OCEL Feature Extraction Documentation

November 2021 - ??? 2022

Contents

1 Document Format

The structure section will go over all the structures that are created in order for many of the feature extraction methods to function. Each structure will have information on input, context behind the structure and a sample image to demonstrate the output on a basic example.

The Feature sections go over feature extraction methods explored throughout the thesis on the topic. All features are aimed at being very general, applicable to any input ocel log. The descriptions will include the input, structures used, output, context and, if required, a very small basic visualization based on the examples that are found in the structures section.)

2 Example OCEL

The following log was taken from ... and will be used for the majority of examples in this document. Of course this log is very basic and will therefore not cover all edge cases that can occur in ocel logs. However, using the log, I hope to show the intuition of all structures and feature extraction methods.

Event identifier	Activity name	Timestamp	Objects involved			
			Order	Item	Package	Route
...	...	...	...	...	...	...
9911	*place_order*	20-7-2019:08.15	$\{o_1\}$	$\{i_1, i_2\}$	$\emptyset$	$\emptyset$
9912	*check_availability*	20-7-2019:09.35	$\emptyset$	$\{i_1\}$	$\emptyset$	$\emptyset$
9913	*place_order*	20-7-2019:09.38	$\{o_2\}$	$\{i_3, i_4, i_5\}$	$\emptyset$	$\emptyset$
9914	*check_availability*	20-7-2019:10.20	$\emptyset$	$\{i_2\}$	$\emptyset$	$\emptyset$
9915	*pick_item*	20-7-2019:11.05	$\emptyset$	$\{i_1\}$	$\emptyset$	$\emptyset$
9916	*check_availability*	20-7-2019:11.19	$\emptyset$	$\{i_3\}$	$\emptyset$	$\emptyset$
9917	*pick_item*	20-7-2019:11.55	$\emptyset$	$\{i_3\}$	$\emptyset$	$\emptyset$
9918	*check_availability*	20-7-2019:13.15	$\emptyset$	$\{i_4\}$	$\emptyset$	$\emptyset$
9919	*pick_item*	20-7-2019:14.25	$\emptyset$	$\{i_4\}$	$\emptyset$	$\emptyset$
9920	*check_availability*	20-7-2019:15.25	$\emptyset$	$\{i_5\}$	$\emptyset$	$\emptyset$
9921	*check_availability*	20-7-2019:16.34	$\emptyset$	$\{i_2\}$	$\emptyset$	$\emptyset$
9922	*pick_item*	20-7-2019:16.38	$\emptyset$	$\{i_2\}$	$\emptyset$	$\emptyset$
9923	*pack_items*	20-7-2019:16.44	$\emptyset$	$\{i_1, i_2, i_3\}$	$\{p_1\}$	$\emptyset$
9924	*store_package*	20-7-2019:16.55	$\emptyset$	$\emptyset$	$\{p_1\}$	$\emptyset$
9925	*start_route*	20-7-2019:16.56	$\emptyset$	$\emptyset$	$\emptyset$	$\{r_1\}$
9926	*load_package*	21-7-2019:08.00	$\emptyset$	$\emptyset$	$\{p_1\}$	$\{r_1\}$
9927	*send_invoice*	21-7-2019:08.17	$\{o_1\}$	$\emptyset$	$\emptyset$	$\emptyset$
9928	*place_order*	21-7-2019:08.25	$\{o_3\}$	$\{i_6\}$	$\emptyset$	$\emptyset$
9929	*failed_delivery*	21-7-2019:08.33	$\emptyset$	$\emptyset$	$\{p_1\}$	$\{r_1\}$
9930	*unload_package*	21-7-2019:08.56	$\emptyset$	$\emptyset$	$\{p_1\}$	$\{r_1\}$
9931	*end_route*	21-7-2019:09.15	$\emptyset$	$\emptyset$	$\emptyset$	$\{r_1\}$
9932	*check_availability*	21-7-2019:10.25	$\emptyset$	$\{i_6\}$	$\emptyset$	$\emptyset$
9933	*receive_payment*	21-7-2019:11.55	$\{o_1\}$	$\emptyset$	$\emptyset$	$\emptyset$
9934	*check_availability*	22-7-2019:08.19	$\emptyset$	$\{i_5\}$	$\emptyset$	$\emptyset$
9935	*pick_item*	22-7-2019:08.44	$\emptyset$	$\{i_5\}$	$\emptyset$	$\emptyset$
9936	*send_invoice*	22-7-2019:08.55	$\{o_2\}$	$\emptyset$	$\emptyset$	$\emptyset$
9937	*receive_payment*	22-7-2019:09.15	$\{o_2\}$	$\emptyset$	$\emptyset$	$\emptyset$
9938	*check_availability*	22-7-2019:10.35	$\emptyset$	$\{i_6\}$	$\emptyset$	$\emptyset$
9939	*pick_item*	22-7-2019:11.23	$\emptyset$	$\{i_6\}$	$\emptyset$	$\emptyset$
9941	*pack_items*	23-7-2019:09.11	$\emptyset$	$\{i_4, i_5, i_6\}$	$\{p_2\}$	$\emptyset$
9942	*send_invoice*	22-7-2019:11.45	$\{o_3\}$	$\emptyset$	$\emptyset$	$\emptyset$
9943	*store_package*	23-7-2019:09.19	$\emptyset$	$\emptyset$	$\{p_2\}$	$\emptyset$
9944	*start_route*	23-7-2019:09.28	$\emptyset$	$\emptyset$	$\emptyset$	$\{r_2\}$
9945	*load_package*	23-7-2019:10.05	$\emptyset$	$\emptyset$	$\{p_1\}$	$\{r_2\}$
9946	*load_package*	23-7-2019:10.09	$\emptyset$	$\emptyset$	$\{p_2\}$	$\{r_2\}$
9947	*deliver_package*	23-7-2019:11.25	$\emptyset$	$\emptyset$	$\{p_2\}$	$\{r_2\}$
9948	*deliver_package*	24-7-2019:09.37	$\emptyset$	$\emptyset$	$\{p_1\}$	$\{r_2\}$
9949	*end_route*	24-7-2019:09.48	$\emptyset$	$\emptyset$	$\emptyset$	$\{r_2\}$
9950	*receive_payment*	24-7-2019:09.55	$\{o_3\}$	$\emptyset$	$\emptyset$	$\emptyset$
...	...	...	...	...	...	...

