MINING KNOWLEDGE GRAPHS FROM LOOSELY STRUCTURED PROCESSES

A USE CASE FROM EMAILING SYSTEMS

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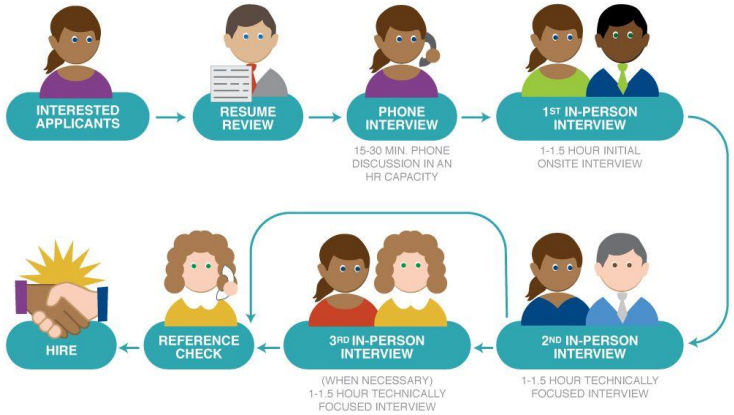
ICSBT 2022 KEYNOTE

Agenda

- Introduction to Processes & Process Analytics
- Spectrum of processes
  - From structured to unstructured processes
- Conceptual models to enable Cognitive Process Analytics
  - Process Knowledge Graph
  - Conversational Assistants
- Domain specific models for Emailing Systems
  - Discover Process Knowledge Graph from emails
  - Conversational Assistant to query Process Knowledge Graph

What is a process

- A **process** refers to **how work** is done
  - A set of **inter-related activities**
  - involving a number of **actors** and **data**
  - triggered by a need and leading to an **outcome**



https://www.vectorstock.com/royalty-free-vector/logistics-transport-scheme-concept-vector-15405312
https://amvedconsultancyservices.com/career.html

WHAT IS A PROCESS

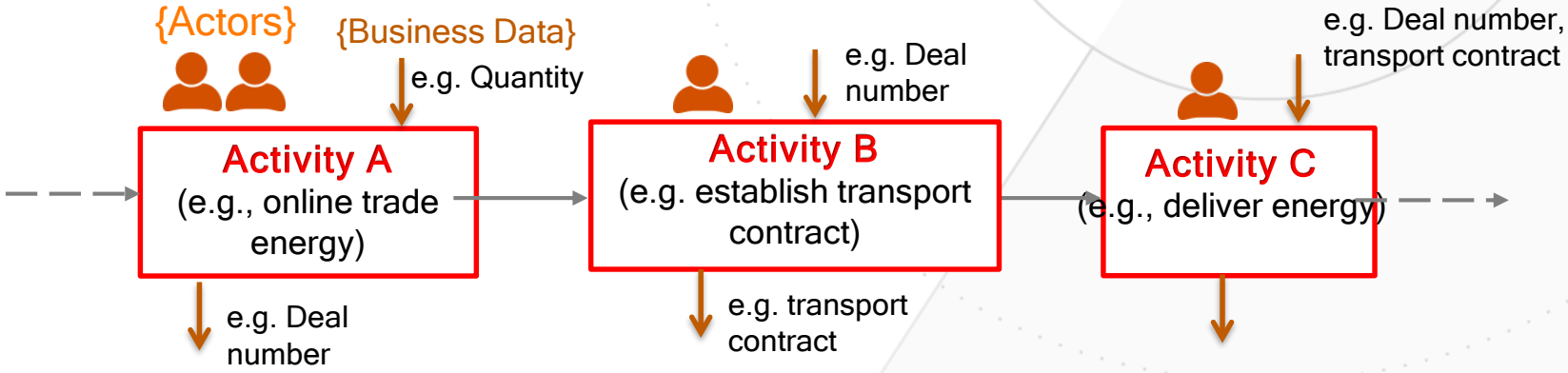
Business Process (BP)

Functional Perspective

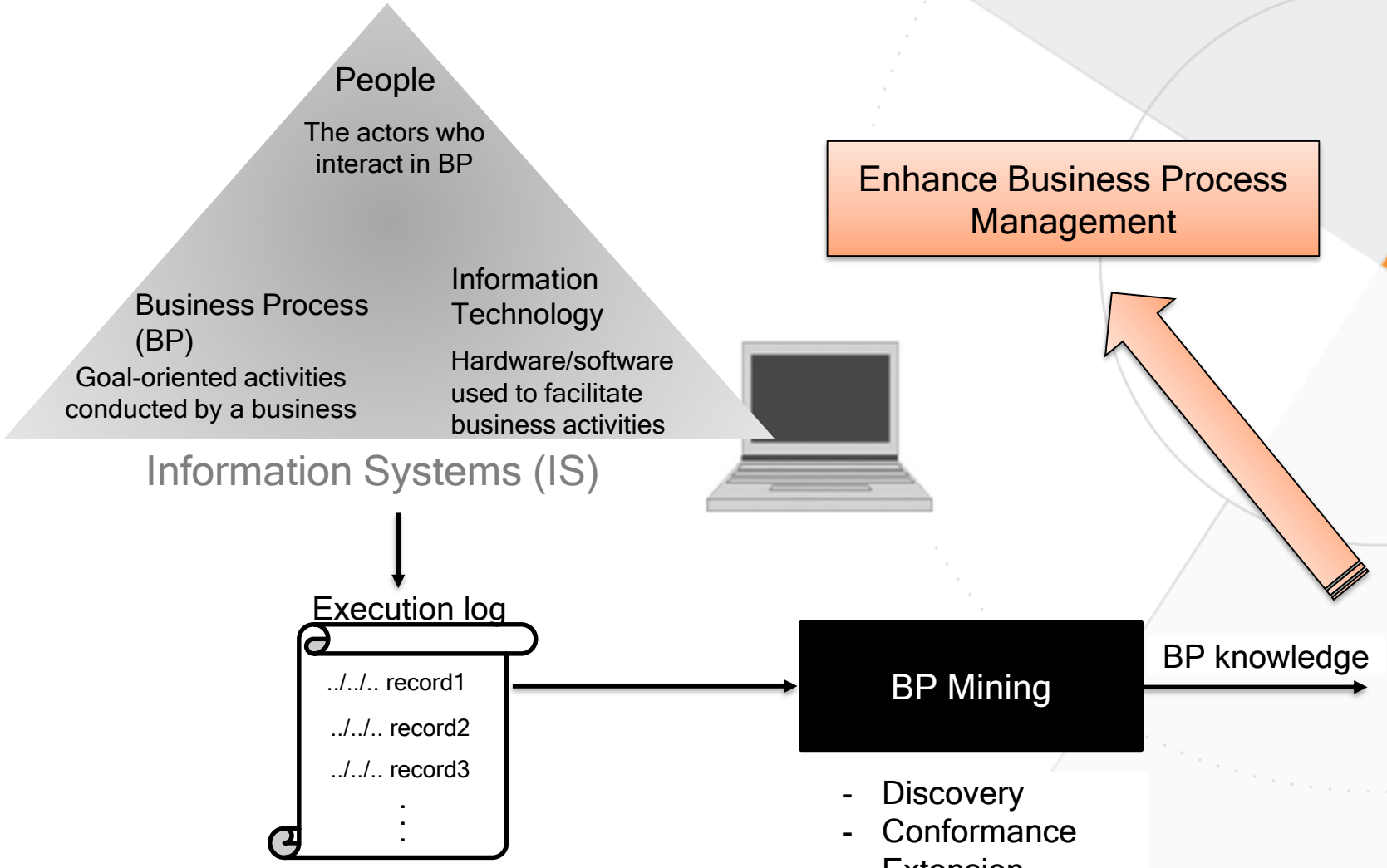
Behavioral Perspective

Organizational Perspective

Data Perspective



PROCESS ANALYTICS LANDSCAPE



Process Execution data

- **Who (resource)** did **what (activity)** and **when (timestamp)**
- What **data, objects, artifacts** are consumed/produced?

- 2 standards: **XES**
  - Predefined process instance notion

patient	activity	timestamp	doctor	age	cost
5781	make X-ray	23-1-2014@10.30	Dr. Jones	45	70.00
5541	blood test	23-1-2014@10.18	Dr. Scott	61	40.00
5833	blood test	23-1-2014@10.27	Dr. Scott	24	40.00
5781	blood test	23-1-2014@10.49	Dr. Scott	45	40.00
5781	CT scan	23-1-2014@11.10	Dr. Fox	45	1200.00
5833	surgery	23-1-2014@12.34	Dr. Scott	24	2300.00
5781	handle payment	23-1-2014@12.41	Carol Hope	45	0.00
5541	radiation therapy	23-1-2014@13.57	Dr. Jones	61	140.00
5541	radiation therapy	23-1-2014@13.08	Dr. Jones	61	140.00
…	…	…	…	…	…

case id | activity name | timestamp | resource | other data

Process Execution data

- **Who (resource)** did **what (activity)** and **when (timestamp)**
- What **data, objects, artifacts** are consumed/produced?

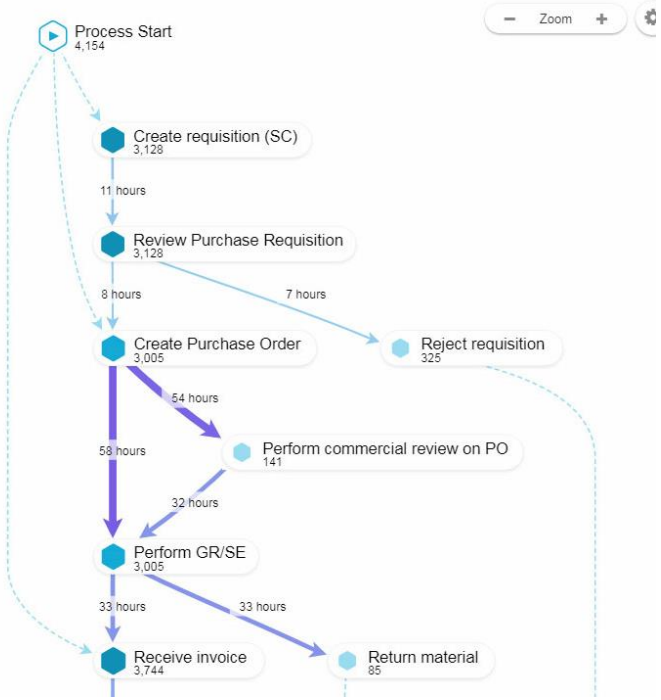
- 2 standards: **OCEL**
  - No predefined process instance
  - Events affect objects

Process Mining techniques

Descriptive	Diagnostics	Predictive	Prescriptive
Process Querying	Performance analysis	Performance dashboards	Cost-aware recommendation
Process discovery	Conformance analysis	Alarm-based dashboards	Best future path
	Root cause	Future path	

process improvement

Process discovery & performance analysis

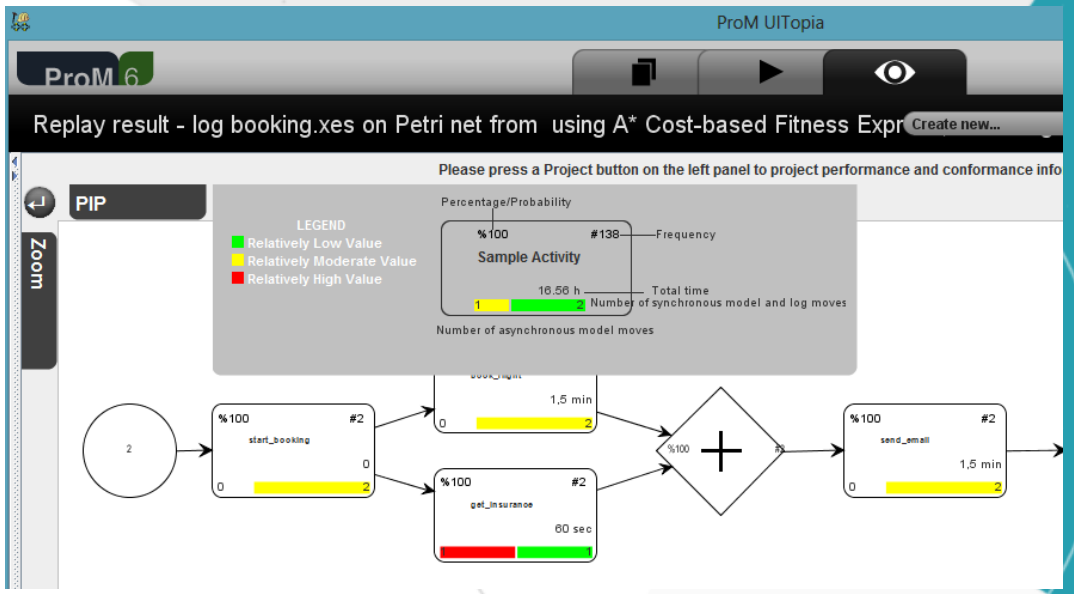


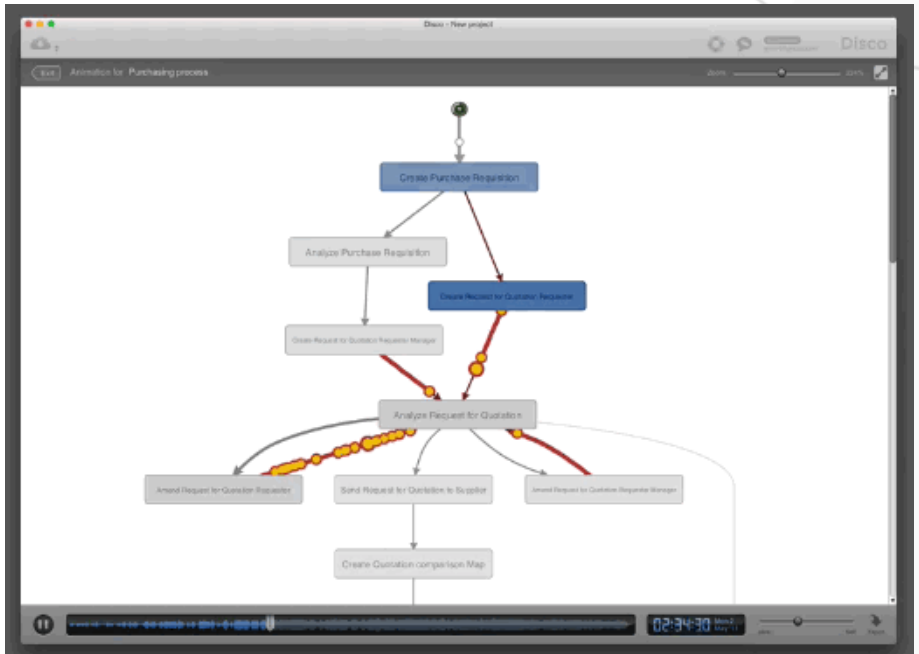
celonis

Celonis Raises $1 Billion At $11 Billion Valuation, Making It New York's — And Germany's — Most Valuable Startup

Conformance checking

ProM process mining workbench

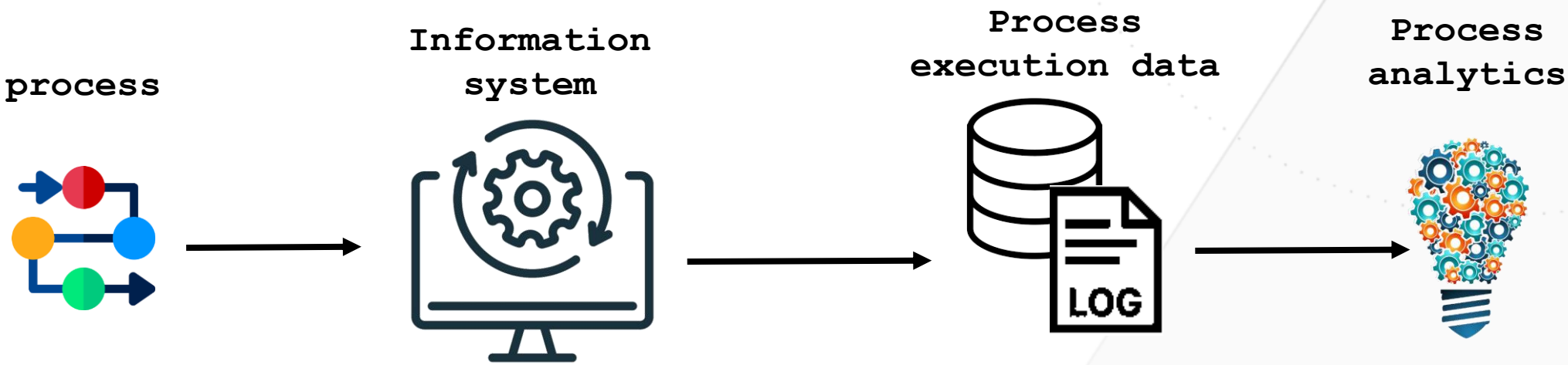




Disco by Fluxicon

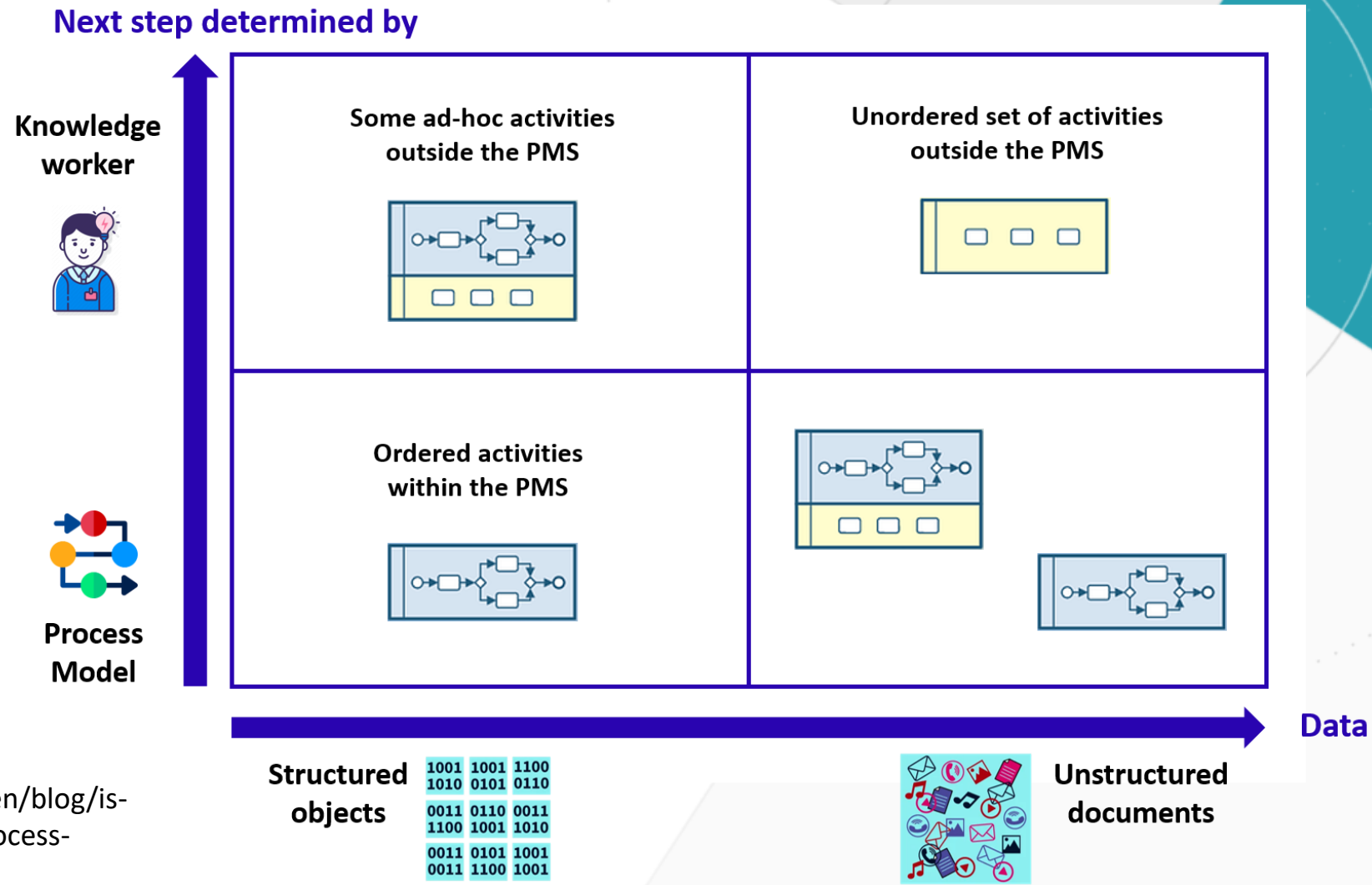
"Idealized" Process Analytics landscape

- Processes are structured,
- fully executed within a process management system,
- which records process execution data,
- that are analyzed using process analytics techniques



