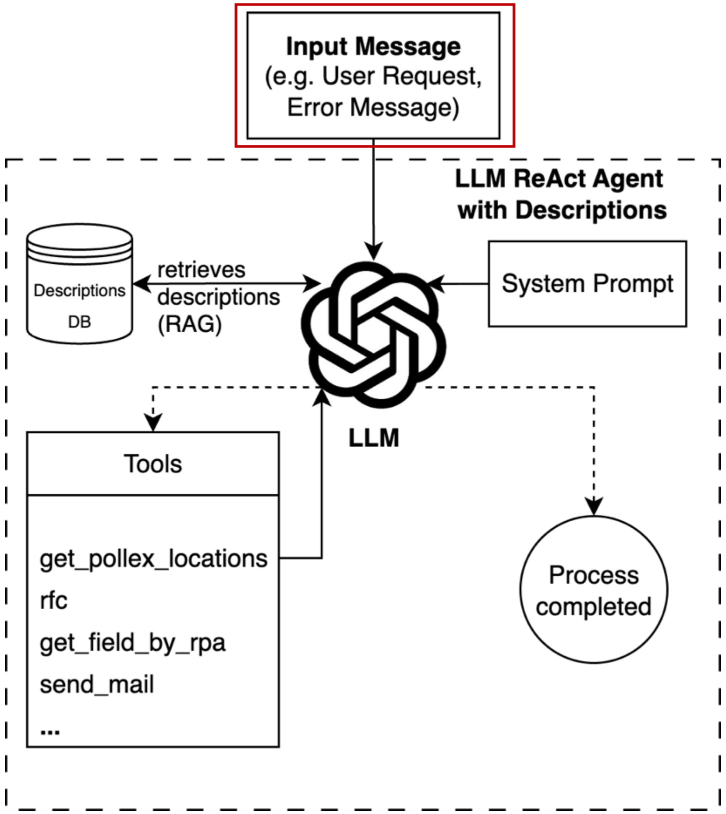
- **ReAct:** Agent receives input and iteratively thinks, acts, and observes using tools (adaptability)
- **Tool:** Function callable by LLM agent using a text command, returns response in text form
- **System prompt:** Description of agent's behavior

Research Design

2. Implementing the LLM Agent – The System Prompt – Unstructured Descriptions



1. Agent receives error message or user request

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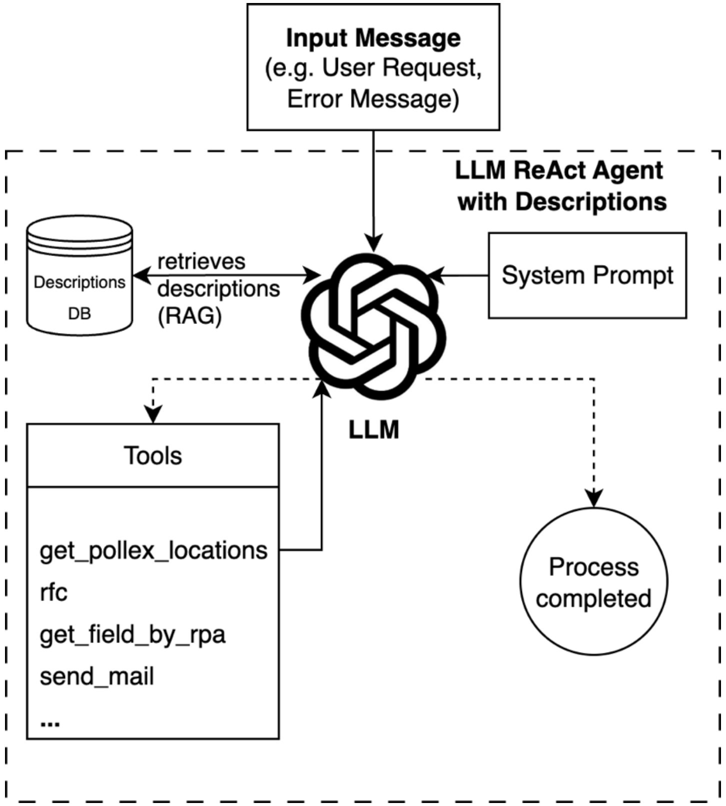