Figure 1: Simple example log

3 Structures

3.1 Object-Based

3.1.1 Object Interaction Graph

Description - This *undirected* graph simply places all objects on the graph as *nodes* and assigns *edges* based on whether an object interacted in the same event as the other.

Context - The goal of this graph is to provide a base graph that allows relationships between objects to be explored.

Strengths

1. Very simple
2. Allows for initial relationships between all objects

limitations

1. Very high number of edges
2. An object that interacts a lot with a target object is displayed the same as an object with very few interaction

Visual example

3.1.2 Object Descendant Graph

Description - This *directed* graph places all objects on the graph as *nodes* and assigns *edges* based on whether an source object participated in the event where the target object participated in its first event. Note that this also means that objects that were created in the same event are descendants of each other.

Context - The goal of this graph is to take advantage of the time dimension in order to separate objects from each other. This helps greatly reduce the degree of each of the nodes.

Strengths

1. More focussed graph on objects that are related by the time dimension.
2. Direction adds ability to easily segment further (via connectedness) and find independence between objects.
3. Allows for disconnected subgraphs

limitations

1. Ignores object relationships related to frequency of interaction with each other.

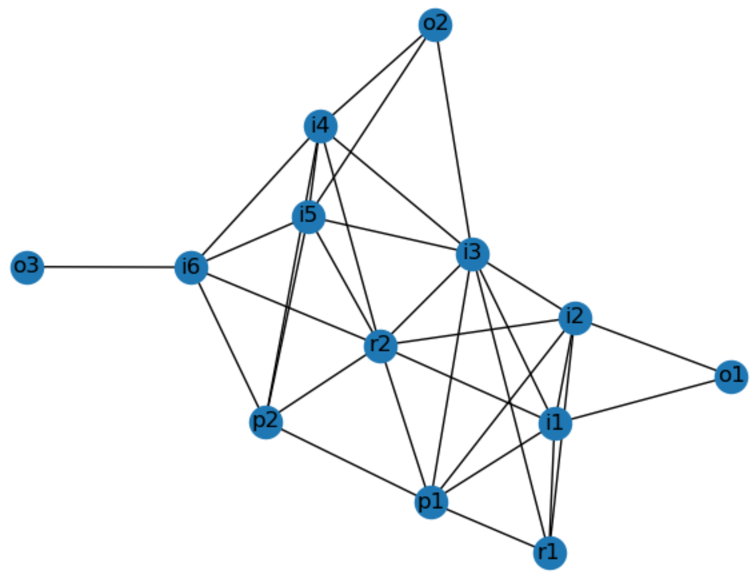


Figure 2: Example of an Object Interaction Graph

2. Can cause many objects to have no edges.
3. General objects (eg. SYSTEM user) will have a very large descendants list.)