Spectrum of processes

- from structured to unstructured processes

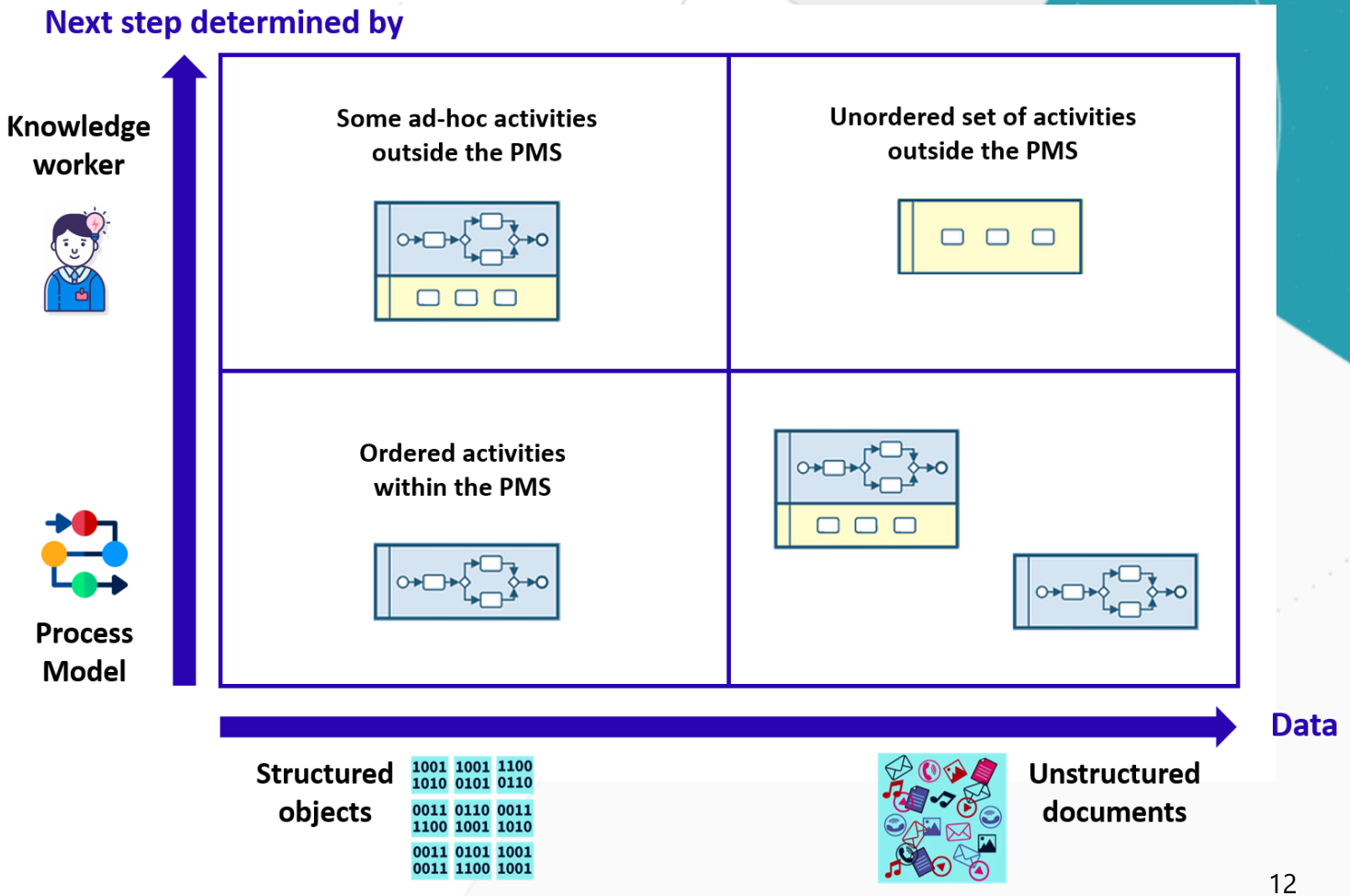


Adapted from: https://www.nedigital.com/en/blog/is-this-an-ibm-bpm-case-management-or-a-process-management-solution

Spectrum of processes

workers may:

- Chat about processes (e.g. using messaging systems)
- Use documents/notes to perform activities
- Use social medias (e.g. for recruitment)



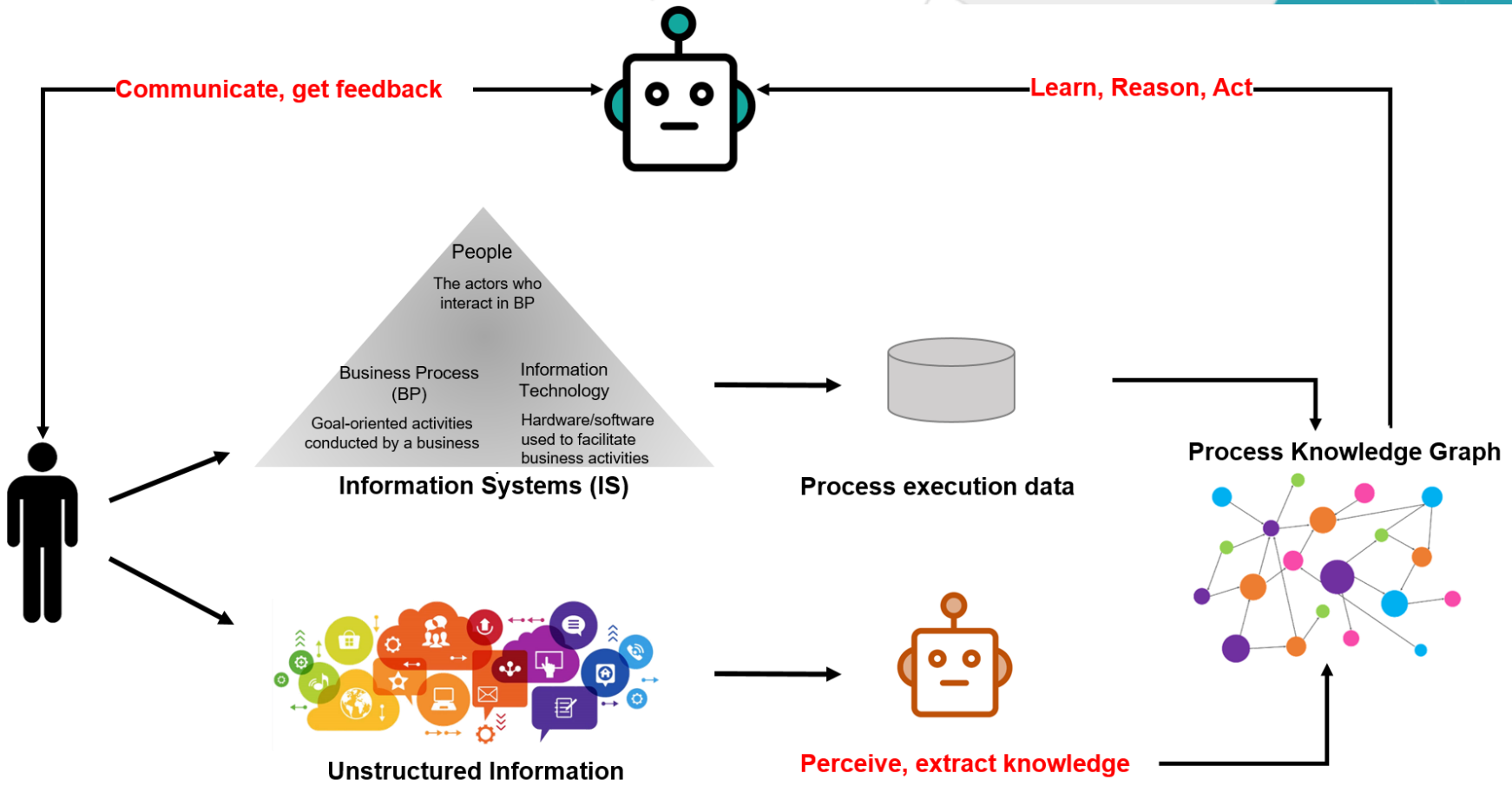
Open Questions

- How to enable process analytics on structured and unstructured data?
- How to enable process analytics on unstructured processes?
- How to extract rich process information from unstructured data?
- How to combine this information with structured process data?
- How to use extracted insights to assist workers in their daily tasks?

Towards Cognitive Process Analytics

A system that:

- analyzes structured + unstructured data
- discover, learn, reason
- act to assist workers (reactive + proactive)



Process Knowledge Graph

- How to effectively store the extracted process information?
- Existing Storage techniques:
  - **Relational databases (SQL like languages):**

    +Pros: simple and widely used model

    -Cons: Querying behavioral aspect is not intuitive (Querying path is complicated with SQL as it requires multiples joins).

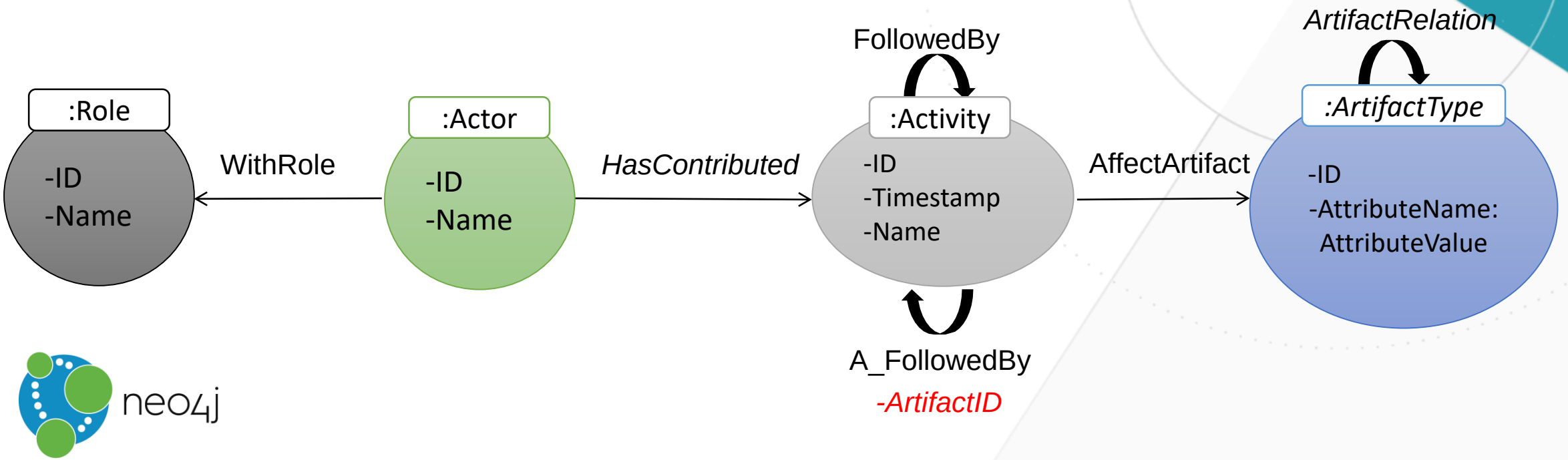
  - **Graph databases:**

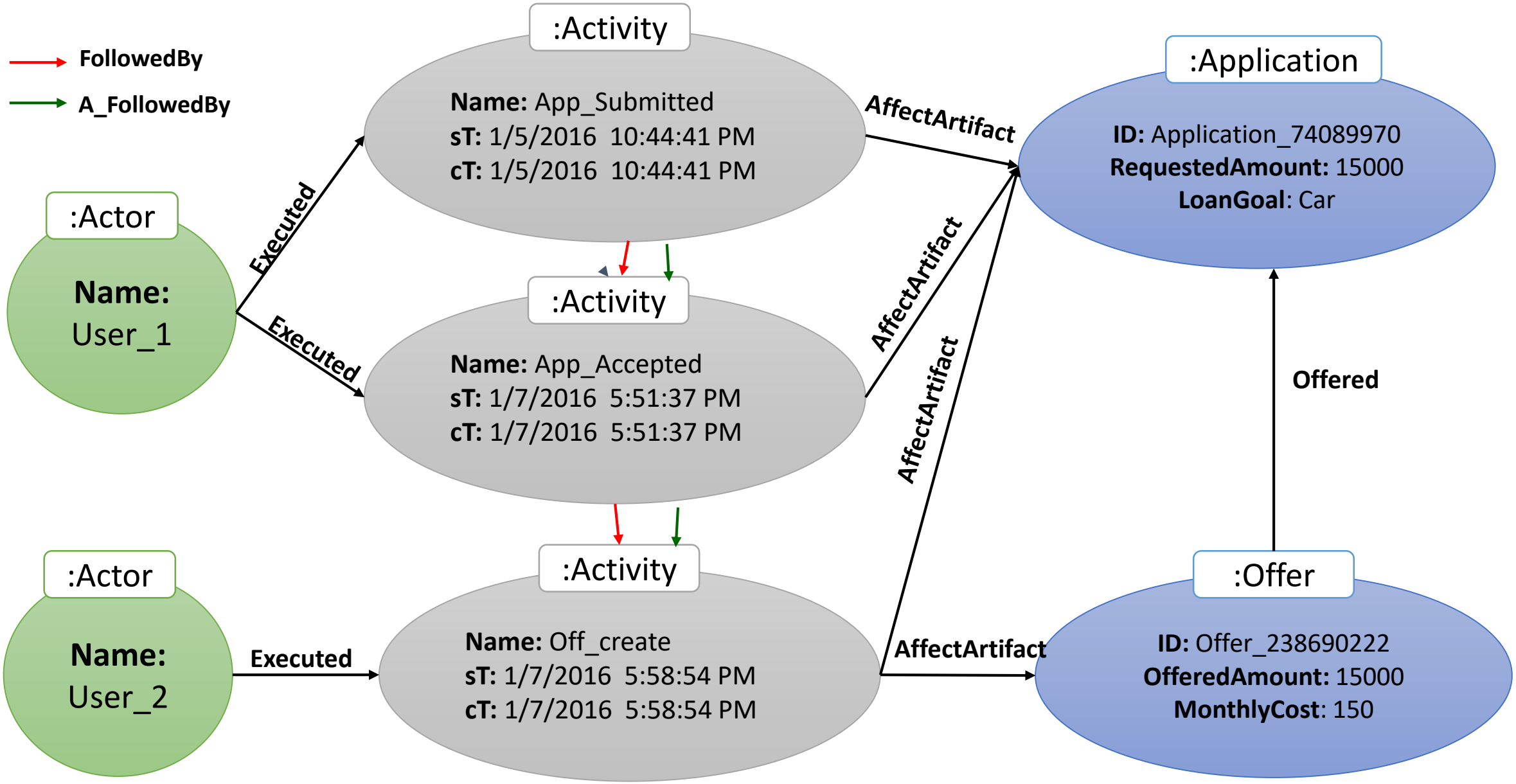
    +Pros: Graph database treats relationship between data as first class citizen

    -Cons: RDF is not compact (does not support internal structure)

Process Knowledge Graph

- Graph-based storage using Labeled Property Graph (LPG): Multi-dimensional event data storage based on OCEL




FollowedBy
A_FollowedBy
:Activity
Name: App_Submitted
sT: 1/5/2016 10:44:41 PM
cT: 1/5/2016 10:44:41 PM
:Application
ID: Application_74089970
RequestedAmount: 15000
LoanGoal: Car
AffectArtifact
:Actor
Name:
User_1
Executed
Executed
:Activity
Name: App_Accepted
sT: 1/7/2016 5:51:37 PM
cT: 1/7/2016 5:51:37 PM
AffectArtifact
AffectArtifact
Offered
:Actor
Name:
User_2
Executed
:Activity
Name: Off_create
sT: 1/7/2016 5:58:54 PM
cT: 1/7/2016 5:58:54 PM
AffectArtifact
:Offer
ID: Offer_238690222
OfferedAmount: 15000
MonthlyCost: 150

Conversational Assistant

- How to easily query the stored process data?

- Main limitation of existing process querying approaches:
  - ➔ require end users to learn and master a specific querying language.
- Process querying is primarily business-driven and should be accessible to business experts who may be inexperienced in database querying.

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Research Problem

- **How to enable cognitive process analysis on email data?**

1. How to extract process related information from emails?

activities, actors, business artifacts, etc.

