

# 1 Credit Application Process

## 1.1 Process model

We created a fictive model as seen in Fig. 1. The constraints (including the additional data constraints) of the process model mean that:

- $C_1$ : *response(ApplyForCredit, Assessment)*: If a person applies for a credit and has a salary lower or equal to 24,000 euros and requests a credit amount higher than 50,000 euros, then the assessment of the application will be complex, cost more than 100 euros and should be handled from a credit assessment officer.
- $C_2$ : *response(ApplyForCredit, Assessment)*: If a person applies for a credit and requests a credit amount higher than 100,000 euros, then the assessment of the application will be complex and cost more than 100 euros.
- $C_3$ : *response(ApplyForCredit, Assessment)*: If a person applies for a credit and has a salary higher or equal to 24,000 euros and requests a credit amount smaller than 100,000 euros, then the assessment of the application will be simple and cost less or equal to 100 euros.
- $C_4$ : *precedence(OutcomeNotification, ApplyForCredit)*: If a person's credit application gets accepted, then this event must be preceded by a person that applies for a credit and has a salary higher than 12,000 euros.

Table 1: Fictive credit application process model in Declare notation with additional data constraints

ID	Constraint	A/T	Payload
1	response	ApplyForCredit Assessment	Salary <= 24000 & Amount > 50000 AssessmentType=Complex & AssessmentCost > 100 & Resource=CreditAssessmentOfficer
2	response	ApplyForCredit Assessment	Amount > 100000 AssessmentType=Complex & AssessmentCost > 100
3	response	ApplyForCredit Assessment	Salary > 24000 and Amount <= 100000 AssessmentType=Simple & AssessmentCost <= 100
4	precedence	OutcomeNotification ApplyForCredit	Result is Accepted Salary > 12000

## 1.2 Redescription Quality Evaluation

In Table 2, we have displayed the discovered redescription rules from every algorithm with respect to the MP-Declare Constraints that they correspond to.