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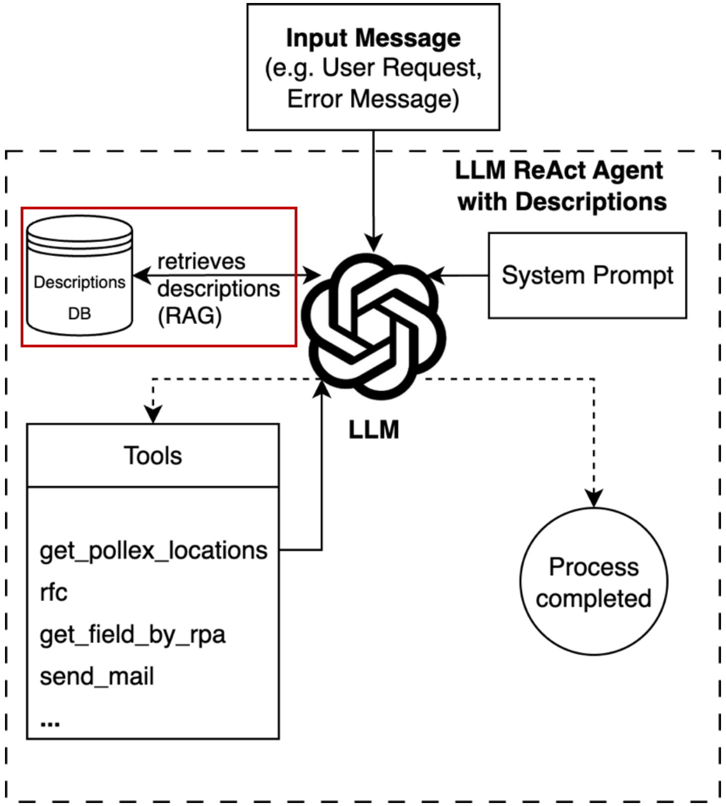

1. Agent receives error message or user request

2. Decision:
   - If error message
     - Agent retrieves the most similar description to the input message
     - Agent follows the description

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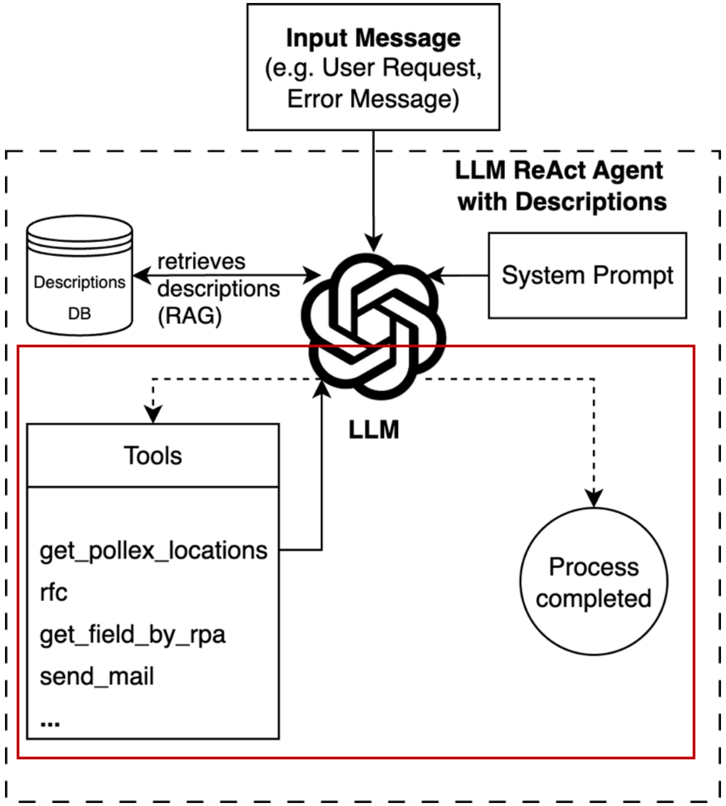