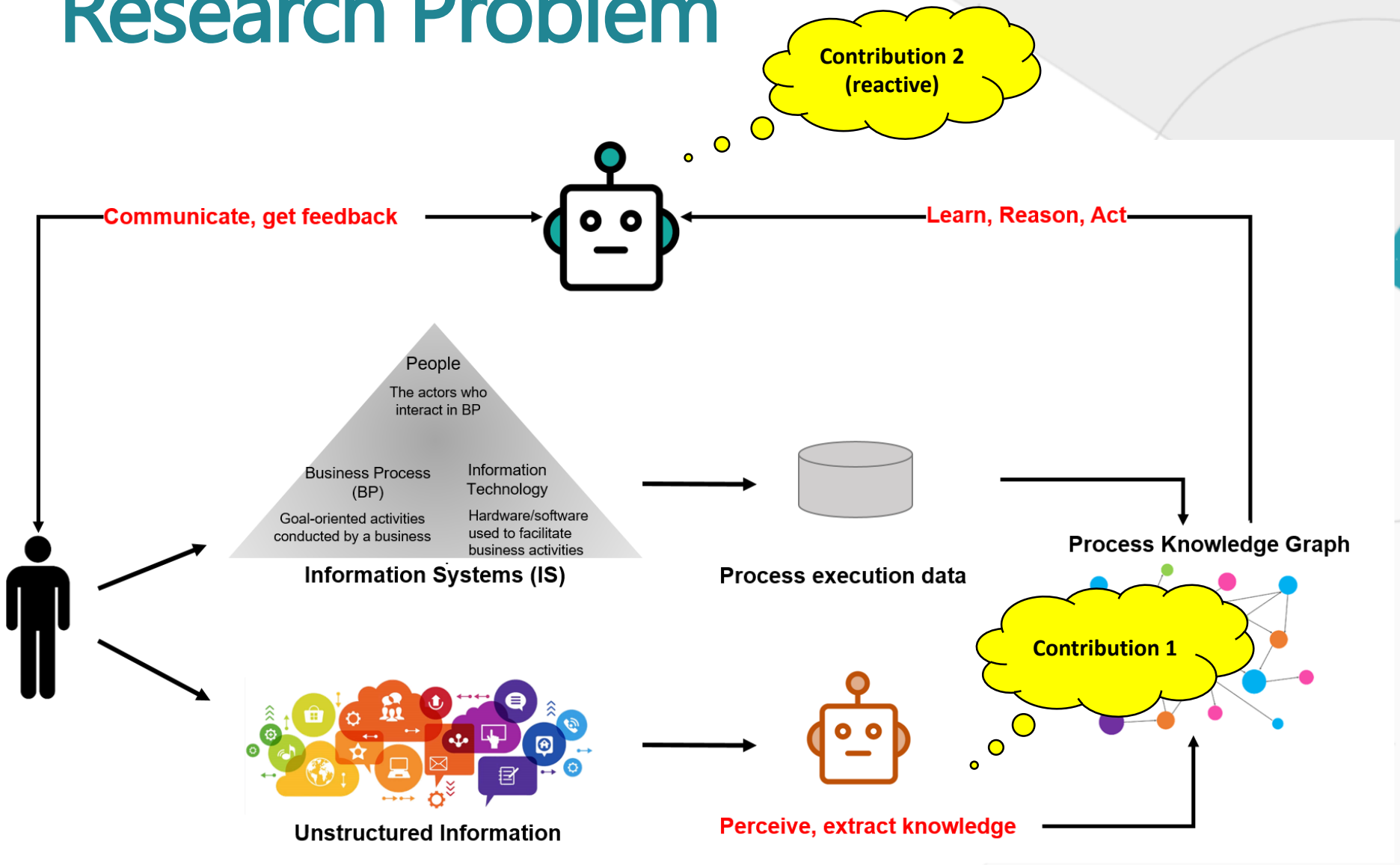
Contribution 1

3. How to assist end users in querying the process data?

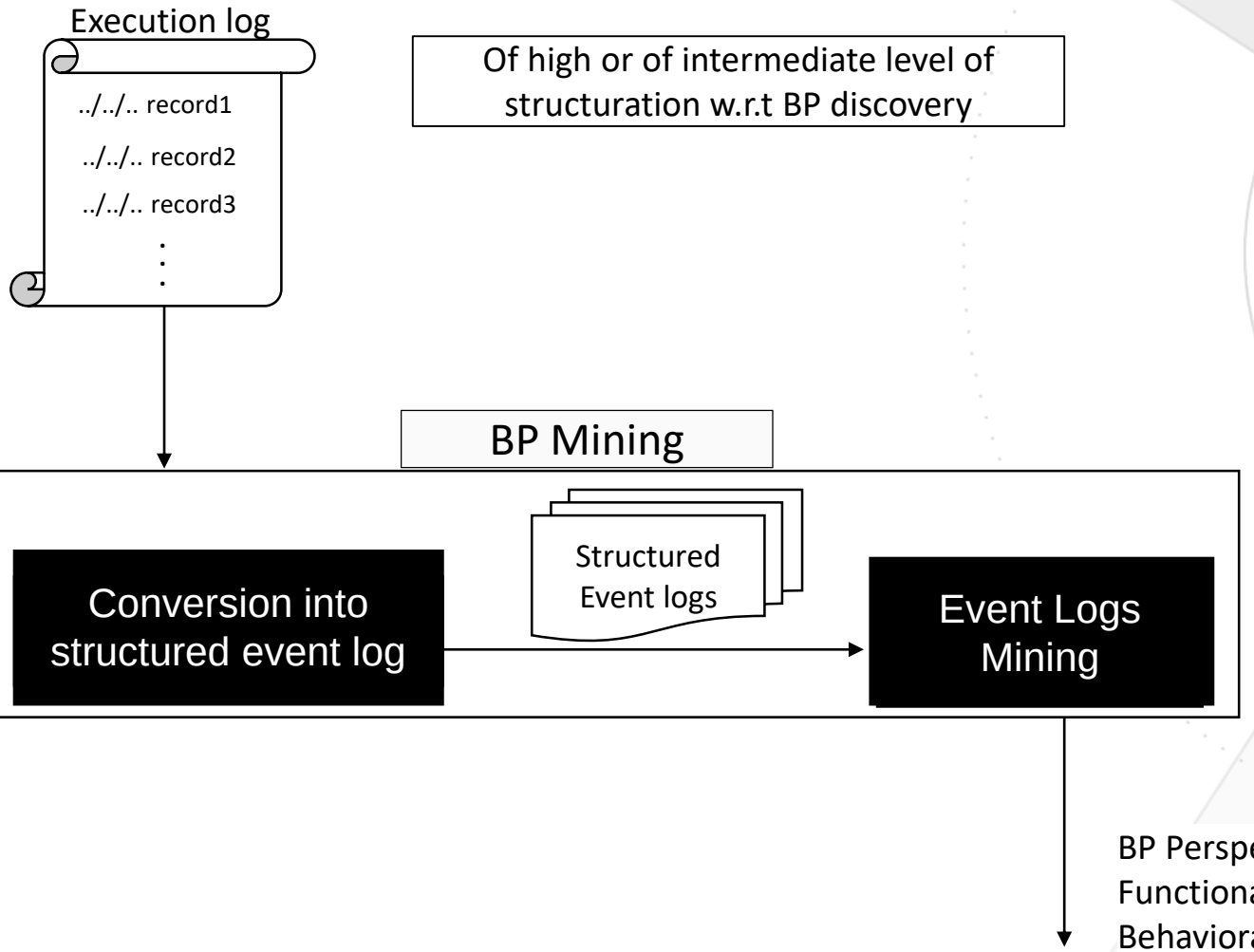
Querying the process data should be accessible to business experts

Contribution 2

Research Problem

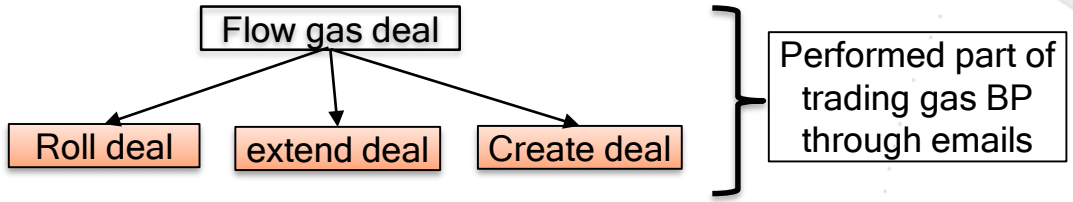


PROCESS MINING



Emailing systems for performing BP activities

EMAILING SYSTEMS FOR PERFORMING BP ACTIVITIES



The importance of analyzing emails for covering the traces of:

- BP that are totally or partially performed outside structured information systems
- Employees interactions regarding BP activities

Enhance Business Process Management (BPM) by covering unmanaged and less structured BP traces

Date: Wed, 15 Nov 2000 02:24:00 -0800
From: daren.farmer@enron.com
To: aimee.lannou@enron.com
cc:
Subject: Re: Flow w/ no nom

Rolled deal 454057 to cover flow at mtr 5192.
d

Aimee Lannou 11/10/2000 02:17 PM
To: Daren J Farmer/HOU/ECT@ECT
cc:
Subject: Flow w/ no nom

Meter 1601 last deal 412219 for 10/00 flowed 11/9

Meter 5192 last deal 454057 for 10/00. flowed 11/3-4

Email1 From Enron database

Informing about rolling a deal

Informing about extending a deal

conversation history

Informing about gas flowing of two deals

Date: Tue, 9 Jan 2001 06:48:00 -0800 (PST)
From: daren.farmer@enron.com
To: aimee.lannou@enron.com
cc:
Subject: Re: Dec 00

I extended 454057 for the month of December.
D

Aimee Lannou 01/09/2001 12:43 PM
To: Daren J Farmer/HOU/ECT@ECT
cc: Edward Terry/HOU/ECT@ECT
Subject: Dec 00

Daren - meter 5192 flowed 8 dth on 12/19, 33 dth on 12/20 and 2 dth on 12/29. The last deal for this meter was 454057 in Nov 00. Could you please extend this deal for these 3 days or create a new one? Please let me know.
AL

Email2 From Enron database

Informing about gas flowing

Requesting extending deal

Requesting creating new deal

GENERAL CONTEXT & MAIN RESEARCH QUESTIONS

Execution log

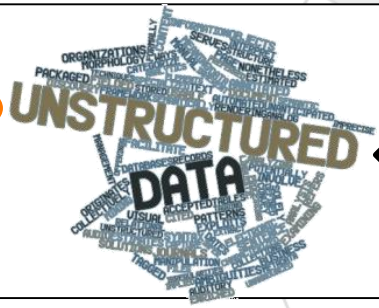
../../.. operation1

../../.. operation2

../../.. operation3

Of high or of intermediate level of structuration w.r.t BP discovery

Of low level of structuration w.r.t BP discovery



Emailing systems for performing BP activities

BP Discovery

More preprocessing steps

Conversion into structured event log

Structured Event logs

Event Logs Mining

Different algorithmic solutions

Q2: How to automate the discovery of BP knowledge from emails ?

Functional

Behavioral

Organizational

Data

BP Perspectives

Q1: What are the BP knowledge that can be discovered from emails to be consistent with emailing systems specifities ?

Main Objectives

Objective 1: Formalize the definition of BP knowledge (i.e. Multiple BP perspectives & event log structure) to be discovered from emails

Objective 2: Propose a totally unsupervised approach for discovering BP w.r.t multiple perspectives

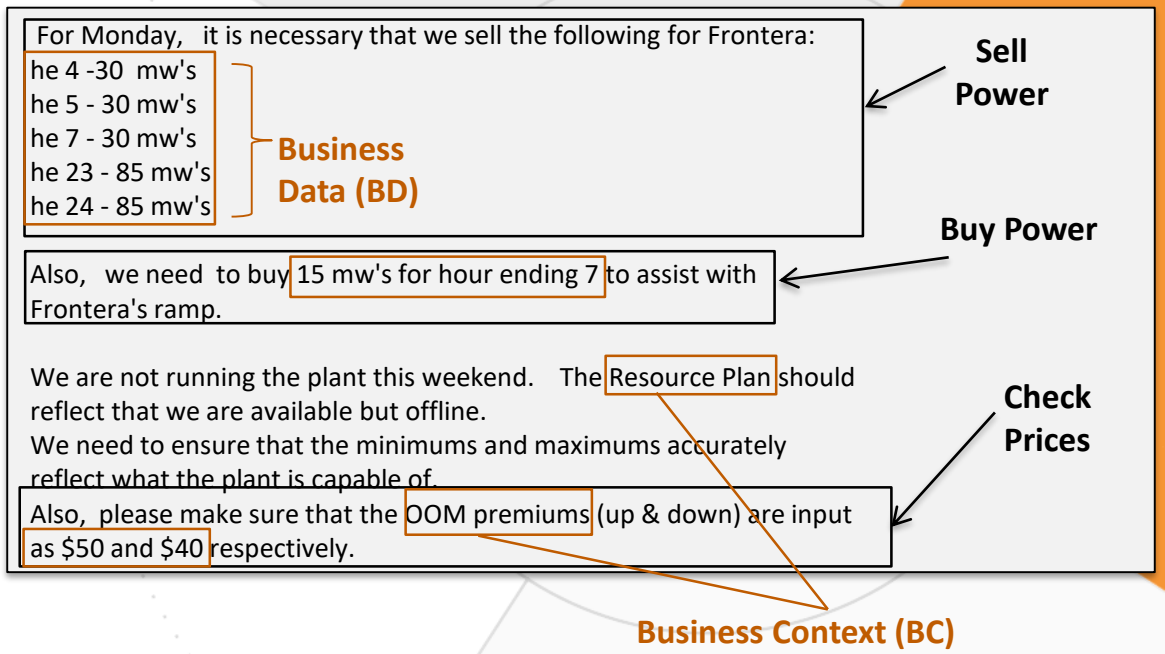
- Without requiring a priori BP information & considerable human intervention
- While allowing the discovery of multiple activities per one email

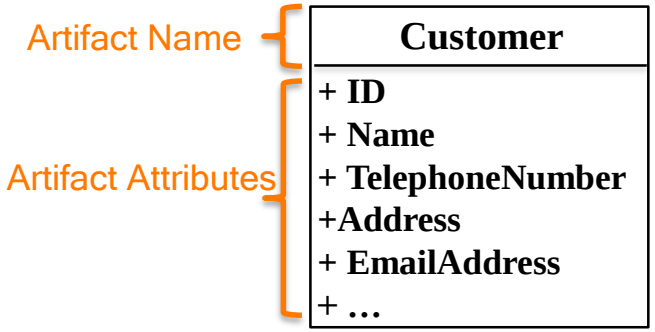
OBJECTIVE 1: BP KNOWLEDGE & EMAILS

- **BP Activity:** Activity Name + Business Information

- **Functional perspective:** Adopt the notion of **BP fragment** rather than complete BP due the incompleteness of BP traces in emails

- Data Perspective: Adopt artifact centric approach in the context of emails





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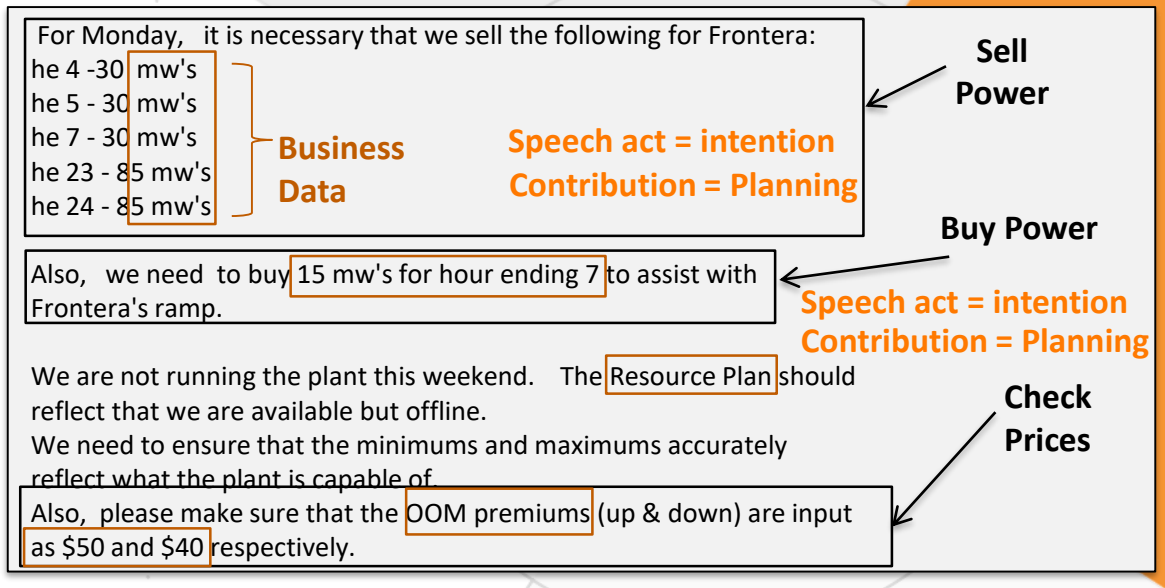


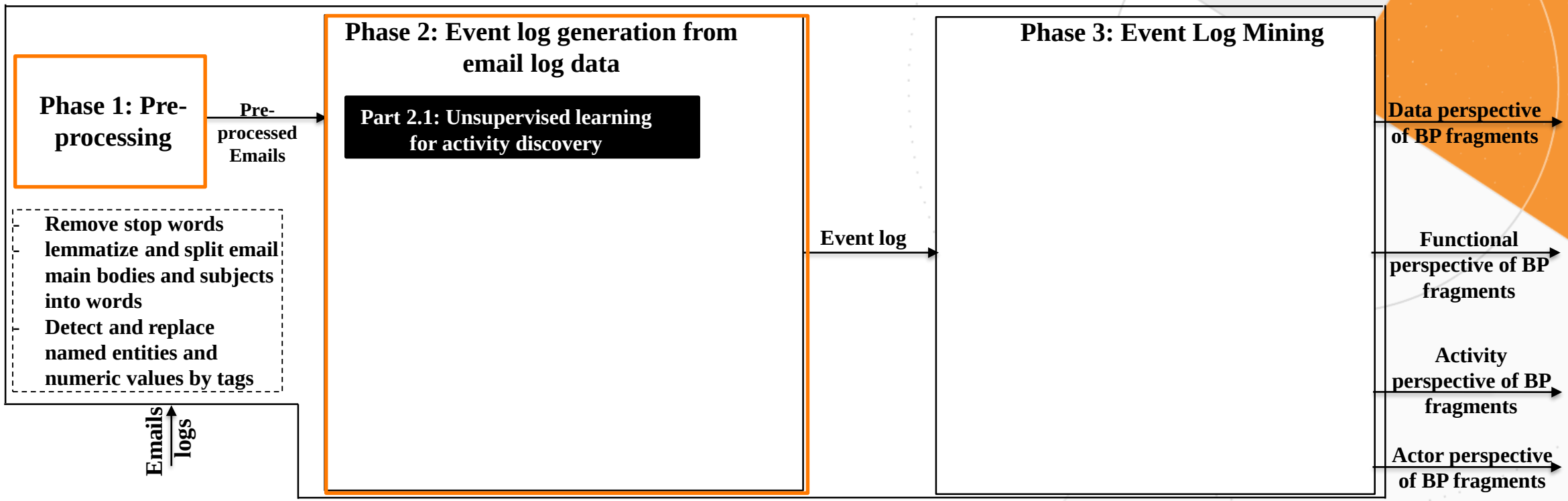
- **Functional perspective:** Adopt the notion of **BP fragment** rather than complete BP due the incompleteness of BP traces in emails

- Data Perspective: Adopt artifact centric approach in the context of emails

- Behavioral Perspective:
  - Adopt declarative approach for activity control flow;
  - Introduce new event type that combines activity & speech act;
    - Information act
    - Intention act
    - Request act
    - Request information act

- Organizational perspective: Consider multiple actors with various contributions (not limited to executing activities) when performing an activity
  - Execution
  - Information
  - Planning
  - Request
  - Request information
  - Observation