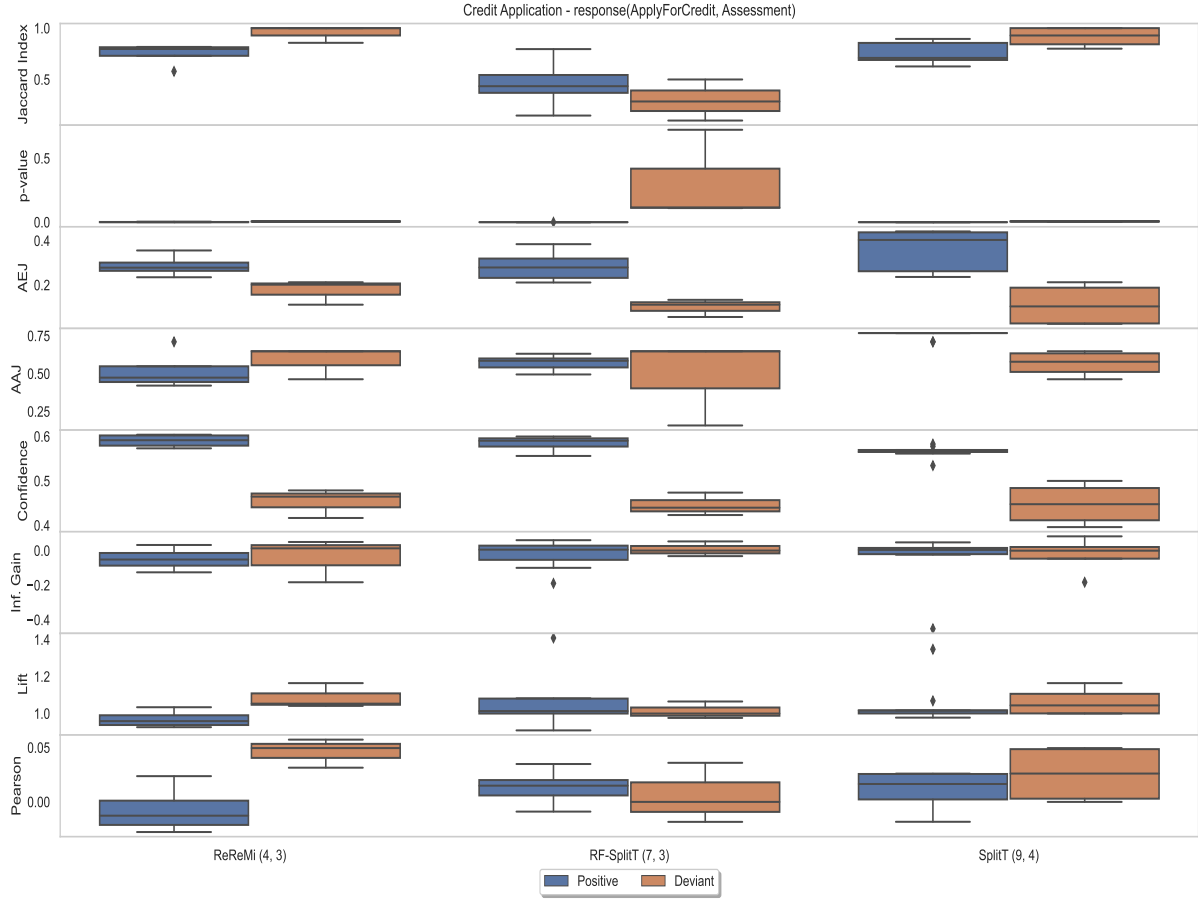


Figure 1: Credit Application - response(ApplyForCredit, Assessment)

It can be seen from the table that RF-SplitT has discovered redescrptions that relate to the Declare constraints that were used to generate the respective event logs, whereas for the other algorithms is not the case. In the paragraphs below, we discuss the quality of the redescrptions:

**response(ApplyForCredit, Assessment):** Observations regarding the quality of the redescrptions discovered from the respective constraint (cf. Fig. 1):

Table 2: Credit Application Process redescription rules

<b>C</b>	<b>A/T</b>	<b>ReReMi</b>	<b>RF-SplitT</b>	<b>SplitT</b>
C <sub>2</sub>	ApplyForCredit	108071<Amount<111552	109448<Amount & Amount<117158 & 115169<Amount	-
	Assessment	80<Cost<93	Type=Complex	
C <sub>3</sub>	ApplyForCredit	91568<Salary<109914	Salary<7714	!109351<Amount & 105320<Amount & 13839<Salary
	Assessment	80<Cost<84	Cost<225 & 84<Cost & Cost<127	!92<Cost & !Type=Complex
<b>C</b>	<b>A/T</b>	<b>ReReMi</b>	<b>RF-SplitT</b>	<b>SplitT</b>
C <sub>1</sub>	ApplyForCredit	-	50178<Amount & Salary<23558	(!34617<Salary & 50757<Amount ) — ( 99627<Amount & 34617<Salary & 50757<Amount ) (! 98<Cost & Type= Complex & ! 101< Cost ) — ( ! Type= Simple & 101<Cost) — (!162<Cost & Type= Simple & 101<Cost )
	Assessment		Type=Complex	
C <sub>2</sub>	ApplyForCredit	46630<Amount	93423<Amount	extensive
	Assessment	72<Cost	100<Cost & Type=Complex & Resource=CreditOfficer	
C <sub>3</sub>	ApplyForCredit	26485<Salary<101546	Amount<50705 &	extensive
	Assessment	\$\mid\$ Amount<49978 Type=Simple & Cost<101	2388<Salary Cost<102	
C <sub>4</sub>	OutcomeNotif.	Result=Rejected	Result=Accepted	Result=Rejected
	ApplyForCredit	Salary<3054	7274<Salary	Salary<6732

1. The behaviour between the algorithms over the different measurements is dissimilar, this is a new behaviour with regard to previous event logs.
2. The RF-SplitT's rules have a lower accuracy, here the SIREN algorithms thrive.
3. The SplitT algorithm was able to discover more redescription, however, its rules are extensive and not at all understandable and could not be used for deviance analysis (cf. Table 2).