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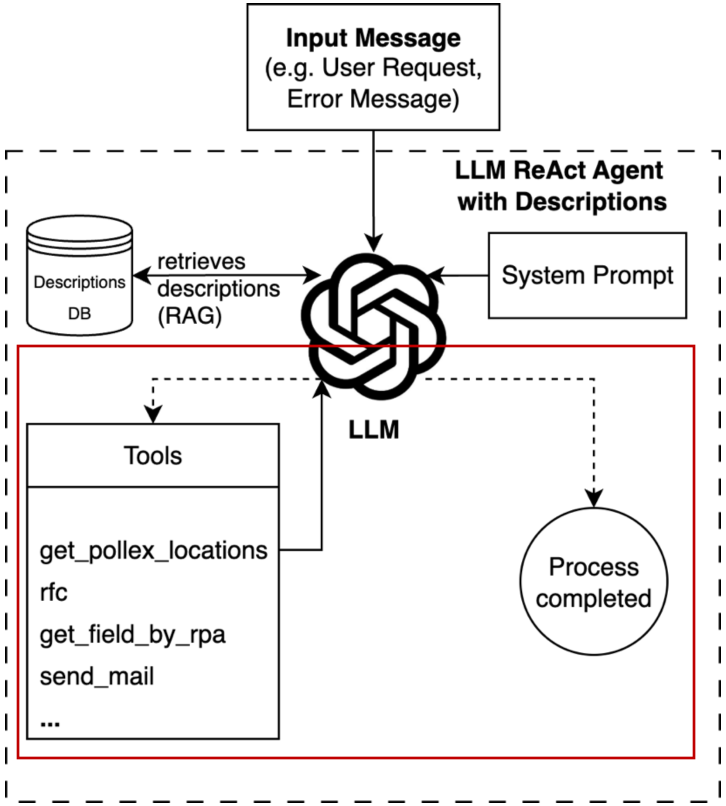
Research Design

2. Implementing the LLM Agent – The System Prompt – Unstructured Descriptions

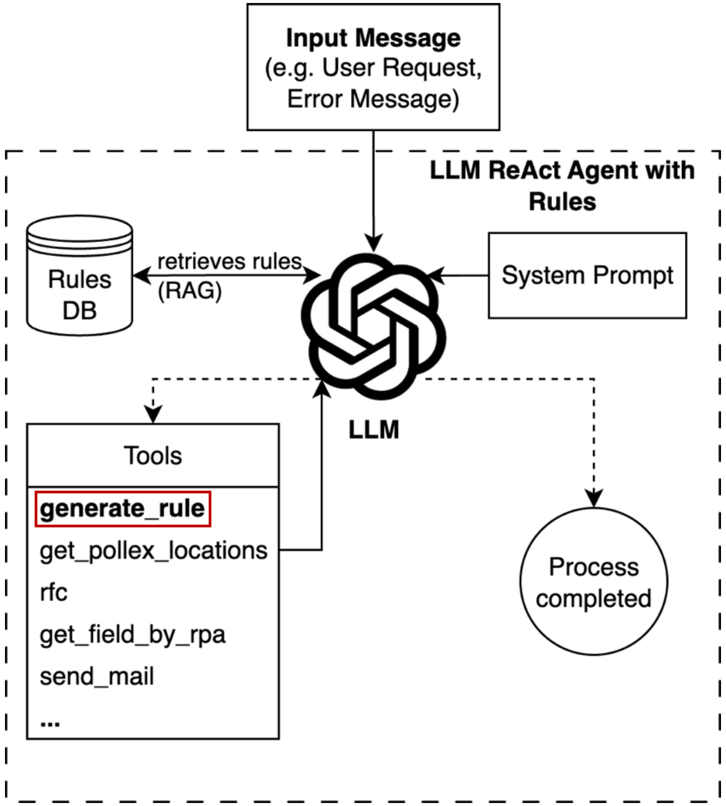


1. Agent receives error message or user request

2. Decision:
   - If error message
     - Agent retrieves the most similar description to the input message
     - Agent follows the description
   - Else (user request)
     - **Agent handles the request directly**

Research Design

2. Implementing the LLM Agent – The System Prompt – Process Rules



1. Agent receives error message or user request

2. Decision:
   - If error message
     - Agent retrieves the most similar rule to the input message
     - Agent follows the rule
   - Else (user request)
     - **Agent generates a rule ("generate_rule"-tool)**
     - **Agent follows the rule**

Research Design

3. Evaluating the LLM Agents' Repeatability vs Adaptabability

Repeatability:

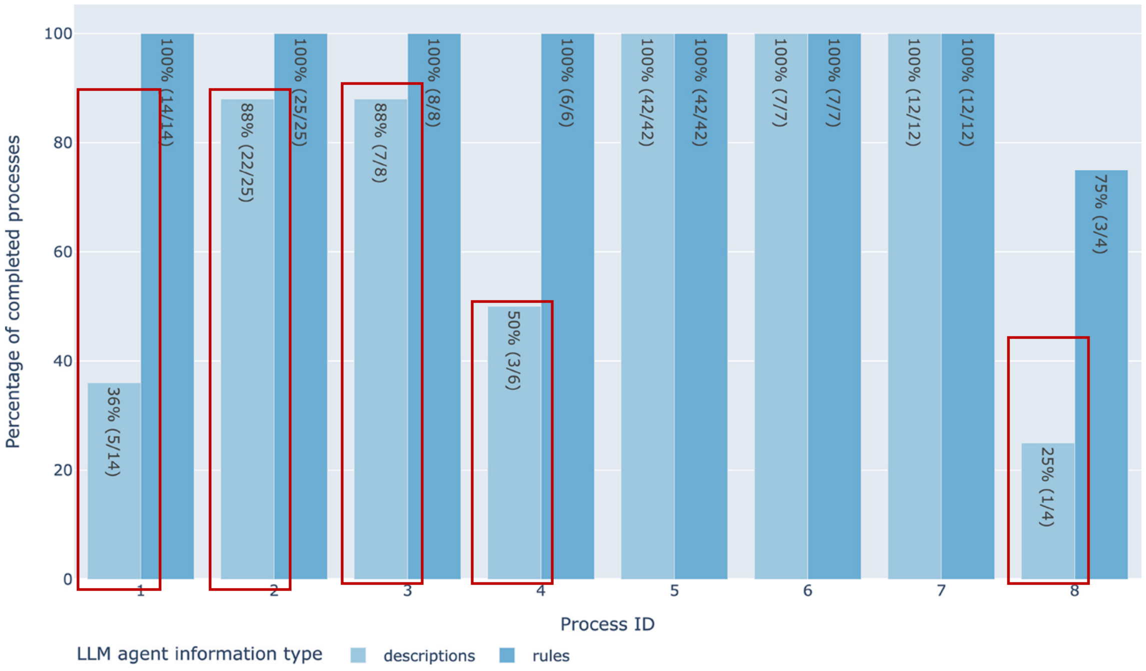
- Automatic evaluation of 119 Instances of 8 real-world processes with diverse characteristics
- Repeated 5 times with different seeds (robustness of repeatability)
- Calculation of economic outcomes (based on human work saved)

Adaptability:

- Manual evaluation of 54 instances of 24 different synthetic processes
- Evaluated once (due to manual effort and existing work)
- 1-3 paths and 1-15 tasks (increasing complexity)

Results

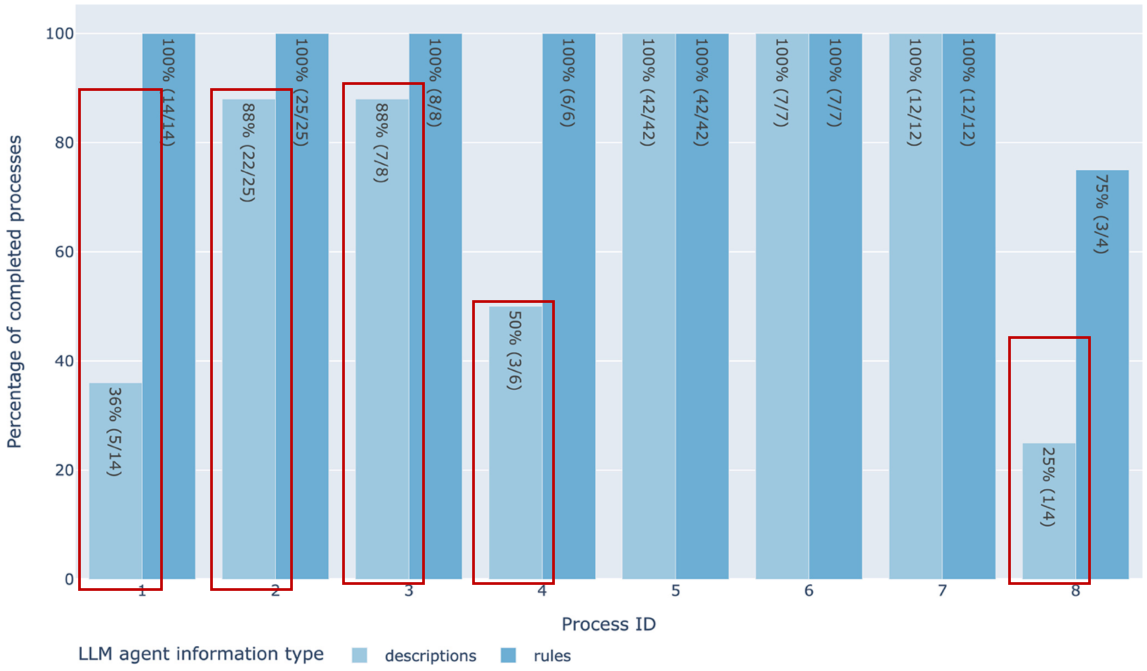
The Repeatability Evaluation – Handling SAP IDoc Errors