Visual example

3.2 Object Lineage Graph

Description - The Object Lineage Graph is a representation of the entire object space of the event log in terms of a directed, labelled property graph. It is a natural progression of the object and descendants graphs in terms of defining each of the edges that exist in terms of a well defined property label graph. This can be formally defined by using triplets where a relationship gets defined by a source, relation, target. ie. (source_obj, relation, target_obj)
Context - The goal of this graph is to use the information gained from the ocel log on top of the object relation graph in order to separate and define the edges such that they can be handled differently. Also if the main focus of a feature is specific to a few types of relations, the remaining relations can be ignored. TOCONSIDER: add relations w.r.t the finishing event? Let users define a relationship based on certain event? Does it make sense to define an ontology?
Strengths

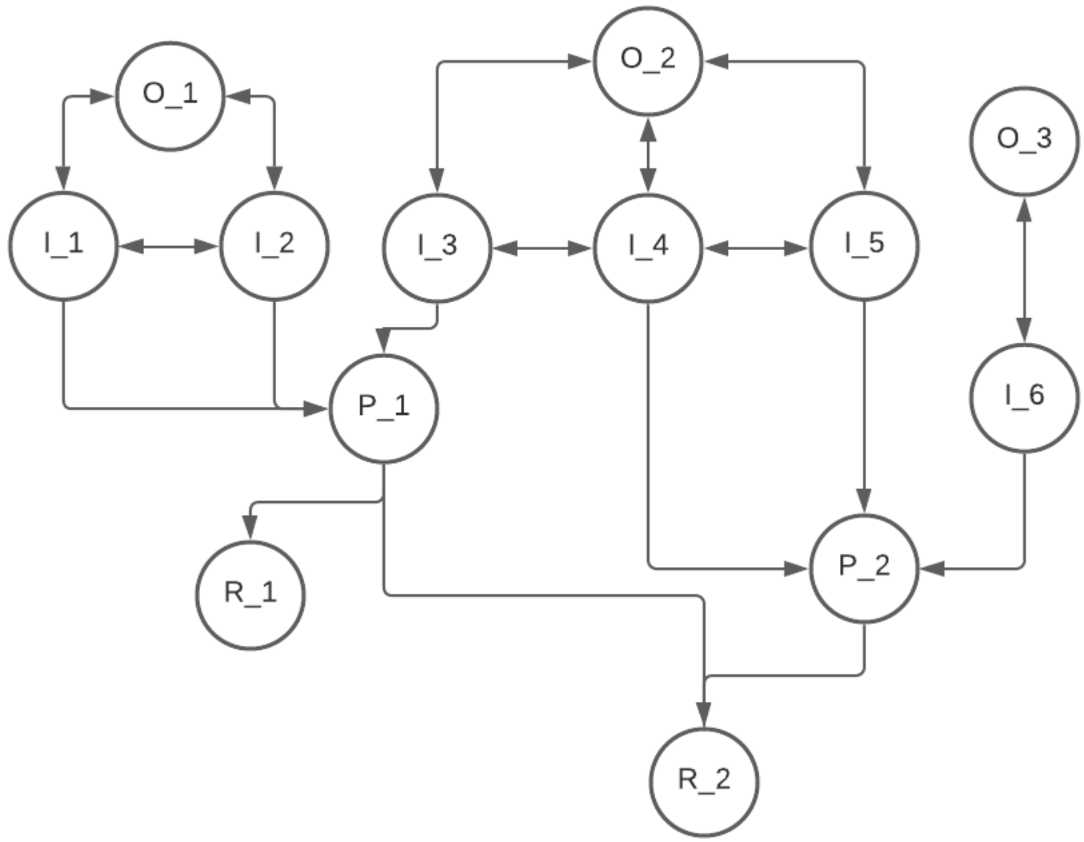


Figure 3: Example of an Object Descendant Graph

1. Allows for the generation of the graph to be completed through 1 iteration of the ocel log.
2. Allows for full use of the edges that exist in the entire ocel log.
3. Allows for separation and filtering of particular relations.
4. Creates a hierarchy of relations between objects in terms of "closeness" or "relatedness" to each other.
5. Very simple to parallelize the generation of the graph by prioritizing the edges found at the earliest stage.