OBJECTIVE 2: A TOTALLY UNSUPERVISED APPROACH FOR BP KNOWLEDGE DISCOVERY



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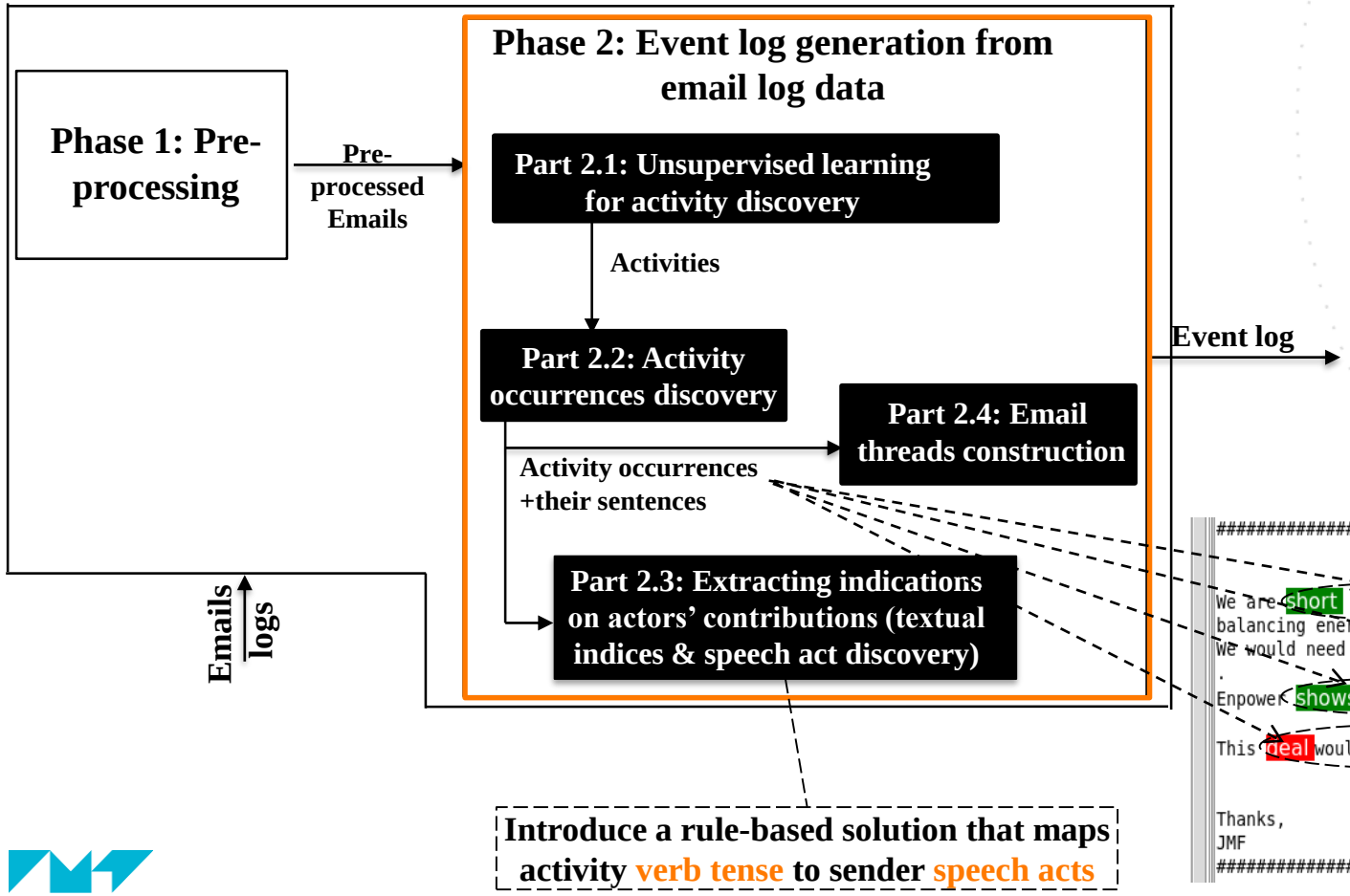

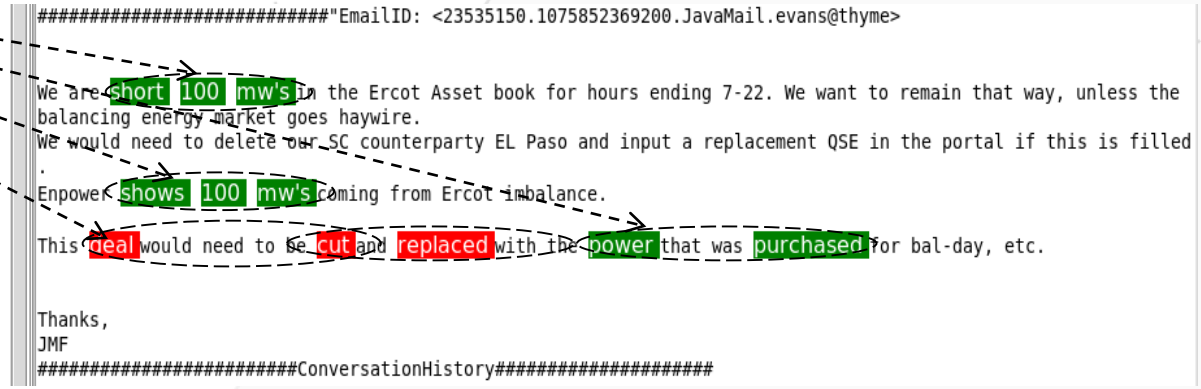

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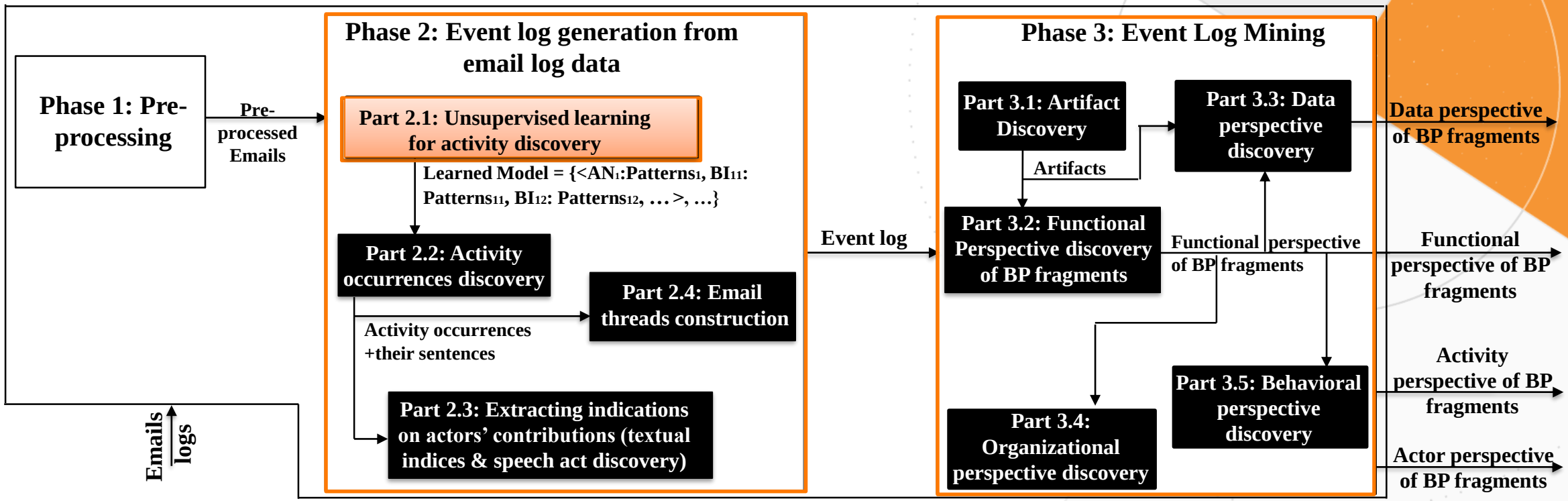

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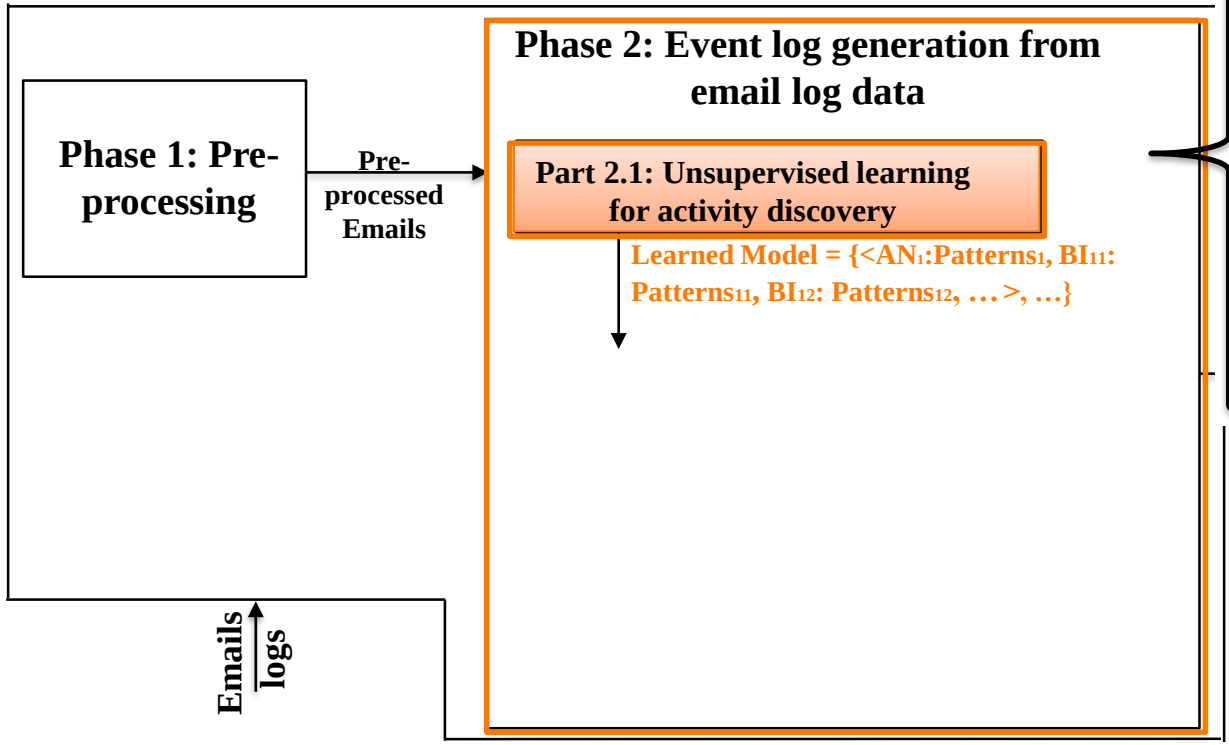
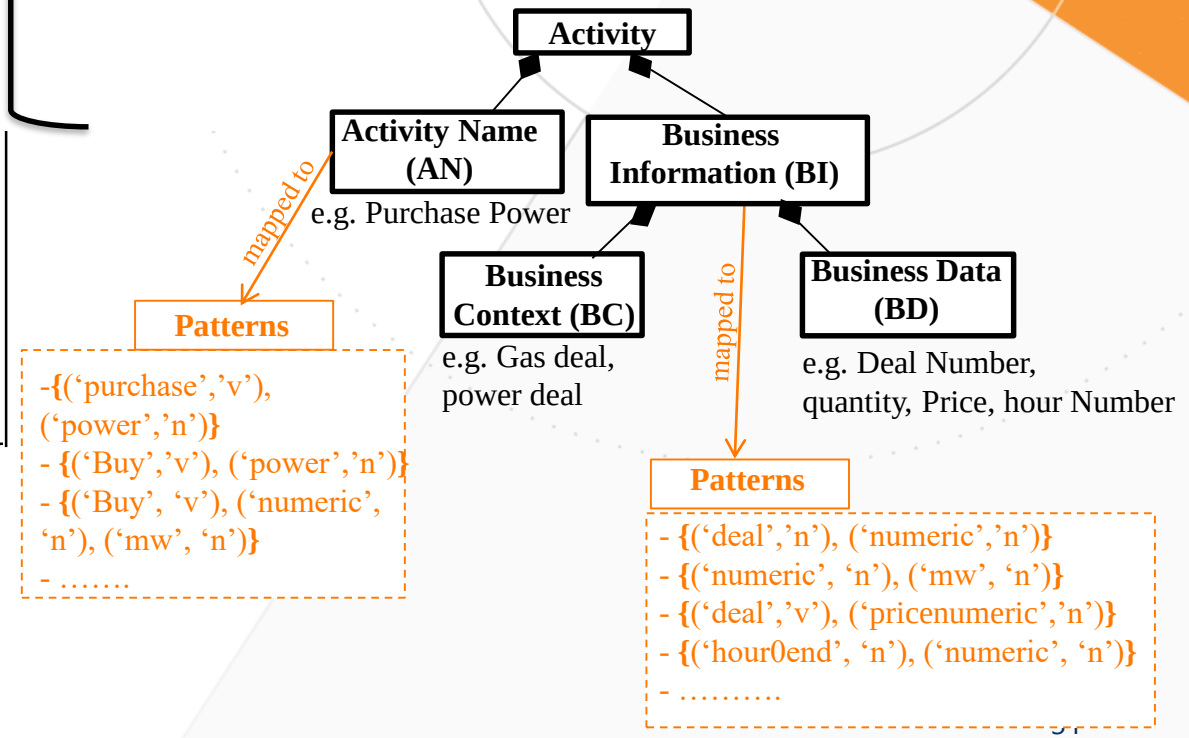


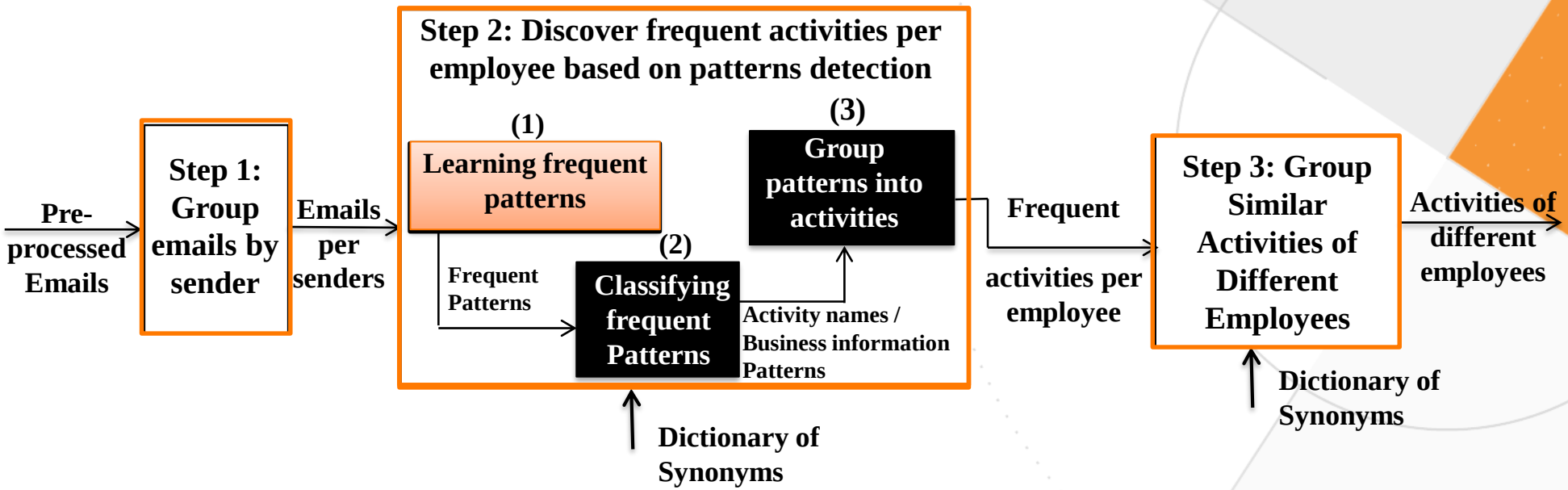
Main Assumptions:

1. For each BP, ∃ a set of actors that frequently execute the same activities
2. One employee that frequently expresses an activity in emails would use close expressions

Frequent patterns of words



UNSUPERVISED LEARNING FOR ACTIVITY DISCOVERY: MAIN STEPS



DISCOVERING PATTERNS: MAIN PROPOSITIONS

1) Consider low dispersion constraints when discovering frequent patterns of words to avoid non-significant patterns

Example of low dispersed pattern in a text

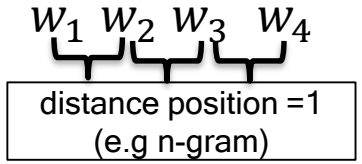
I have created deal tickets 241558 and 241560 for July 99 - March 00 based on the info below. Due to time constraints, I have not researched pricing and volumes, I trust that the info supplied to me agrees with the contract.

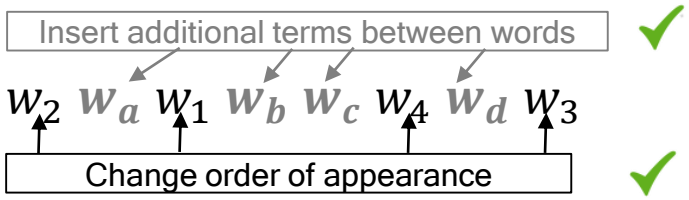
Example of highly dispersed pattern in a text

I have created a spreadsheet to assist in the tracking and booking of the gas supply related to Tenaska IV. If you have suggestions or comments on the file, contact either me or Mark.

Megan - You can copy the Jan 01 Est tab and update the volumes with actuals. The file should calculate the resulting settlement with Tenaska. I will then update the demand fee on the deal ticket to true-up the month. Since we haven't gone through actuals in the spreadsheet, we may have to do some tweaking with the formulas. Anyway, this should give us a good start and you will be able to see where we closed the month in Logisitics.

2) Do not impose constraints concerning the order of appearance of words (≠ Sequential Pattern Mining algorithms, e.g. n-gram)





3) Introduce the notion of patterns of concepts to tolerate the use of synonyms rather than identical words in emails

Pattern of concepts = {C1, C2, C3,…} where Ci = {syn1i, syn2i,…} such that all words have pairwise reciprocal synonymy relations to potentially refer to a unique meaning

email1= ['purchase', 'power',….]

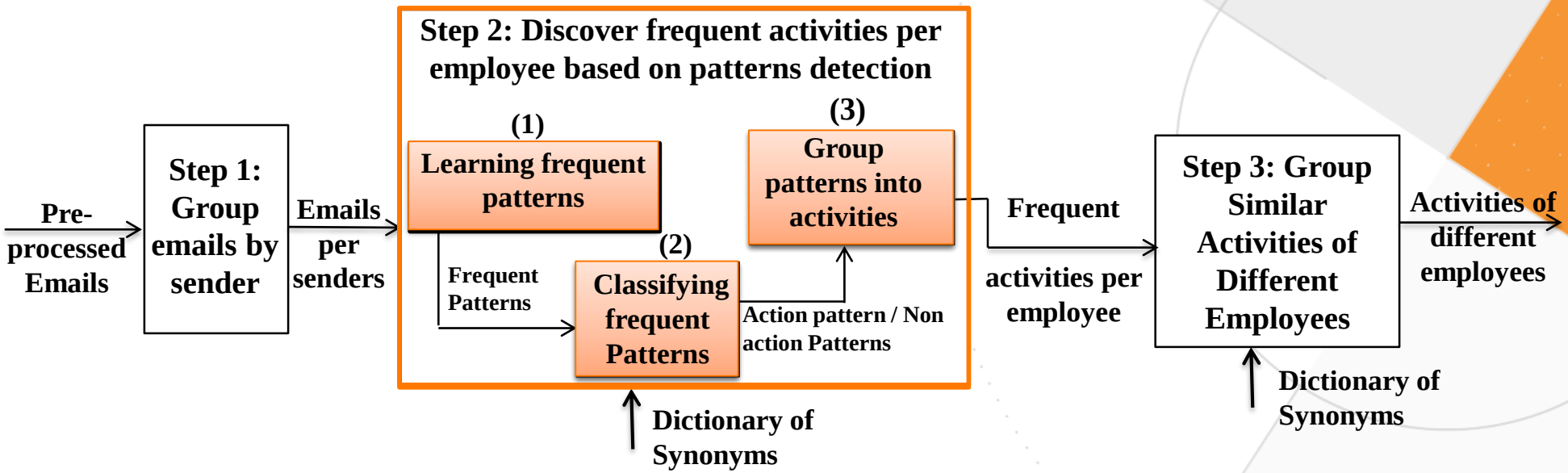
email2= ['buy' 'power',…]

⇒ In common Pattern of concept

[{'purchase', 'buy'}, {'power'}]