- LLM agent with descriptions cannot successfully complete all instances of processes 1, 2, 3, 4, and 8

Results

The Repeatability Evaluation – Handling SAP IDoc Errors



- LLM agent with descriptions cannot successfully complete all instances of processes 1, 2, 3, 4, and 8

→ LLM agent with descriptions „forgets" or skips steps and overlooks decision-relevant information

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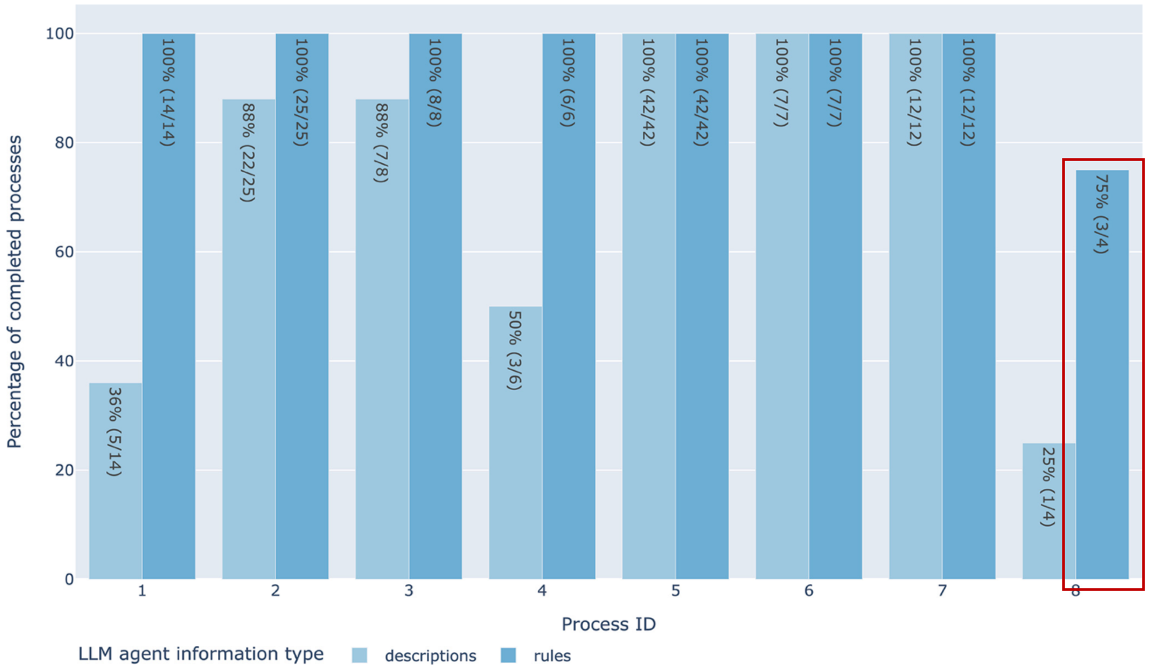
The Repeatability Evaluation – Handling SAP IDoc Errors



- LLM agent with descriptions cannot successfully complete all instances of processes 1, 2, 3, 4, and 8

→ LLM agent with descriptions „forgets“ or skips steps and overlooks decision-relevant information