**precedence(ApplyForCredit, OutcomeNotification):** Observations regarding the quality of the redescription discovered from the Credit Application positive event log (cf. Fig. 2):

1. The ratio of discovered rules discovered from RF-SplitT is higher than the ones from the SIREN algorithms.
2. The RF-SplitT rules have a higher accuracy compared to the other algorithms.
3. None of the algorithms was able to discover rules from the deviant traces with respect to the constraint.

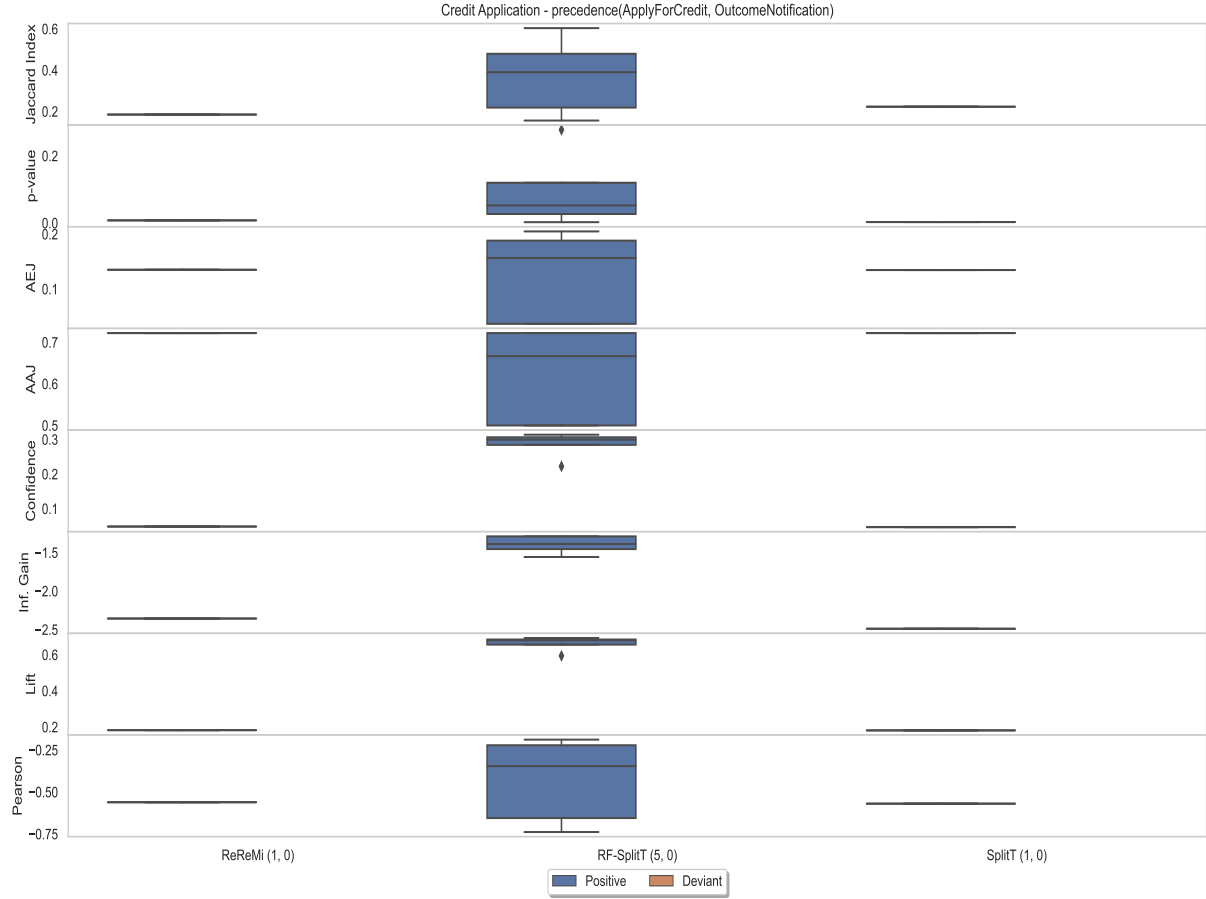


Figure 2: Credit Application - precedence(ApplyForCredit, OutcomeNotification)