C1 C2

UNSUPERVISED LEARNING FOR ACTIVITY DISCOVERY: APPROACH OVERVIEW



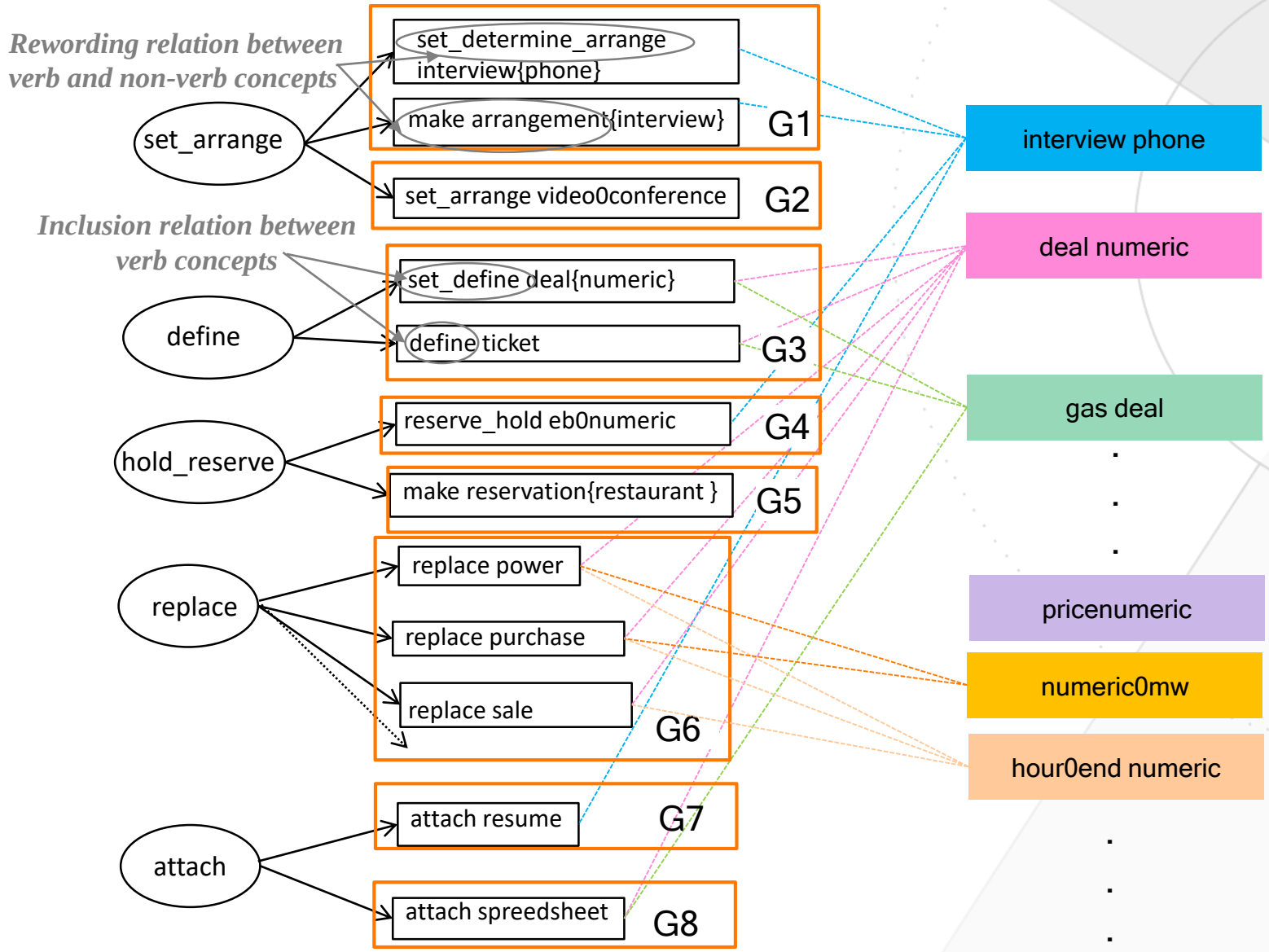
PC_{11}={{'arrange_v',' set_v'}, {'interview_n'}} → Action pattern → AN pattern

PC_{22}={{'set_v', 'define_v}, {'time_n'},{'slot_n'}} → Action pattern → AN pattern

PC_{13}={{'preliminary_n'}, {'interview_n'}} → Non-Action pattern → BI pattern

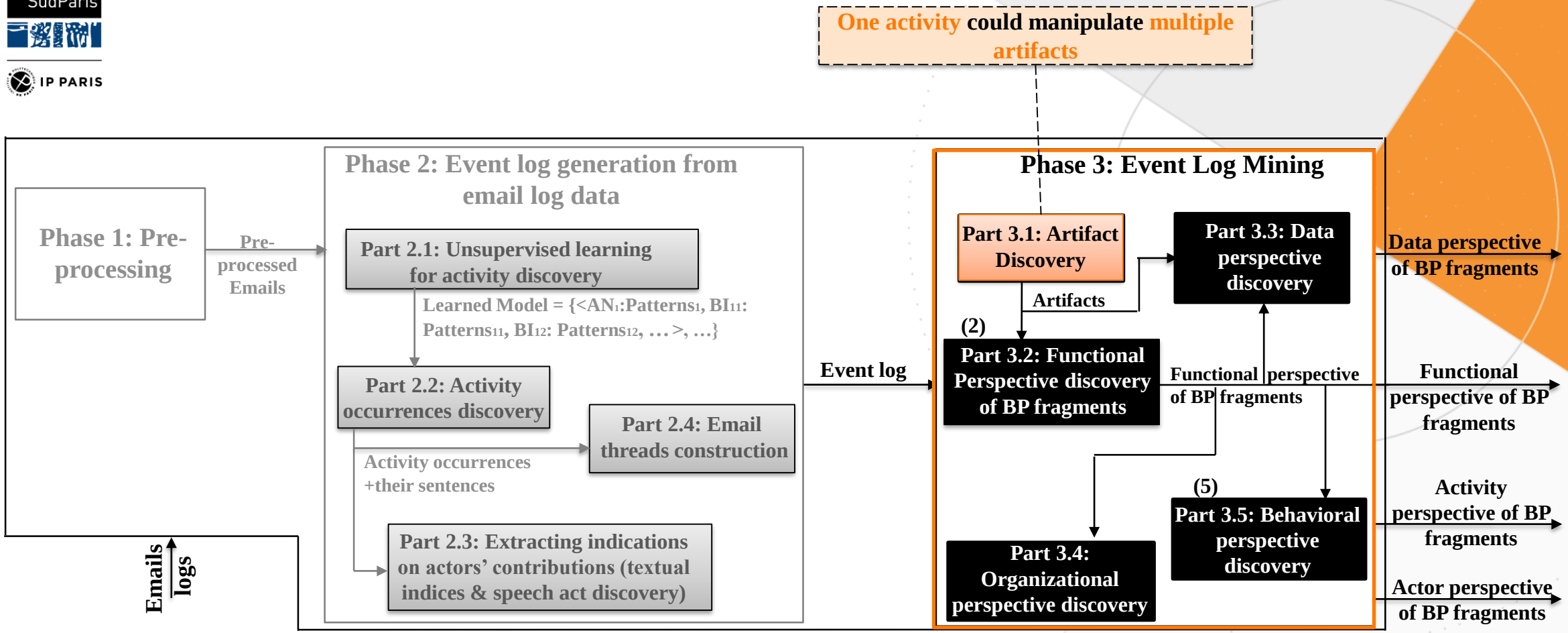
(1) Organize Action patterns by similar realization type

(2) Identify Highly correlated BI patterns to the action patterns (In term of coexistence in the same email)



(3) Obtain activities: Regroup action patterns of the same realization type by business context similarity

EVENT LOG MINING: APPROACH OVERVIEW



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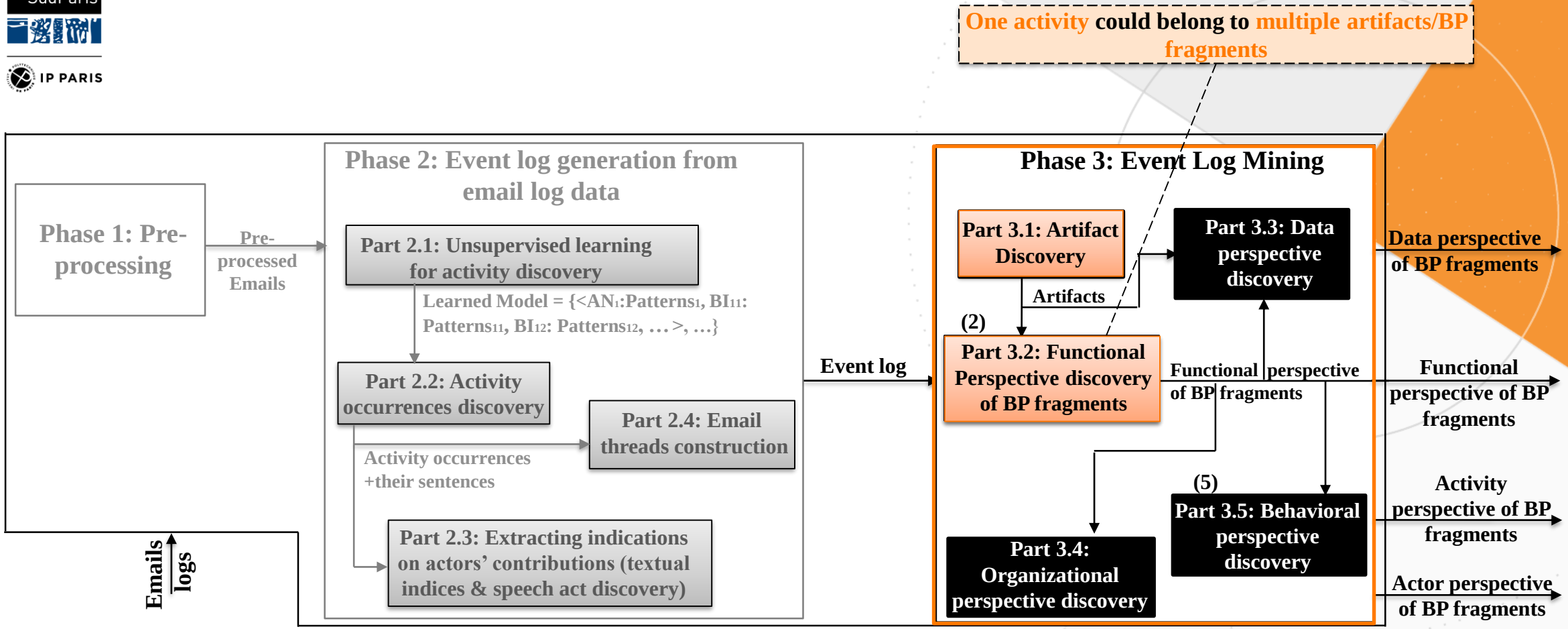
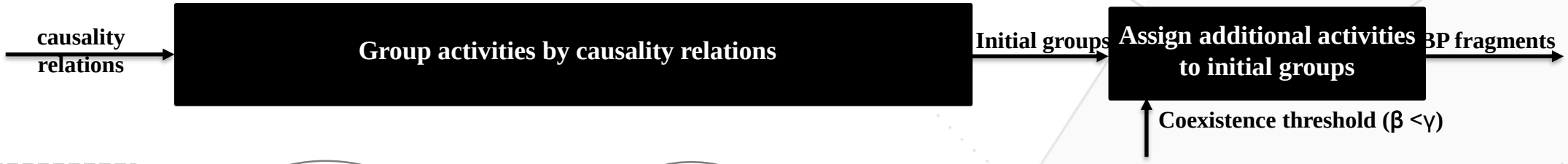


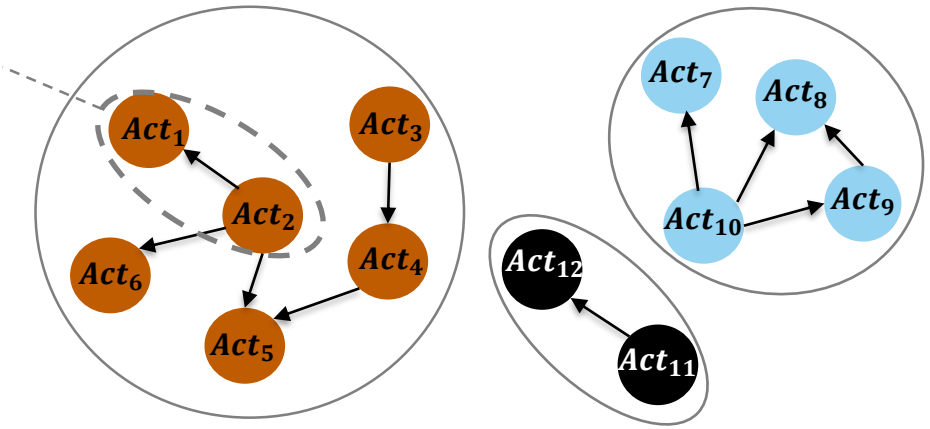
BP FRAGMENT DISCOVERY: MAIN ASSUMPTIONS & PROPOSITIONS

Assumption 1 : Each BP fragment differs from other ones by a set of causality relations between BP elements (i.e. activities, actors & artifacts)

Main Proposition: Discover causality relations between BP elements as a first step towards grouping activities into BP fragments

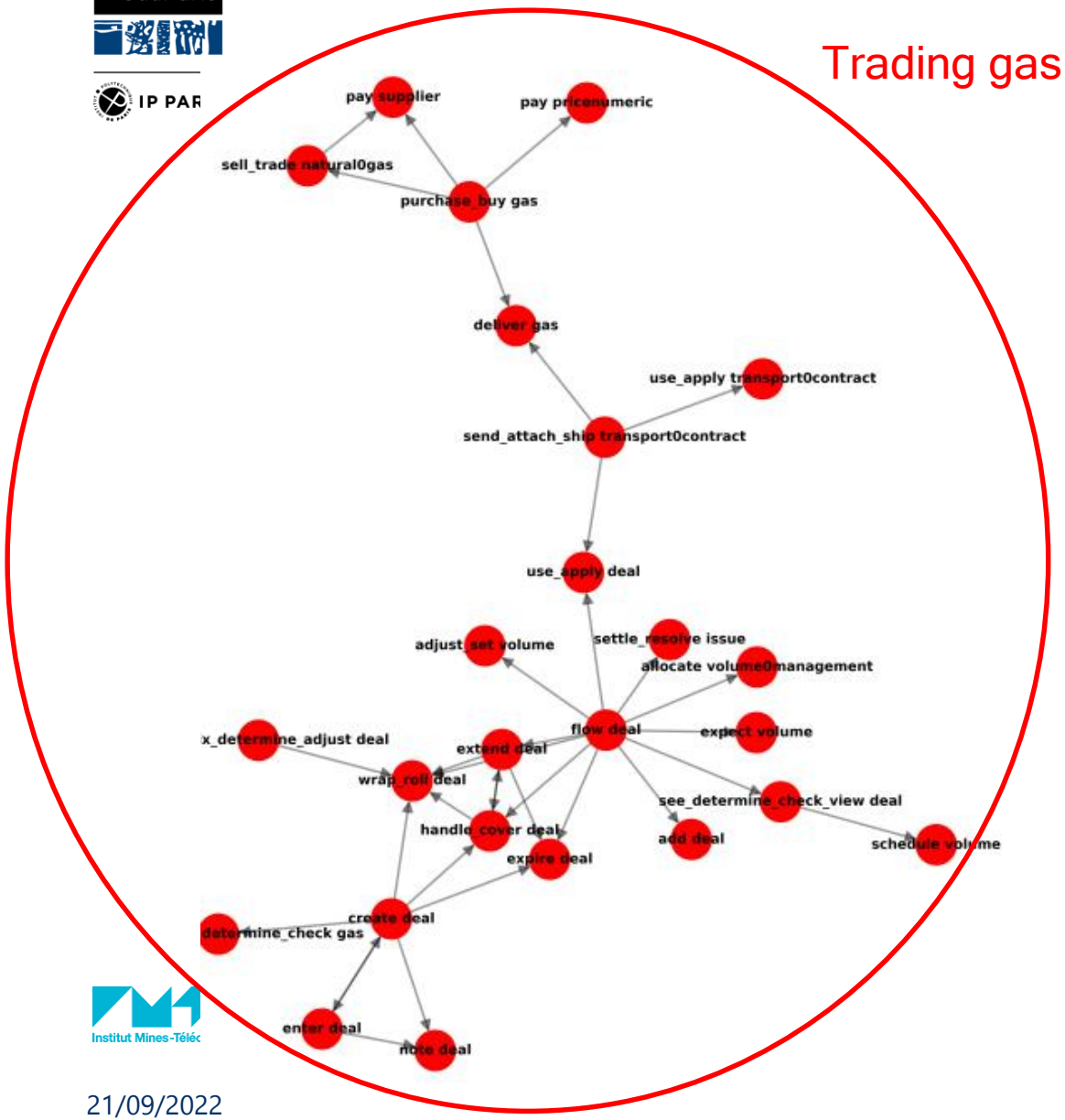


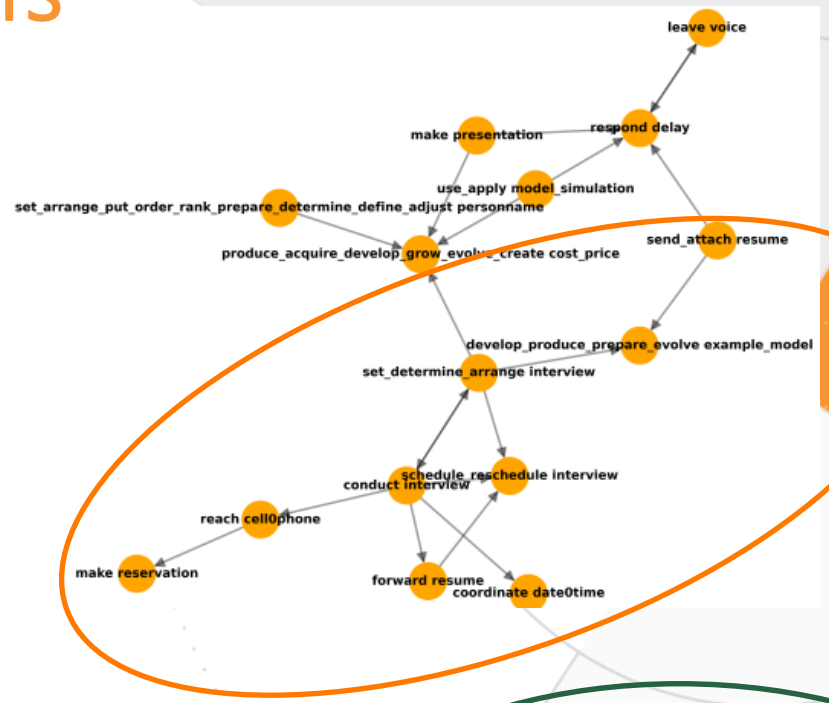
Act_i & Act_j must have causality relations referring to common BC and actor groups