Limitations

1. The graph only takes into account the relations with respect to object generation.

2. As the relations are mainly defined by the starting event, relations with respect to all other events are listed under "unrelated" which may not be the case.

Visual Example

4 Relationships

hint: I wrote context and the definitions for some of the relationships to gauge the correctness of them before fully committing to writing it for all of them. Let me know if they are ok like that!

4.1 Math extra prerequisites

hint: in addition to the standard ocel definitions

$$OE(o) = \{e \in E \mid o \in \pi_{omap}(e)\}$$

4.2 Interaction

Description - The most basic type of relationship. The interaction relationship is applied when an object interacts in the same event as the other. In a directed graph, the arc goes both ways.

Context - The relationship gives a very basic ability to see which objects interact with which. Objects that do not interact with each other *directly* could still affect them *indirectly*.

Definition -

$$REL_{interacts}(o_1, o_2) = \begin{cases} 1 & \exists e \in OE(o_1)\colon o_2 \in \pi_{omap}(e) \\ 0 & \text{else} \end{cases} \tag{1}$$

4.3 Descendants/Ancestors

Description - An object o_1 is a descendant of another if the other object o_2 is an ancestor of the object. An ancestor means that the object participated in the event where the descendant is first seen in the log. The only exception being when both objects start with the same event.

Context - Object descendants and ancestors show a type of lineage within the object space. It shows which objects were the input and output and extracts implicit knowledge of what is required for each type of process instance on an object level.

Definition -

4.4 Co-Birth

Description - Two objects have the co-birth relation with each other when both have the same starting event.

Context - The co-birth relationship extracts knowledge regarding which objects are necessary to create in the same event. It can for example be used to find events which act as a factory for new objects along with providing all the additional information that relates the new objects.

Definition -

4.5 Co-Death

Description - Two objects have the co-birth relation with each other when both have the same ending event.

Context - The co-death relationship is the obvious successor to the co-birth relationship. It provides the same sort of information except for the context being geared more towards which events consume and kill many objects at once.

Definition -

4.6 co-life

Description - co-life is a more restrictive version of co-birth and co-death as it provides a relationship where objects have the exact same event lifecycle.

Context - The co-life relationship is the strongest kind of dependence relationship that exists. It highlights objects that participate in every event together from the start to the end. The relationship can portray redundancy in the events that allow for objects to fail without reducing the performance.

Definition -

4.7 Merge

Description - An object o_1 merges with object o_2 if both objects are of the same type, o_2 participates in o_1's final event and o_2 still has future events.

Context - The merge relationship looks at intra-object-type relations and if they pass on their responsibilities to a different object of the same time. For example, if a user were to order two items in two separate orders, the orders may be merged with each other in order to simplify the shipping process.

Definition -

4.8 Inheritance (call this sacrifice?)

Description - An object o_1 inherits from object o_2 if the starting event of o_1 is the same as the ending event from o_2.

Context - This relationship shows which objects sacrifice themselves in order to create new object(s). This can be used for example in a manufacturing process where a copper object and a tin object can create a bronze object. After the event, the tin and copper no longer exist, but a new bronze object is created.

Definition -

4.9 Killer

Description - A killer object o_1 kills object o_2 if it participates in the last event of o_2 while not dying at the same time.

Context - As opposed to the Merge relationship, the killer relationship looks at inter-object-type interactions.

Definition -

$$REL_{killer}(o_1, o_2) = \begin{cases} 1 & end(o_2) \in OE(o_1) \wedge end(o_1) \neq end(o_2) \\ 0 & \text{else} \end{cases} \tag{2}$$

4.10 Peeler (Peels)

Description - An object o_1 peels o_2 when events between both objects are only executed between the two objects.

Context - The relationship can be useful for finding events in processes which are completely dependent on a small, very specific number of objects. It can also be an indicator that there is a lack of resources in a particular role or resources are collaborating very close with each other.