### 1.3 Redescription Execution Time Analysis

In order to estimate the time required for deviance analysis in practice, we performed a runtime measurement for the different redescription algorithms. The results obtained are shown in Table 3. To allow a fair comparison, we run all algorithms on the same data models. Our measurements handle the time that an algorithm requires to discover the respective rules on a given input dataset. For the Credit Application example, we found that the SplitT algorithm has the

lowest execution time, while the ReReMi algorithm is the worst one. The reason why the ReReMi algorithm takes more time is because of its greedy behaviour, where it traverses all attributes and literals in the data model. The, SplitT algorithm, on the other hand, is a decision tree based algorithm where the trees grow based on the entropy calculation, resulting in faster tree discovery. The RF-SplitT algorithm is ranked second. This was also to be expected since it is an ensemble of decision trees and therefore takes more time than the SplitT algorithm. In summary, all execution times are in a range that is unproblematic for practical use.

Table 3: Execution times for Credit Application Process

	C <sub>1</sub> ,C <sub>2</sub> ,C <sub>3</sub>		C <sub>4</sub>		Time (s)		Rank
	P	N	P	N	P	N	
<b>ReReMi</b>	312.73	2.06	2.73	0.11	315.46	2.17	3
<b>RF-SplitT</b>	20.72	15.77	7.68	0.76	28.4	16.53	2
<b>SplitT</b>	3.07	0.78	0.67	0.45	3.74	1.23	1

#### 1.4 Comparisons and Analysis of Discovered Redescriptions Evaluation

The final result of the deviance analysis pipeline is a detailed report in form of a human-readable text that explains the reasons of the deviance in general, as well as the causes for the deviance of the single process execution (cf. ReReMi (Table 4), RF-SplitT (Table 5) and SplitT (Table 6)). The tables have two sections, the '*Deviances of the event logs in general:*' and '*Analysing traces in detail:*'. In the '*Deviances of the event logs in general:*' section, the comparisons and analysis of deviant redescriptions with positive ones are handled. For example, in the Table 4 is detected that deviant traces that have appliers of credit requiring a credit amount between 108,071 euros and 111,552 euros lead to an assessment cost between 80 and 93 euros. However, in a positive traces that assessment cost takes place only when the required credit amount is lower than 49,978 euros. Moreover, as part of providing reasons on why particular deviant traces occurred, we can see that in Table 4 the trace with ID 397 has deviated because the salary of the applier was not in the range where credit applications are accepted.

Table 4: Excerpt of the deviance report in natural language text (Credit Application Process - ReReMi)

**Deviances of the event logs in general:**

The first mined negative rule is 'If the credit amount varies between 108071 and 111552 that implicates that the assessment cost alternates between 80 and 93. (r1)' and its subrules comparisons to the positive subrules are below:

- The amount for the event 'Apply For Credit' varies between 108071 and 111552 in the negative rule, while in the positive rule r21, it is lesser than 49978.

The second mined negative rule is 'If the credit salary varies between 3421 and 12413 that implicates that the assessment cost varies between 87 and 100. (r2)' and its subrules comparisons to the positive subrules are below:

- The assessment cost for the event 'Assessment' varies between 87 and 100 in the negative rule, while in the positive rule r14, it doesn't go lower than 94.
- The salary for the event 'Apply For Credit' varies between 3421 and 12413 in the negative rule, while in the positive rule r21, it alternates between 26485 and 101546.

The third mined negative rule is 'If the credit salary ranges from 91568 to 109914 that implicates that the assessment cost varies between 80 and 84. (r0)' and its subrules comparisons to the positive subrules are below:

- The salary for the event 'Apply For Credit' ranges from 91568 to 109914 in the negative rule, while in the positive rule r14, it is below 21267.
- The assessment cost for the event 'Assessment' varies between 80 and 84 in the negative rule, while in the positive rule r14, it is bigger than 94.