BP FRAGMENT DISCOVERY: RESULTS

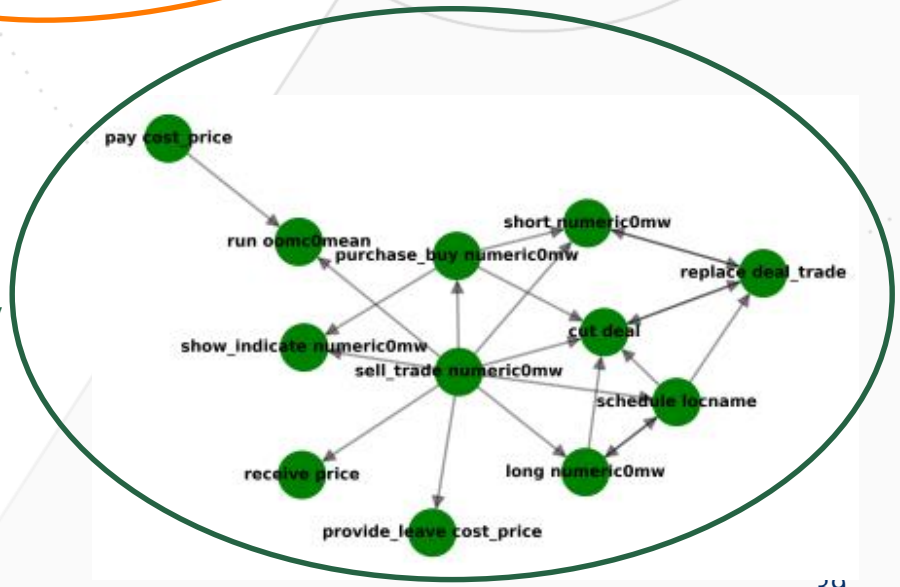
Trading gas



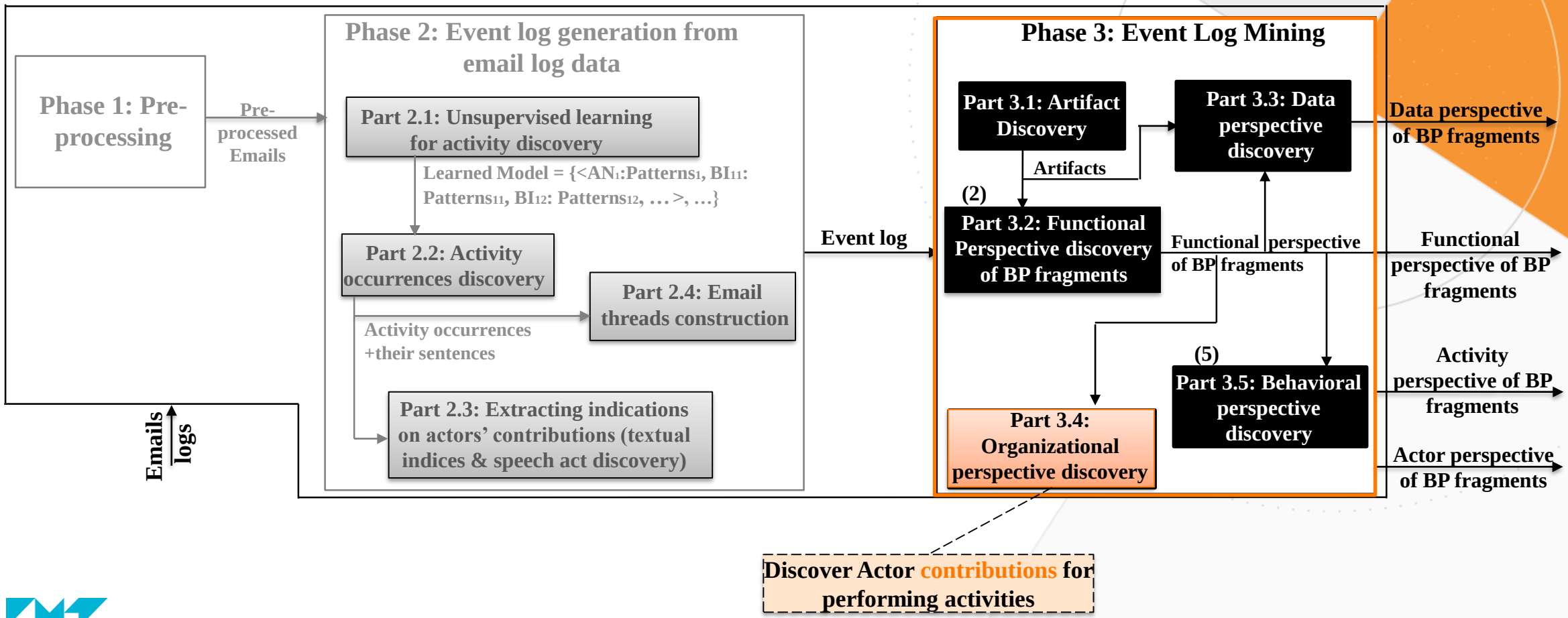


Organizing Interviews

Trading Electricity Power

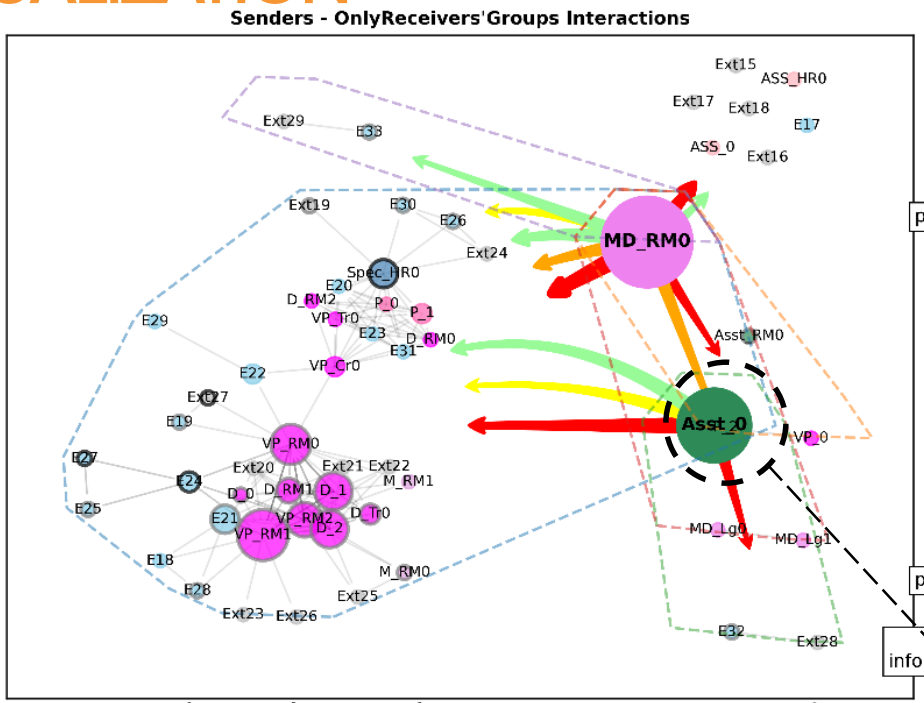


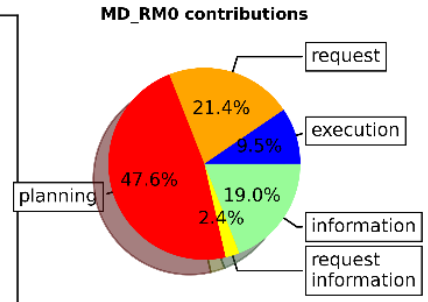
EVENT LOG MINING: APPROACH OVERVIEW

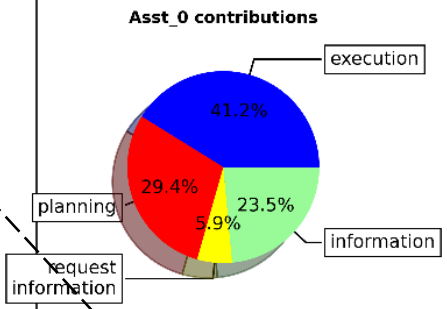


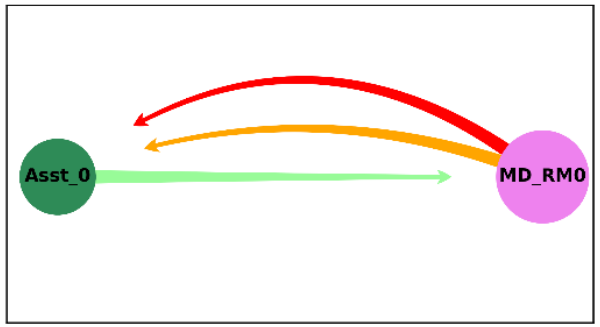
ORGANIZATIONAL PERSPECTIVE DISCOVERY: EXAMPLE OF VISUALIZATION

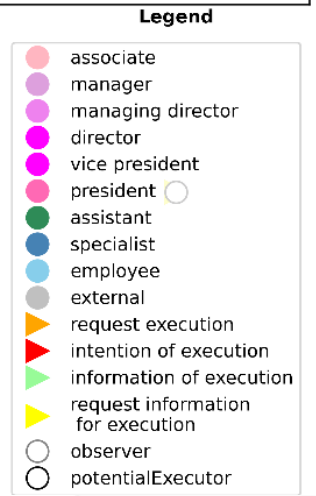
Organizational perspective of the activity set_determine_arrange interview





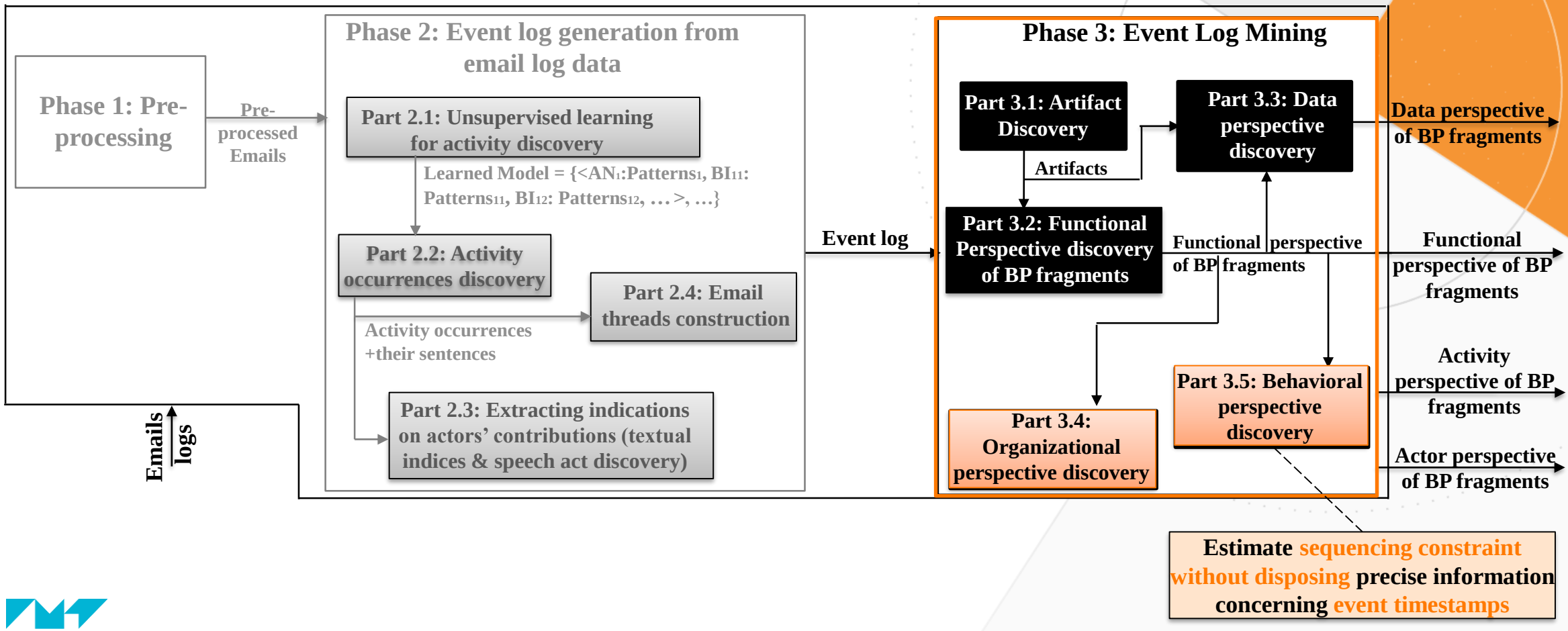






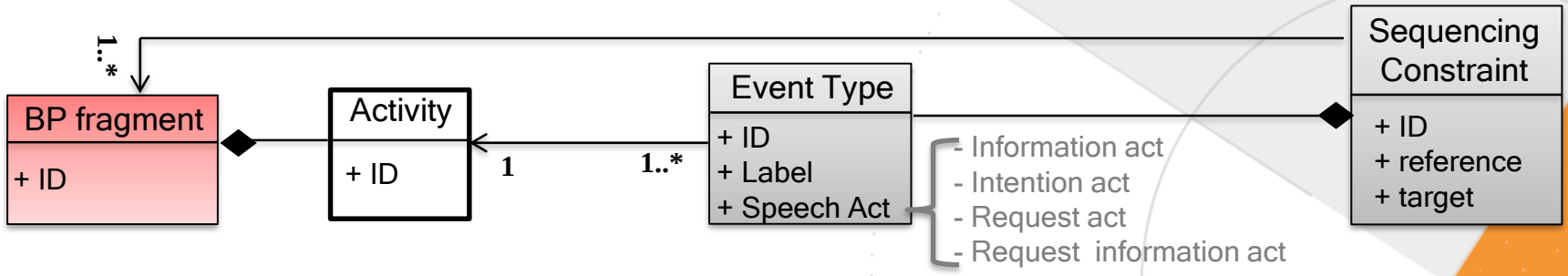
- Node size~Number of sent/received emails
- Node color ~ Actor Organizational role

EVENT LOG MINING: APPROACH OVERVIEW



BEHAVIORAL PERSPECTIVE: DEFINITION

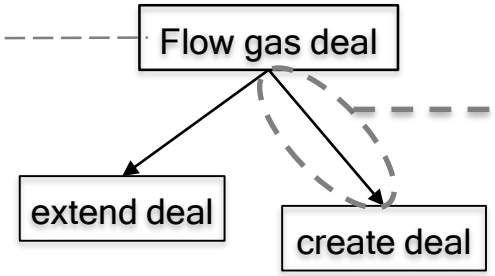
Main Entities



Behavioral Models

Activity Model

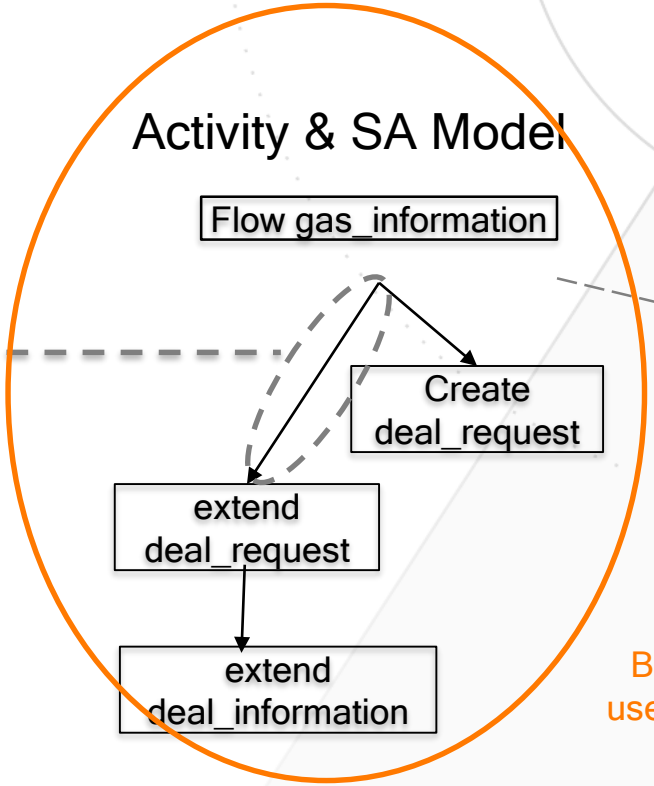
Activity event type
i.e. execution of one activity included in the email



=> event timestamp ≠ email timestamp

Sequencing constraints

Activity & SA Model



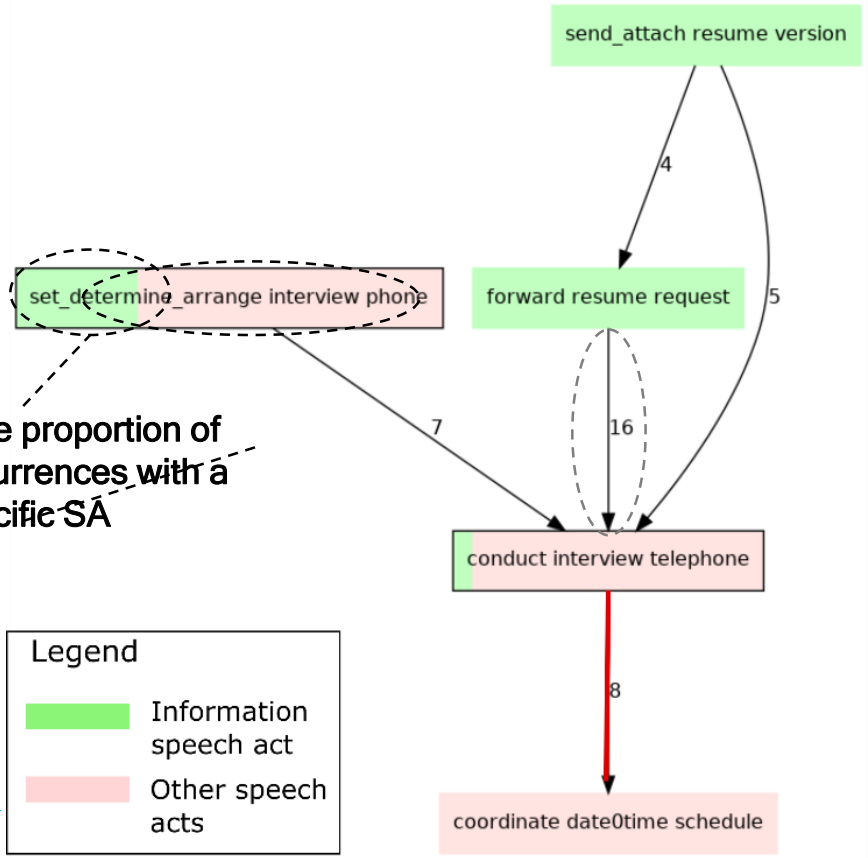
Activity & SA event type
i.e. sending an email containing the activity expressed with a specific speech act

=> event timestamp = email timestamp

Better reflects how emails are used in the context of performing BP

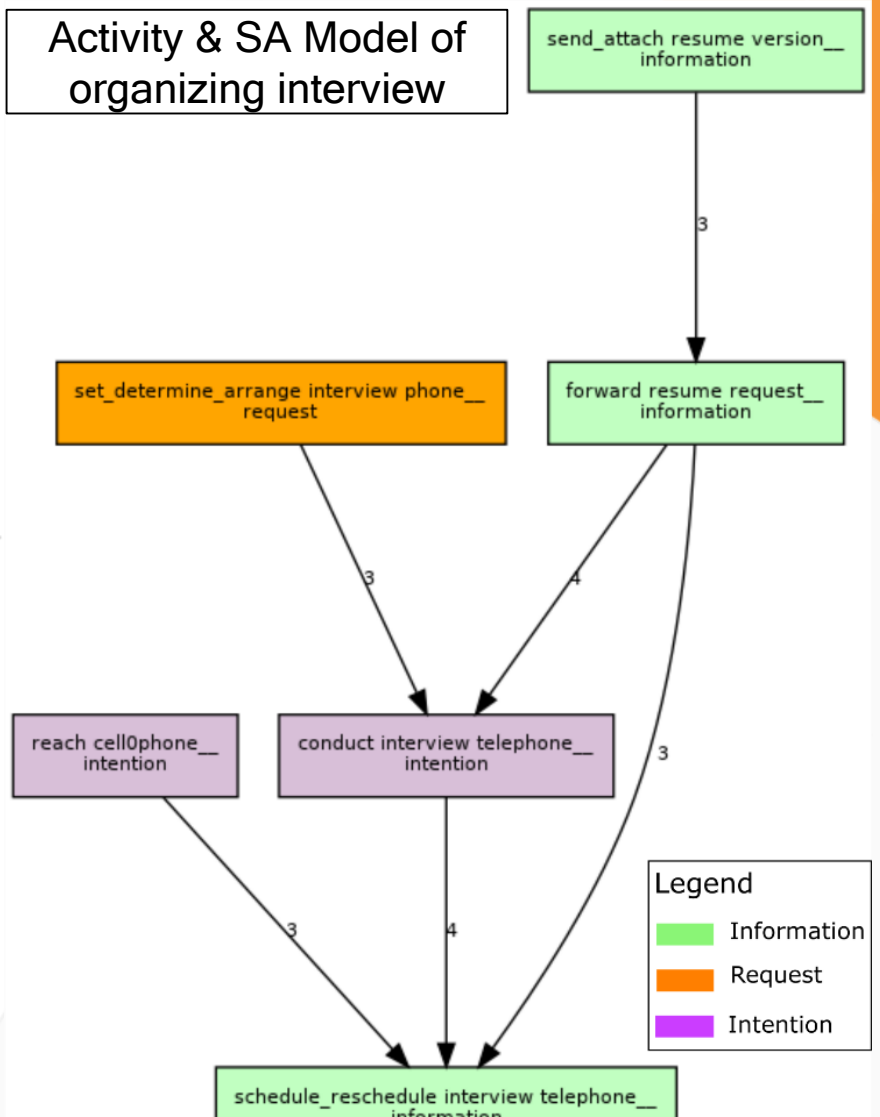
BEHAVIORAL PERSPECTIVE: VISUALIZATION EXAMPLES