- LLM agent with process rules only fails to complete one instance of process 8

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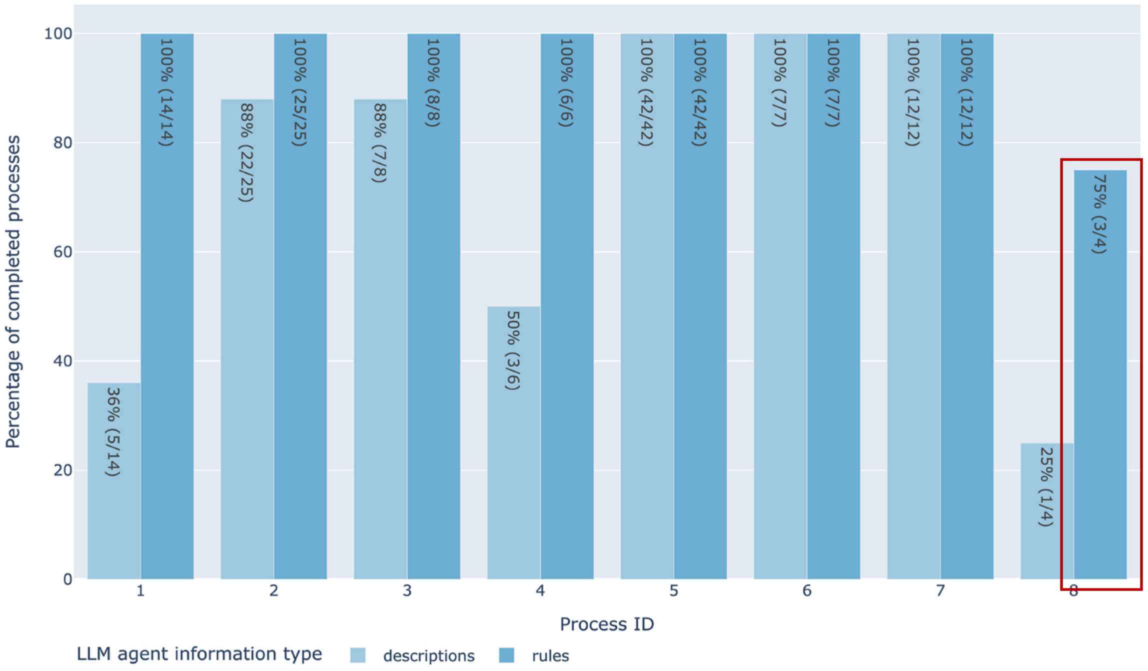
Results

The Repeatability Evaluation – Handling SAP IDoc Errors



	Descriptions	Rules
Completions	84 %	99 %

→ 15 % Improvement using process rules

→ Leading to a cost reduction of 89 %*

*10 instances included human work even if automation „works"

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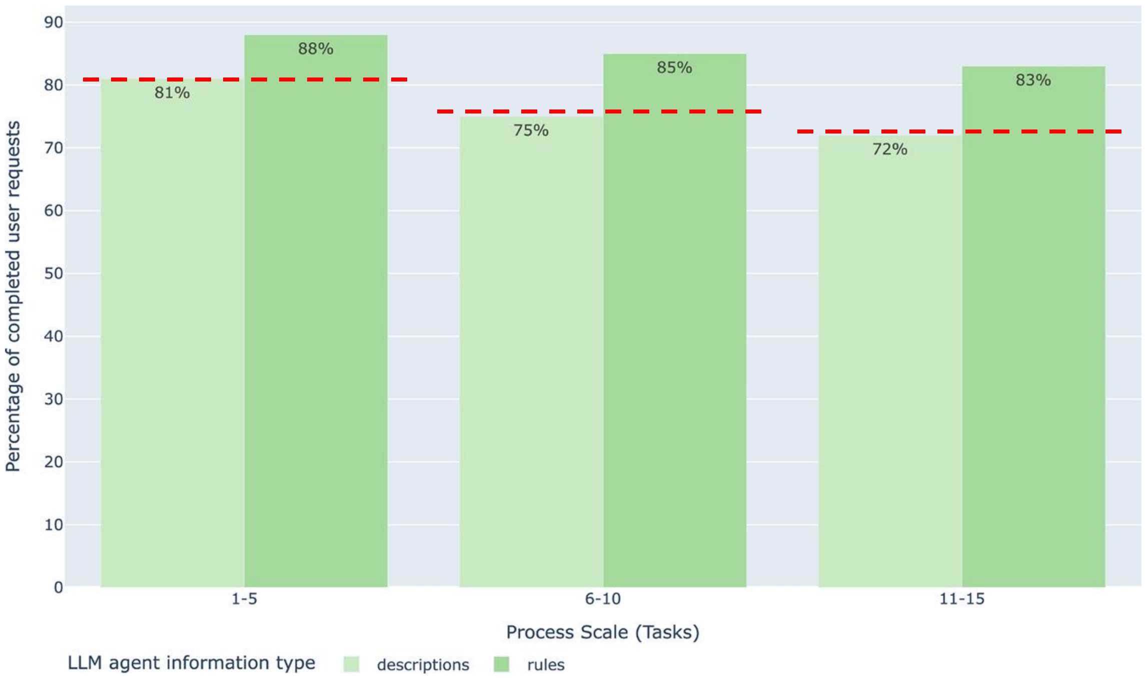
Results