**Analysing traces in detail:**

- The process execution with 'Case No. 379' is deviant because the notification result differs from Rejected (r32).
- The process execution with 'Case No. 385' is deviant because the credit salary does not vary between 26485 and 101546 (r21), the assessment cost is smaller than 72 (r10) and the process is not executed by BankManager (r14).
- The process execution with 'Case No. 397' is deviant because the credit salary doesn't alternate between 26485 and 101546 (r21).

Table 5: Excerpt of the deviance report in natural language text (Credit Application Process - RF-SplitT)

**Deviances of the event logs in general:**

The first mined negative rule is 'If the credit amount is bigger than 109448 and the credit amount is below 117158 and the credit amount is bigger than 115169 that implicates that the assessment type is Complex. (r0)' and its subrules comparisons to the positive subrules are below:

- The amount for the event 'Apply For Credit' is bigger than 115169 in the negative rule, while in the positive rule r4, it is smaller than 50705.
- The assessment type for the event 'Assessment' is Complex in the negative rule, while in the positive rule r10, it is equal to Simple.

The second mined negative rule is 'If the credit salary is bigger than 32780 that implicates that the assessment cost is lower than 225 and the assessment cost doesn't go lower than 84 and the assessment cost is bigger than 127. (r5)' and its subrules comparisons to the positive subrules are below:

- The salary for the event 'Apply For Credit' is bigger than 32780 in the negative rule, while in the positive rule r1, it is lower than 23558.
- The assessment cost for the event 'Assessment' is bigger than 127 in the negative rule, while in the positive rule r4, it is below 102.

The third mined negative rule is 'If the credit salary is below 7714 that implies the assessment cost is lower than 225 and the assessment cost doesn't go lower than 84 and the assessment cost is lower than 127. (r3)' and its subrules comparisons to the positive subrules are below:

- The assessment cost for the event 'Assessment' is lower than 225 in the negative rule, while in the positive rule r3, it is lower than 166.
- The salary for the event 'Apply For Credit' is below 7714 in the negative rule, while in the positive rule r4, it doesn't go lower than 2388.

**Analysing traces in detail:**

- The process execution with 'Case No. 292' is deviant because the notification result differs from Accepted (r24), the notification result is not Accepted (r23) and the credit salary is not below 4573 (r22).
- The process execution with 'Case No. 386' is deviant because the credit salary is ,above 11521 (r12) the credit salary is above 23558 (r1) and the assessment cost goes lower than 100 (r21).
- The process execution with 'Case No. 399' is deviant because the credit amount is above 50705 (r4), the assessment cost is not below 100 (r10) and the credit amount is higher than 86833 (r14).



Table 6: Excerpt of the deviance report in natural language text (Credit Application Process - SplitT)

#### **Deviances of the event logs in general:**

The first mined negative rule is 'If the credit amount doesn't exceed 106411 and the credit salary exceeds 3570 and the credit salary is not bigger than 14742 that implicates that the assessment cost goes lower than 125 and the assessment cost doesn't go lower than 100.

(r37)' and its subrules comparisons to the positive subrules are below:

- The salary for the event 'Apply For Credit' exceeds 3570 in the negative rule, while in the positive rule r73, it is smaller than 7533.
- The salary for the event 'Apply For Credit' exceeds 3570 in the negative rule, while in the positive rule r73, it exceeds 7676.
- ...

The second mined negative rule is 'If the credit amount goes lower than 109351 and the credit amount doesn't go lower than 105320 and the credit salary is bigger than 13839 that implicates that the assessment cost doesn't exceed 92 and the assessment type is not Complex. (r50)' and its subrules comparisons to the positive subrules are below:

- The amount for the event 'Apply For Credit' goes lower than 109351 in the negative rule, while in the positive rule r73, it is not bigger than 118656.
- The amount for the event 'Apply For Credit' doesn't go lower than 105320 in the negative rule, while in the positive rule r73, it is not bigger than 118656.
- ...

The third mined negative rule is 'If the credit amount goes lower than 114743 and the credit amount is bigger than 108071 that implicates that the assessment cost doesn't go lower than 80 and the assessment cost goes lower than 94. (r39)' and its subrules comparisons to the positive subrules are below:

- The amount for the event 'Apply For Credit' goes lower than 114743 in the negative rule, while in the positive rule r73, it goes lower than 118656.
- The amount for the event 'Apply For Credit' is bigger than 108071 in the negative rule, while in the positive rule r73, it goes lower than 118656.
- ...