Activity Model of the BP fragment organizing interview



Reflects the proportion of activity occurrences with a specific SA

Activity & SA Model of organizing interview



EVENT LOG GENERATION: EVALUATION DATASET

- Size: 7056 emails from the public Enron dataset
- Dataset composition: Emails of employees having different organizational and business roles collected in the way that they form actor groups

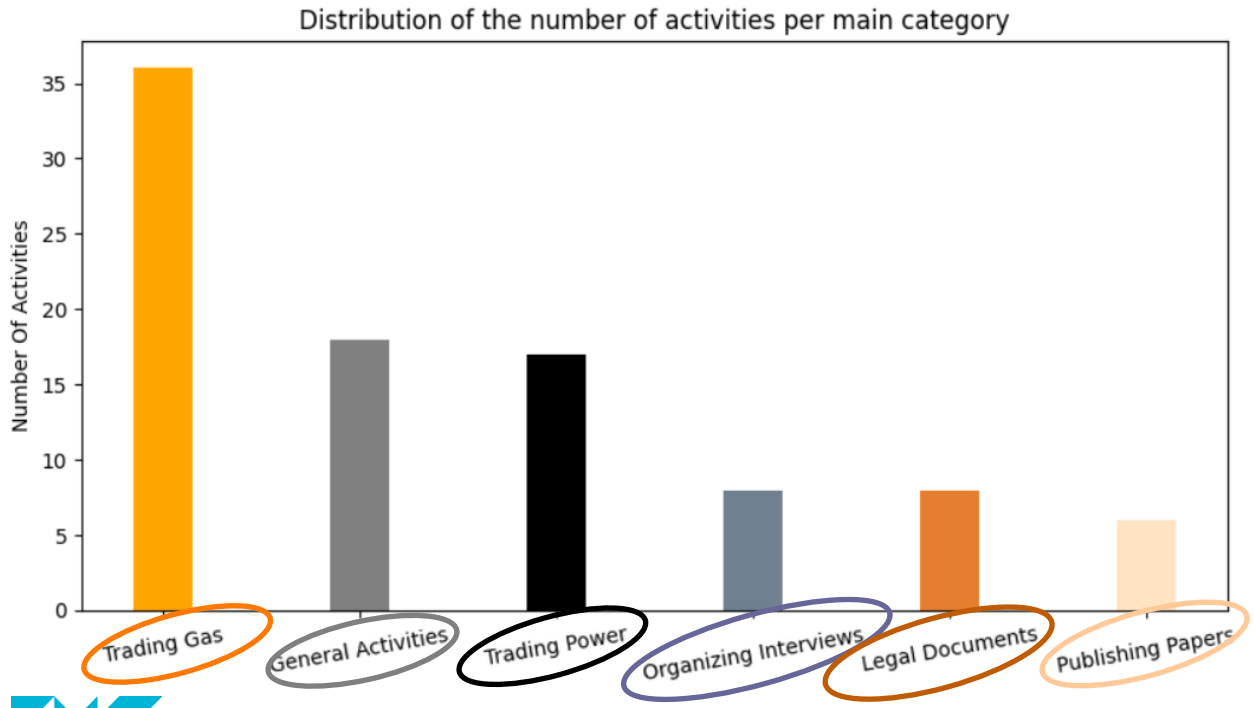
Organizational roles of employees

Business roles of employees

Ep	*OR*	*BR*	N_{em}	N_{emRe}	N_{Re}	N_{emTh}	N_{reTh}
E1	Managing Director	Trading	343	421	18	1180	95
E2	Senior Counsel	Legal	102				
E3	Managing Director	Risk	2283	504	8		
E4	Assistant	Management	357				
E5	Manager	Logistics	738	682	31		
E6	Specialist	Settlements	108				
E7	Specialist	Logistics	100				
E8	Employee	Employee	158				
E9	Specialist	Logistics	80				

EVENT LOG GENERATION: OVERVIEW ON THE DISCOVERED ACTIVITIES FROM THE EMAILS OF THE 9 EMPLOYEES

- Total number of discovered activities: 102
- % of Relevant activities: 93 %
- Example of activities (see the following table)
- Main categories:



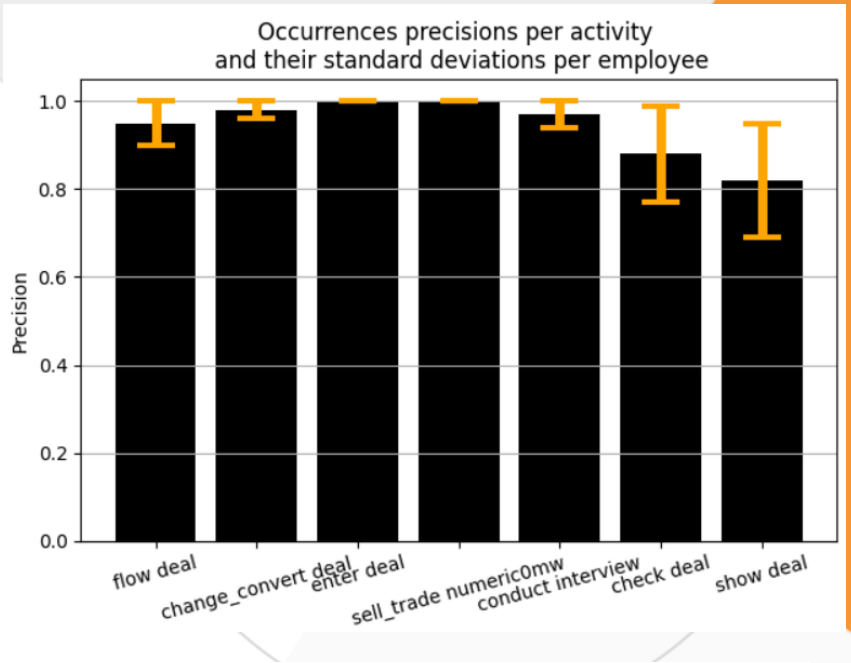
ID	Activity	N_{Occ}
1	*flow deal{gas}*	189
4	*create deal{numeric}{ticket}*	113
5	*sell_trade numeric0mw{pricenumeric}*	99
7	*conduct interview{telephone}{informal}*	93
8	*extend deal{numeric}{rest}*	90
10	*send_attach resume{version}{electronic*	81
12	*purchase_buy gas{plant}*	69
15	*set_determine_arrange interview{phone}*	60
20	*send_attach_ship transport0contract{deal}{term}*	49
24	*sell_trade natural0gas{plant}*	41
29	*purchase_buy numeric0mw{pricenumeric}*	34
30	*make reservation{hotel}*	33
32	*long numeric0mw{hour0end*	27
35	*schedule_reschedule meeting{assistant}*	26
36	*send_attach info_information*	26
43	*attend meeting*	20
48	*deliver gas*	18
58	*write_publish book*	16
62	*short numeric0mw{he0numeric}*	14
79	*execute agreement*	10
91	*register conference*	9
95	*review comment*	8

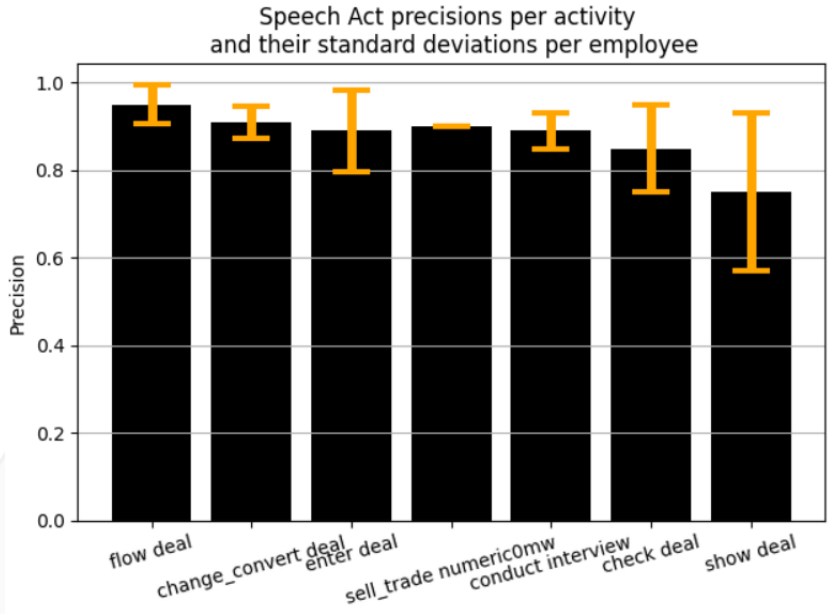
EVENT LOG GENERATION: EXPERIMENTS FOR EVALUATION

Experiment 2: Study the Overall Features of the generated event log

BP element	Number	Metric & Value
Activities	102	Relevance = 0.93
Activity occurrences	3102	Precision = 0.85
Speech acts	--	Precision = 0.88
Threads	1287	Consistency = 0.85
Relevant information values	194	

- It reflects to which degree each obtained thread refers to one instance;
- It corresponds to the average of the inverse number of the annotated instances per each obtained thread;





Research Problem

- **How to enable cognitive process analysis on email data?**

1. How to extract process related information from emails?

activities, actors, business artifacts, etc.

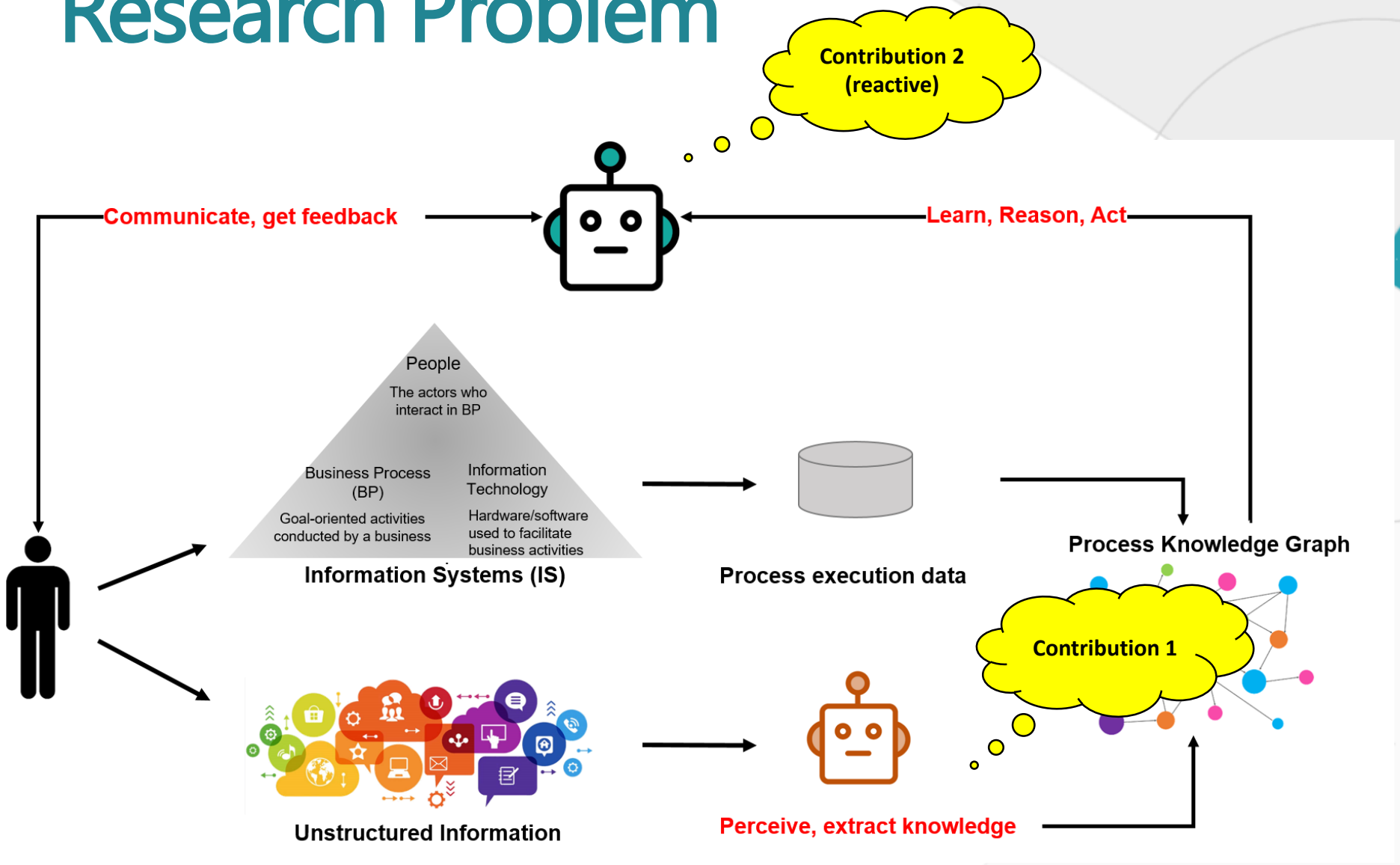
Contribution 1

3. How to assist end users in querying the process data?

Querying the process data should be accessible to business experts

Contribution 2

Research Problem



Research problem

- How to easily query the stored process data?

- Existing works can be categorized into:
  - **Rule-based approaches :**

    +Pros: Independent from training data + high generality and adaptability to new DB

    -Cons: Has its own assumption about the query, NL question and DB schema.
  - **Machine-learning approaches :**

    +Pros: Allows the user to express his question in NL with great flexibility.

    -Cons: This necessitates the use of training data, which is not always available.

We propose a hybrid NLI system that combines rule-based and machine learning approaches.

NL to cypher

- example

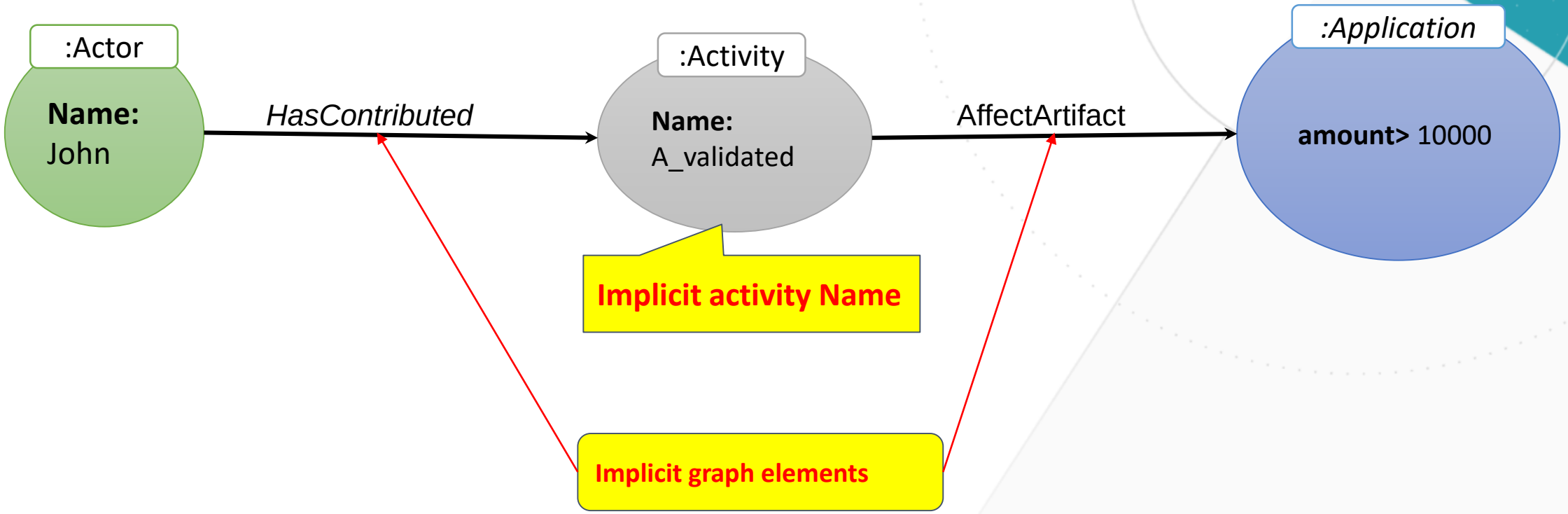
Applications with an amount greater than 10000 and validated by John

```
MATCH (actor: Actor)-[:HasContributed]-(activity: Activity),
      (activity)-[:AffectArtifact]-(application: Application)

WHERE actor.Name= 'JOHN' AND application.amount> 10000
      AND activity.Name= 'A_validation'

RETURN (application)
```