Definition -

$$REL_{peels}(o_1, o_2) = \begin{cases} 1 & \forall_{\{o_1, o_2\} \subseteq \pi_{omap}(e)} e \in OE(o_1) \colon \pi_{omap}(e) = \{o_1, o_2\} \\ 0 & \text{else} \end{cases} \tag{3}$$

4.11 Minion Object (MinionOf)

Description - An object o_1 is a minion of o_2 if all events participated by o_1 are also participated by o_2. o_2 must also have other events without o_1.

Context - The relationship can be useful for finding objects that are reliant on other objects to function. They are completely dependent on the activity of a different object. This can be used in eg. inefficiencies of a particular resource, not being able to act independently. It can also be used to see what each instance of a process explicitly requires in order to get a job done.

Definition -

$$REL_{minion}(o_1, o_2) = \begin{cases} 1 & OE(o_1) \subset OE(o_2) \\ 0 & \text{else} \end{cases} \tag{4}$$

5 Object Based Features

5.1 Point wise Features

This section includes features that are related to single objects. This means that each object produces its own vector which can be used for further computation.

5.1.1 Activity Existence

Property	Value
User Input	None
Structure Input	None
Output	OHE of activity names per object
Function Name	add_activity_existence

Context - The goal of this feature is to get a representation of which activities each object participates in. This gives an overall view of how an object participates does action in a log.

5.1.2 Object Lifetime

Property	Value
User Input	None
Structure Input	None
Output	uint64 seconds an object lived
Function Name	add_object_lifetime

Context - The goal of this feature is to understand how long an object was interacting in the system.

5.1.3 Object Unit Set Ratio

Property	Value
User Input	None
Structure Input	None
Output	float64 [0,1] ratio being a unit set in type
Function Name	add_obj_unit_set_ratio

Context - The goal of this feature is to understand what type of object it is. Whether it operates alone as a type (eg. Orders) or with many other of the same type (eg. items) throughout all events it takes part in.

5.1.4 Average number of other objects in Events

Property	Value
User Input	None
Structure Input	None
Output	float64 avg object interactions per event
Function Name	add_avg_obj_event_interaction

Context - The goal of this feature is to understand how social the object is with any other type of object while executing events.

5.1.5 Unique Neighbor Count

Property	Value
User Input	None
Structure Input	Object Graph
Output	uint64 number of neighboring objects
Function Name	add_unique_neighbor_count

Context - The goal of this feature is to understand with how many objects in total the target object is working with.

Visual example

5.1.6 Object Type Interaction Count

Property	Value
User Input	Object Type (Default: All)
Structure Input	Object Graph
Output	uint64 number for each input object type
Function Name	TBA

Context - The goal of this feature is to quantize to what type of objects the target object is interacting with in all events.

Visual example

5.1.7 starting or ending object

Property	Value
User Input	None
Structure Input	Object Lineage Graph
Output	bool for each column
Function Name	TBA

Context - The goal of this feature is to see whether the target object is a root or a leaf object. These bool values could add understanding to positioning in the lifecycle of a collection of objects.

Visual example need to update graph

5.1.8 Direct Object Descendants / Ascendants number

Property	Value
User Input	List of relationships
Structure Input	Object-Centric Multi Graph
Output	uint64 number for each relationship
Function Name	add_direct_rel_count

Context - The goal of this feature is to collect basic counting information for the number of times an object interacts in a particular way.

Visual example

5.1.9 Lineage Level with total height of lineage

Property	Value
User Input	None
Structure Input	Object Lineage Graph
Output	uint64 numbers for level and total height
Function Name	TBA

Context - The goal of this feature is to understand how far through the object chain, the target object is first witnessed.

Visual example

5.1.10 Object Wait time for specific event

Property	Value
User Input	Source Activity Name AND Target activity name
Structure Input	None
Output	uint64 time in seconds
Function Name	TBA

Context - The goal of this feature is to differentiate between items and see how long an object has to wait in order for the next step to initiate. Eg. From Figure 1: If pick_item is the source and pack_items is the target, the time i1 has to wait for pack_items to occur is far greater than i3's wait time.