The Adaptability Use Case – Fulfilling User Requests



- LLM agent with process rules completes more processes successfully

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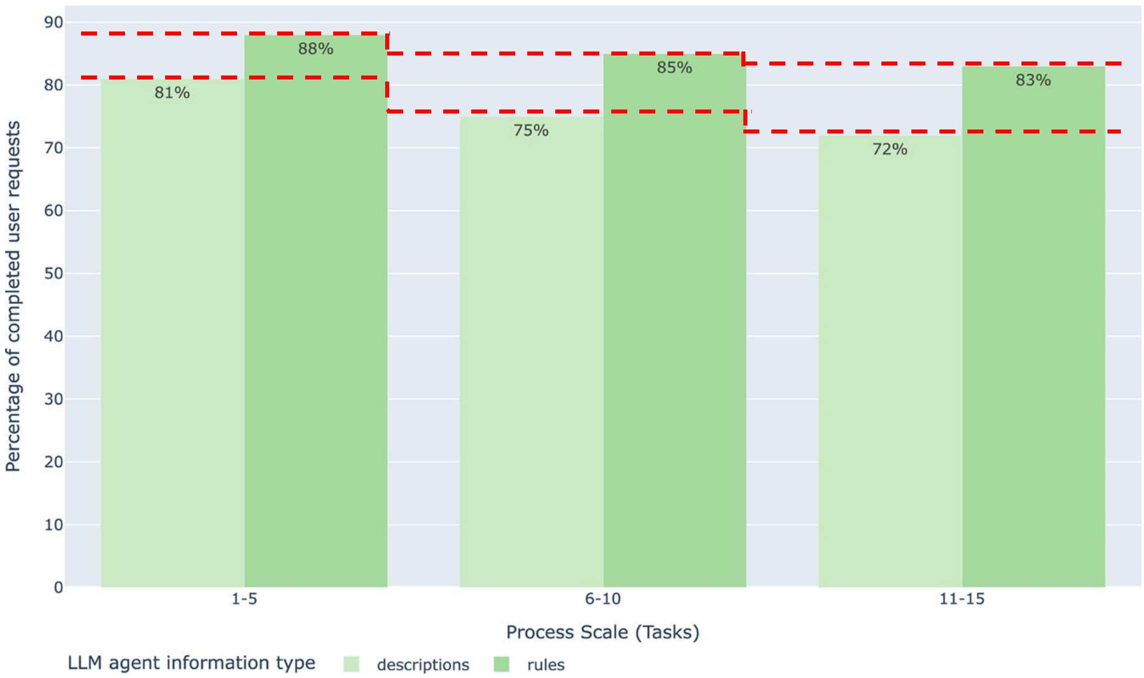
Results