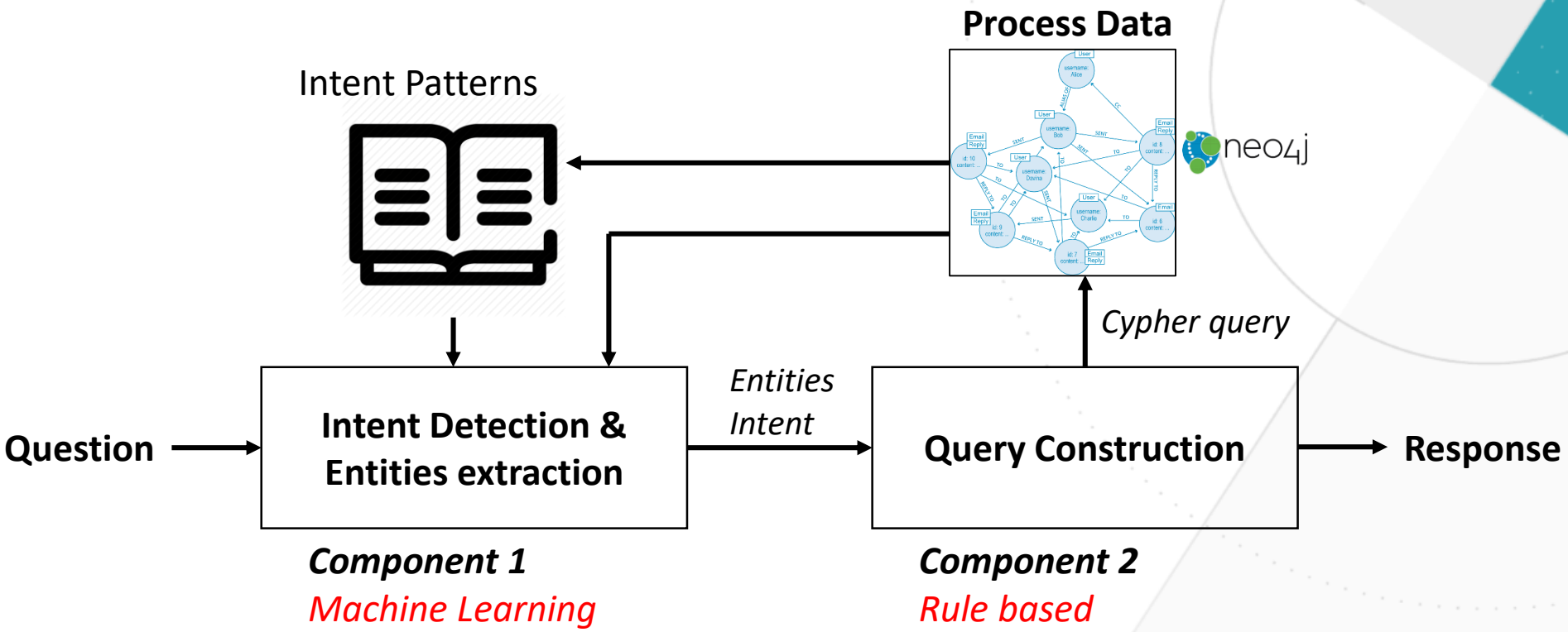
NL to cypher

- example

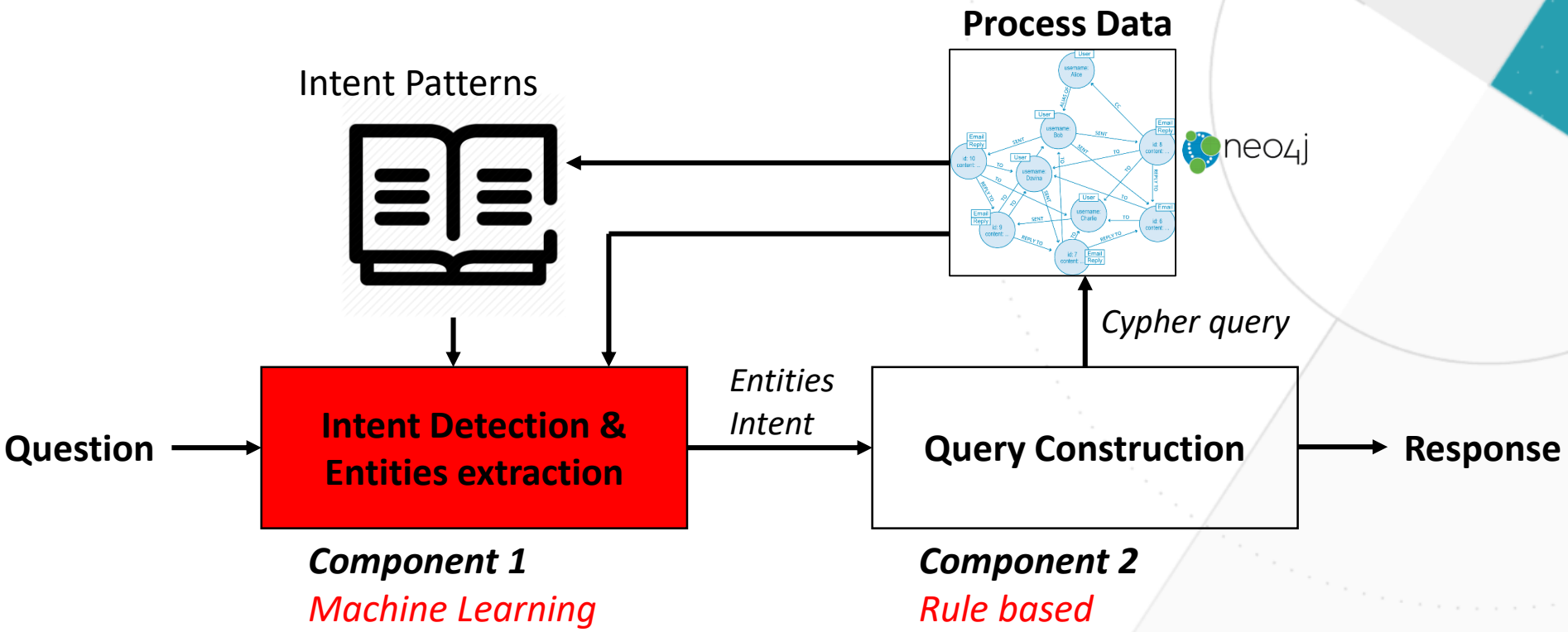
Applications with an amount greater than 10000 and validated by John



Bird's-eye view



Bird's-eye view



Component 1

- Intent detection

The intent describes the question purpose

- Minimal graph elements are required to construct the cypher query => **MATCH**
- What type of information should be returned => **RETURN**

We defined a set of intent patterns inferred from our meta-model

"Applications with an amount greater than 10000 and validated by John"

Application_AffectArtifact

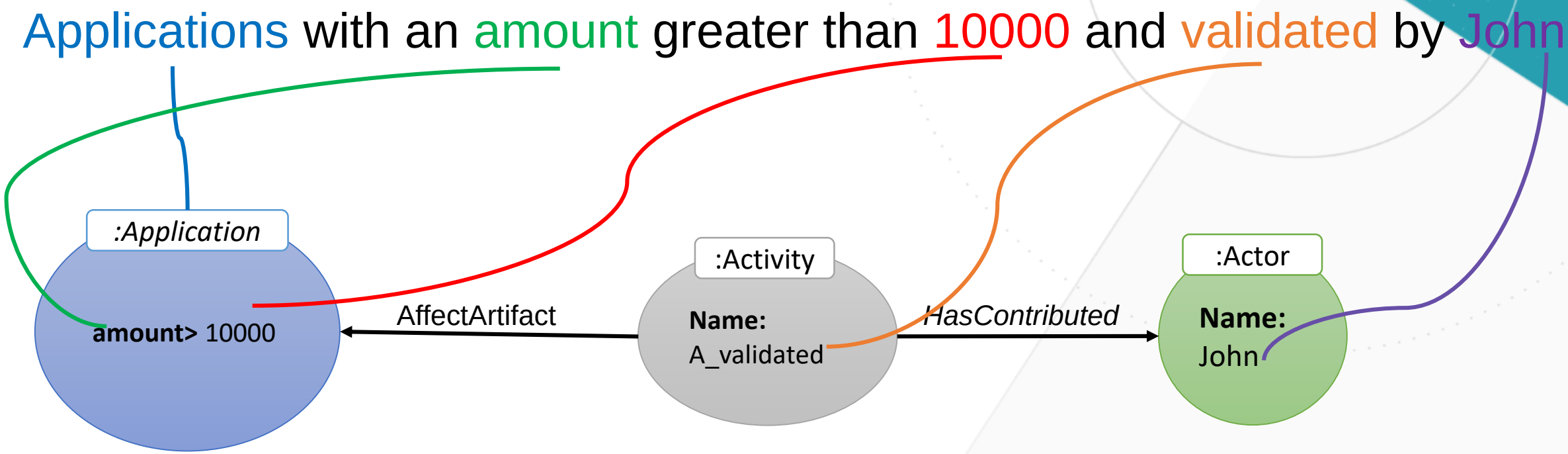
"How many tasks were executed today?"

Activity_Count

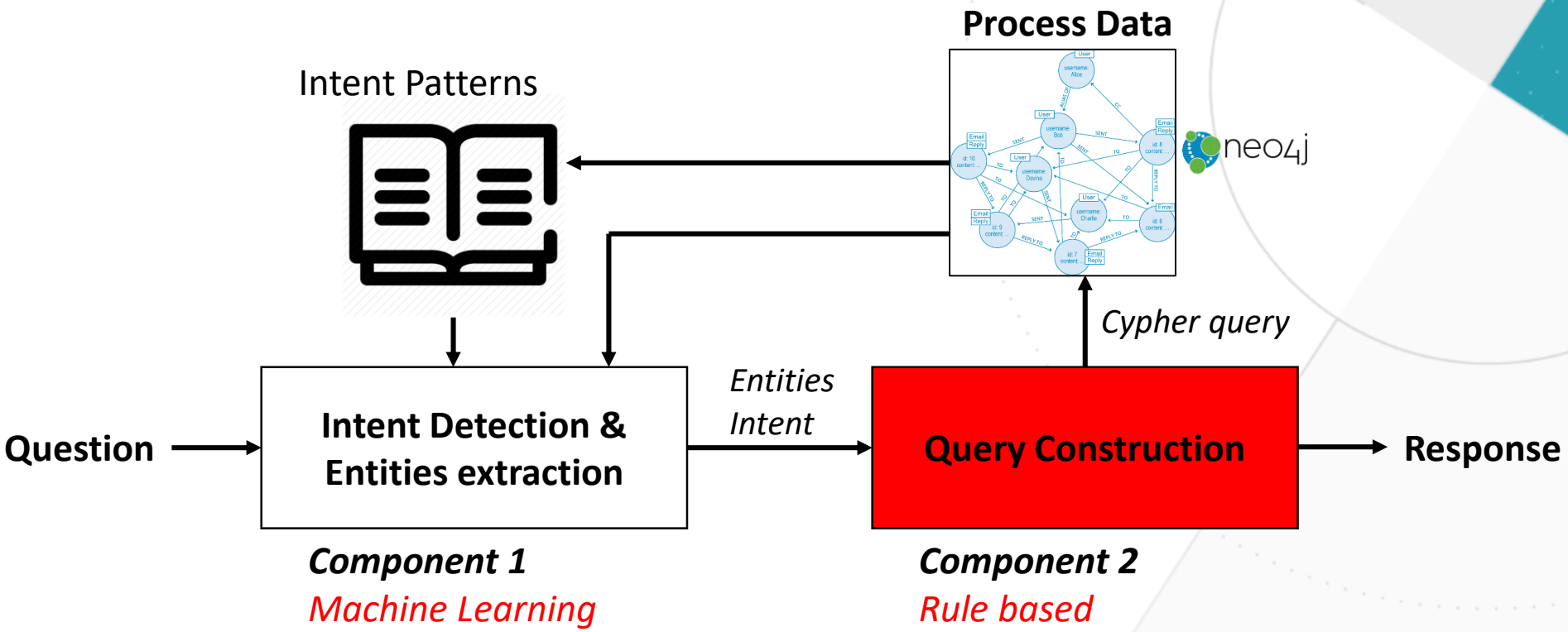
Component 1

- Entities Extraction

- Entities are words that appear in the question and should be mapped to the graph elements (nodes, relationships, attributes, values).



Bird's-eye view



Component 2

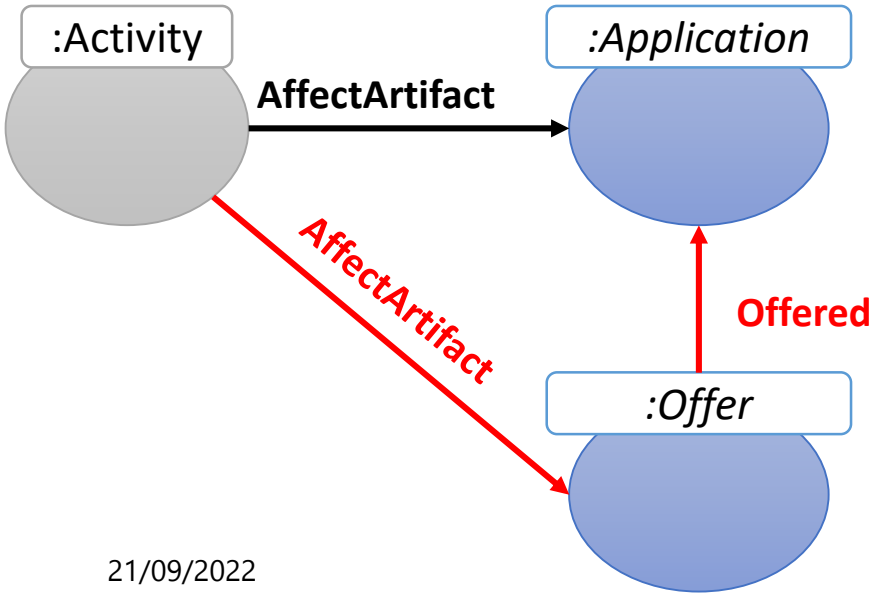
- Query construction

Application type | Activity Name | Date

Return all car loan applications validated within the last three months, and which received 3 offers minimum, order them by their requested amounts.

Number | Offer node | Application amount

- ***Intent:*** **Application_AffectArtifact**




```
MATCH (activity: Activity)-[:AffectArtifact]-(application: Application),
      (activity)-[:AffectArtifact]-(offer: Offer),
      (offer)-[:Offered]-(application)

RETURN (application)
```

Component 2

- Query construction

WHERE application.Type= 'Car' **AND** activity.Name='A_validated' **AND** activity.Time> 14-10-2021

Return all car loan applications validated within the last three months, and which received 3 offers minimum, order them by their requested amounts.

trigger word of greater than operator

WITH application, COUNT(offer) as offerCT

WHERE offerCT >=3

Component 2

- Query construction

Return all car loan applications validated within the last three months, and which received 3 offers minimum, order them by their requested amounts.

trigger word of ORDER BY

Application amount

ORDER BY application.amount

Component 2

- Query construction

Return all car loan applications validated within the last three months, and which received 3 offers minimum, order them by their requested amounts.

```
MATCH (activity: Activity)-[:AffectArtifact]-(application: Application),
            (activity)-[:AffectArtifact]-(offer: Offer),
             (offer)-[:Offered]-(application)

WHERE application.Type= 'Car' AND activity.Name='A_validated'  AND    activity.Time> 14-10-2021

WITH application, COUNT(offer) as offerCT

WHERE offerCT >= 3

RETURN (application)

ORDER BY application.amount
```

Achievements : contribution 1

1) Formalize the definition of BP knowledge that could be discovered from emails
2) Introduce a totally unsupervised approach for BP fragment discovery w.r.t multiple perspectives

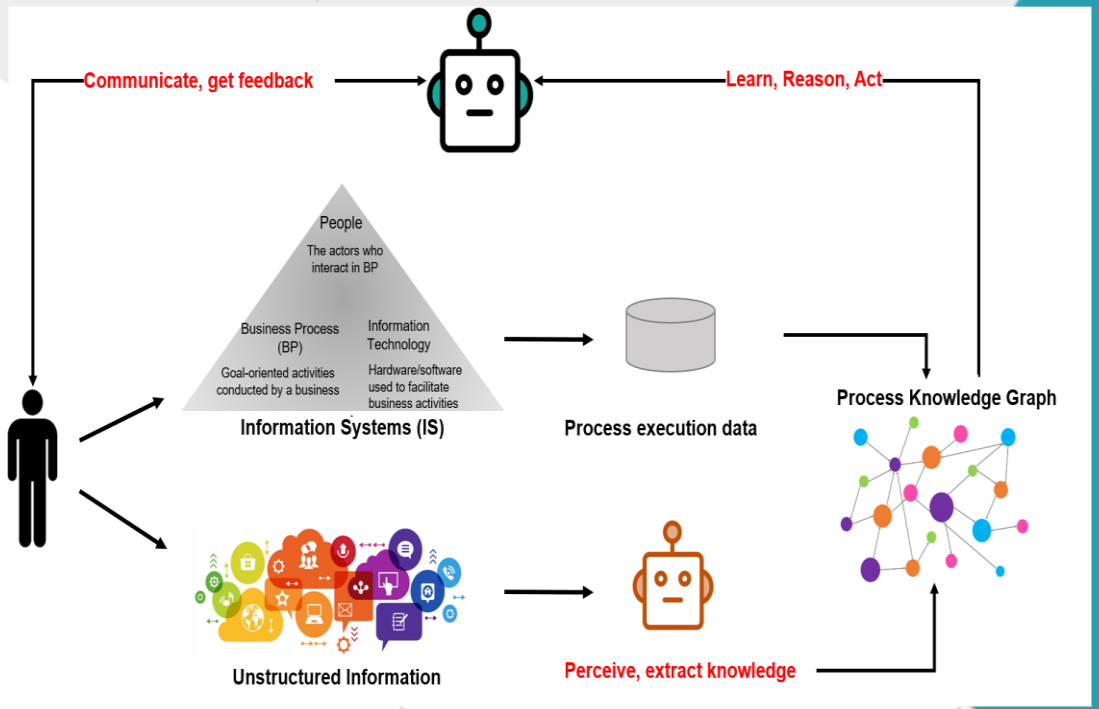
- Without requiring priori information concerning BP knowledge in emails => minimize human intervention

- Composed of several algorithmic solutions for event log generation & event log mining:
  - Introduce a learning solution for activity discovery from emails based on discovering low dispersed patterns of concepts & grouping patterns without requiring the prior definition of the number of activities
  - Rely on overlapping grouping of activities to discover artifacts & BP fragments (Data and Function perspectives)
  - Discover actor contributions when performing activities (Organizational perspective)
  - Estimate the event sequencing constraints in the absence of precise information concerning event timestamps (Behavioral Perspective)
- Validated using the public dataset Enron while sharing the obtained results to ensure a type of comparison with existing works

Achievements : contribution 2

- We proposed an intent-based NLI for querying process execution data.
  - facilitates the querying activity by understanding and interpreting the intent of the user from a natural language question,
  - constructs automatically the corresponding Cypher query to be executed over the process data stored in a graph database, and returning the answer
  - Validated using the public a real-life event log from BPIC’17.

Conclusion



- Cognitive Process Analytics system that understands, reasons, discovers actionable insights and interacts
- Where we are today

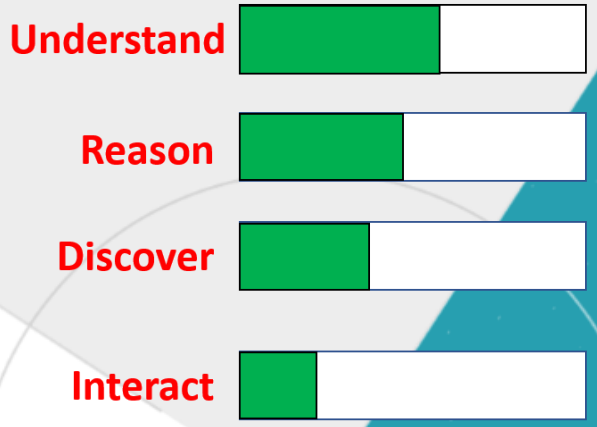
Understand — **Operationalize structured/unstructured data, feed into process knowledge graphs**

Reason — **Reason over knowledge graphs** (recent efforts by the community to enable process analytics on knowledge graphs)

Discover — **Reactive and proactive bots**

Interact — **See, talk and hear** (we are still in the beginning)

Research directions



- Enrich process knowledge graphs
  - Currently we capture information at the instance level
  - Add and connect extra layers (process, system, organization, etc.)
- Develop reasoning approaches over enriched knowledge graphs
- From reactive to proactive conversational bots
  - Current work on analyzing received emails and generating response templates

Email answering from process perspective

- An RPA approach to automate the generation of email replies when performing processes within emailing systems.

Goal:

- help employees access process oriented knowledge included in emails
- assist them in performing their repetitive process activities.

The provided recommendations are mainly:

1. Email responses templates,
2. The related process knowledge:
    - activities of emails responses,
    - speech acts,
    - the related business data values

References

[1] M.E et al., **Discovering Activities from Emails Based on Pattern Discovery Approach.** BPM (Forum) 2020: 88-104

[2] M.E et al., **Discovery of Activities' Actor Perspective from Emails based on Speech Acts Detection.** ICPM 2020: 73-80

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[4] M.E et al., Discovering Business Processes And Activities From Messaging Systems: State-Of-The Art. WETICE 2020: 137-142

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[6] N.L, M.E et al., **Emails Analysis for Business Process Discovery.** ATAED@Petri Nets/ACSD 2019: 54-70

[7] M. K, et al.: **An Intent-Based Natural Language Interface for Querying Process Execution Data**. ICPM 2021: 152-159

THANK YOU