Visual example

5.1.11 Object specific event directly follows

Property	Value
User Input	None
Structure Input	None
Output	uint64 for DF in the events (with frequency information)
Function Name	add_object_wait_time

Context - The goal of this feature is to differentiate between how objects live in the ocel log. Allows to separate objects with different behaviors for further analysis

5.1.12 Lonewolf Object

Property	Value
User Input	None
Structure Input	None
Output	bool8 whether the object completely operates by itself
Function Name	add_is_lonewolf

Context - The goal of this feature is to tell if an object is operating by itself.

Context - The goal of this feature is to tell if an object is operating by itself.

5.2 Local Features

5.3 Global Features

5.3.1 Object Type Count

Property	**Value**
User Input	None
Structure Input	None
Output	uint64 numbers for each type
Function Name	add_global_obj_type_count

Context - The goal of this feature is to have an overview of how many instances of each type of object exists in the log.

5.3.2 Global Object Type Count

Property	**Value**
User Input	None
Structure Input	Object Lineage Graph
Output	uint64 numbers for each type
Function Name	add_global_obj_type_count

Context - The goal of this feature is to have an overview of how many instances of each type of object exists in the log.

5.3.3 Basic Statistics on attribute values per object type

Property	**Value**
User Input	None
Structure Input	None
Output	uint64/float64 numbers for each type and their attributes
Function Name	add_global_obj_attribute_statistics

Context - The goal of this feature is to have a brief overview of how many objects in the event log have an attribute along with a valid value (ie. non NaN or None). It gives a brief overview of the amount of data the objects in the log hold. Added statistics: count, mean, std. dev, median, mode.

6 Event Based Features

6.1 Point wise Features

6.1.1 Number of objects involved separated by object type

Property	Value
User Input	None
Structure Input	None
Output	uint64 for each object type in log
Function Name	TBA

Context - The goal of this feature is to assign the different types of objects in a numerical way.

6.1.2 Number of objects created by event per object type

Property	Value
User Input	None
Structure Input	None
Output	uint64 number for each object type
Function Name	TBA

Context - The goal of this feature is to differentiate between objects that have already been seen in the log and objects that appear for the first time in the event.

6.1.3 Activity of Event

Property	Value
User Input	None
Structure Input	None
Output	OHE of activity names
Function Name	TBA

Context - The goal of this feature is to assign the activity name in a numerical way.

6.2 Local Features

6.3 Global Features

6.3.1 Object Interactions per event statistics

Property	Value
User Input	None
Structure Input	None
Output	uint64/float64 numbers for each type and their attributes
Function Name	TBA