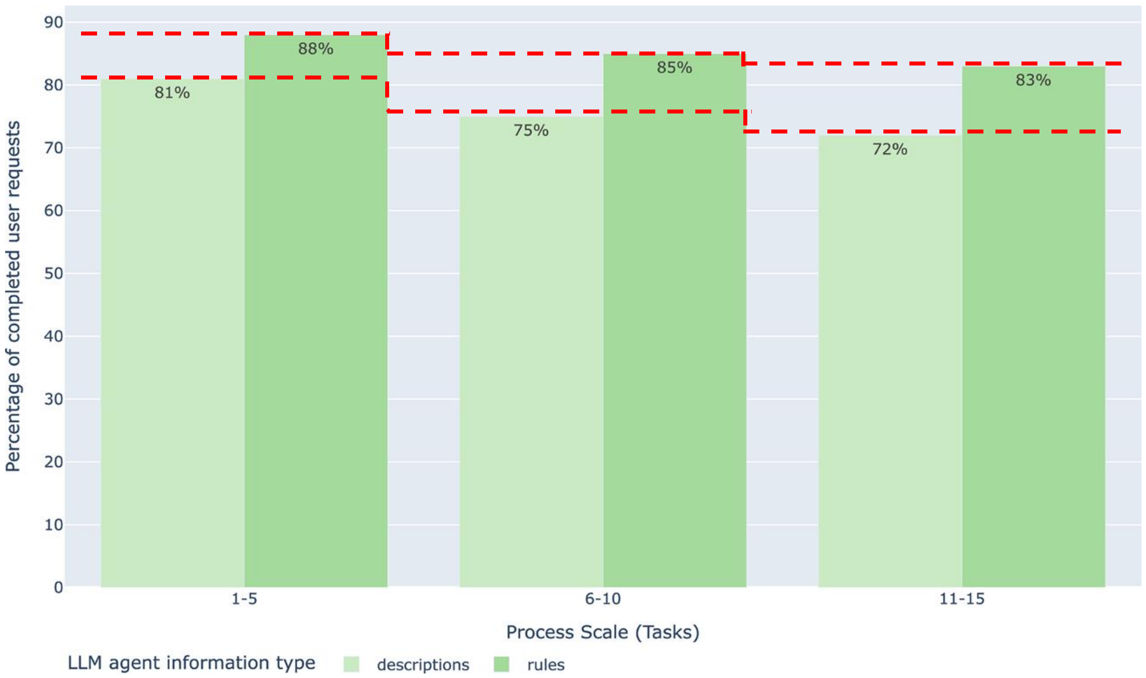
The Adaptability Use Case – Fulfilling User Requests



- LLM agent with process rules completes more processes successfully
- LLM agents' automation capabilities decline with increasing process length

Results

The Adaptability Use Case – Fulfilling User Requests



	Descriptions	Rules
Completions	76 %	85 %

→ 9 % Improvement using process rules

Contributions and Implications

Theory

Insights into structured and unstructured process representations:

Contributions and Implications

Theory

Insights into structured and unstructured process representations:

- Structured process representations improve process alignment of LLM agents

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Practice

An LLM automation agent blueprint:

Contributions and Implications

Theory

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Practice

An LLM automation agent blueprint:

- Capable of “cognitive” processes

Contributions and Implications

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An LLM automation agent blueprint:

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- Highly repeatable (rules database)

Contributions and Implications

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An LLM automation agent blueprint:

- Capable of “cognitive” processes
- Highly repeatable (rules database)
- Simultaneously adaptable (“rule generation”-tool)

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Contributions and Implications

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An LLM automation agent blueprint:

- Capable of "cognitive" processes
- Highly repeatable (rules database)
- Simultaneously adaptable ("rule generation"-tool)
- Integrates other automation methods (e.g., RPA)

Contributions and Implications

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An LLM automation agent blueprint:

- Capable of “cognitive” processes
- Highly repeatable (rules database)
- Simultaneously adaptable (“rule generation”-tool)
- Integrates other automation methods (e.g., RPA)

→ A step towards “cognitive automation”

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Limitations and Future Research

Limitations

- Processes are naturally not evenly distributed (real-world use case)

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Limitations and Future Research

Limitations

- Processes are naturally not evenly distributed (real-world use case)

- Approach partially relies on quality of BPMN and user requests

→ Missing information in BPMN or user request leads to automation failure

- LLM agent currently does not store information

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Future Research

1. Extend the LLM agent design by:
   a) A rule storage for successfully automated processes
   → self-adaptive learning

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2. Evaluate the LLM agent design in a second use case to strengthen the results

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2. Evaluate the LLM agent design in a second use case to strengthen the results

3. Evaluate the LLM agent design in the actual real-world environment (energy grid provider)

Thank you for your attention!

Ask many questions, please!

Check out the online-appendix:

https://github.com/skaltenp/llm_agents_with_process_rules