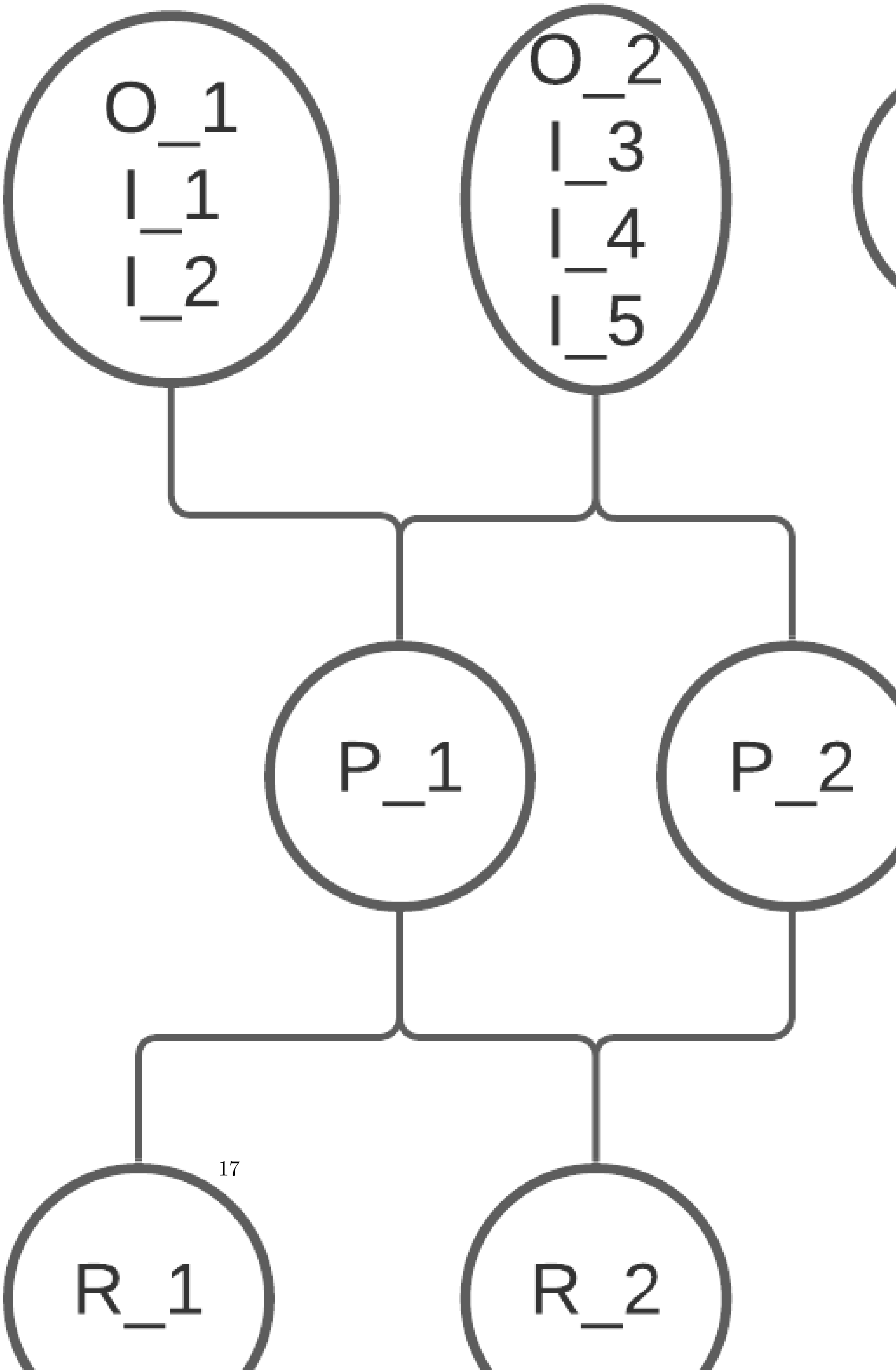
Context - The goal of this feature is to get an overall view the variety of events and their interaction patterns in the OCEL log.

6.3.2 Time Series: rate of change of number of events occurring in the same time window

Property	Value
User Input	time window size
Structure Input	None
Output	float64 for each timewindow
Function Name	TBA

Context - The goal of this feature is to gather information about how active the OCEL log is.

Visual Example TODO


O_1
I_1
I_2
O_2
I_3
I_4
I_5
P_1
P_2
R_1
R_2

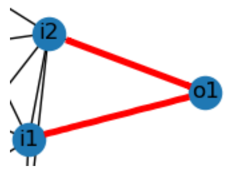


Figure 5: o1 has two unique neighbors. i1 and i2.

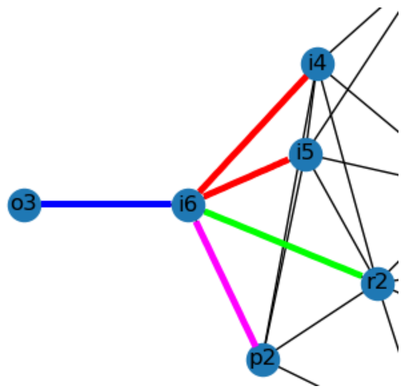


Figure 6: Object i6 has 5 neighbors. There is 1 of order, package, route and 2 are of type item

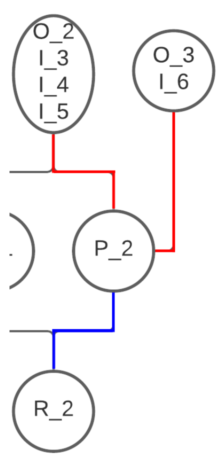


Figure 7: P_2 has two direct ascendants and one direct descendant

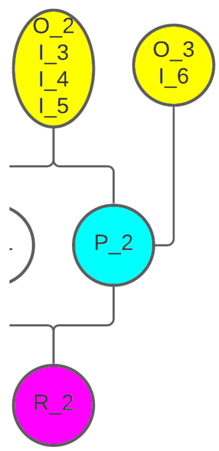


Figure 8: P_2 only has direct ancestors and neighbors. Therefore P_2 sits at level 2 out of 3