The fourth mined negative rule is 'If the credit salary is bigger than 3421 and the credit salary is not bigger than 12556 that implicates that the assessment cost varies between 87 and 100. (r42)' and its subrules comparisons to the positive subrules are below:

- The salary for the event 'Apply For Credit' is bigger than 3421 in the negative rule, while in the positive rule r73, it is smaller than 7533.
- The salary for the event 'Apply For Credit' is bigger than 3421 in the negative rule, while in the positive rule r73, it exceeds 7676.
- ...

#### **Analysing traces in detail:**

- The process execution with 'Case No. 293' is deviant because the credit salary is higher than 6732 (r168).
- The process execution with 'Case No. 382' is deviant because the notification result is not Rejected (r168). 9
- The process execution with 'Case No.399' is deviant because the credit salary doesn't exceed 26485 (r81), the process is not executed by BankManager (r114) and the process is not executed by BankManager (r85).

## 2 Road Traffic Fines Process

### 2.1 Process model

Table 7: Road Traffic Fines Declare Constraints

ID	Constraint	A/T	Payload
1	response	InsertFineNotification AddPenalty	NotificationType=P Amount < 5000
2	response	InsertFineNotification AddPenalty	NotificationType=C Amount > 5000
3	response	AddPenalty SendForCreditCollection	Amount > 5000 Resource=Admin
4	response	AddPenalty SendForCreditCollection	Amount < 5000 Resource=Police

To build this process model, we took the event log <sup>1</sup> and mined a declarative process model out of it. A subset of the mined model which is also used in this paper is shown in Table. 7. The constraints (including the additional data constraints) of the process model mean that:

- $C_1$ : *response(InsertFineNotification, AddPenalty)*: If a notification of fine insertion is of type P, then the amount of the penalty is smaller than 5,000 euros.
- $C_2$ : *response(InsertFineNotification, AddPenalty)*: If a notification of fine insertion is of type C, then the amount of the penalty is higher than 5,000 euros.
- $C_3$ : *response(AddPenalty, SendForCreditCollection)*: If the amount of a penalty is higher than 5,000 euros, then the collection of the credit should be handled by an admin staff.
- $C_4$ : *response(AddPenalty, SendForCreditCollection)*: If the amount of a penalty is lower than 5,000 euros, then the collection of the credit should be handled by a police staff.

### 2.2 Redescription Quality Evaluation

In Table 8, we have displayed the discovered redescription rules from every algorithm with respect to the MP-Declare Constraints that they correspond to. It can be seen from the table that every algorithm has discovered redescriptions that relate to the Declare constraints that were used to generate the respective event logs. In the paragraphs below, we discuss the quality of the redescriptions:

<sup>1</sup>DOI: [10.4121/uuid:270fd440-1057-4fb9-89a9-b699b47990f5](https://doi.org/10.4121/uuid:270fd440-1057-4fb9-89a9-b699b47990f5)

Table 8: Road Traffic Fines Process redescription rules

<b>C</b>	<b>A/T</b>	<b>ReReMi</b>	<b>RF-SplitT</b>	<b>SplitT</b>
$C_1$	InsertFineNotification AddPenalty	NotificationType=P 5000<Amount	NotificationType=P 4974<Amount	NotificationType=P 5000<Amount
$C_2$	InsertFineNotification AddPenalty	NotificationType=C Amount<4950	NotificationType=C Amount<4975	! NotificationType=P Amount<4950
<b>C</b>	<b>A/T</b>	<b>ReReMi</b>	<b>RF-SplitT</b>	<b>SplitT</b>
$C_1$	InsertFineNotification AddPenalty	NotificationType=P Amount<4909	NotificationType=C & Resource=Police Amount<5903	NotificationType=P ! 5000<Amount
$C_2$	InsertFineNotification AddPenalty	NotificationType=C 5000<Amount	NotificationType=C 4953<Amount	NotificationType=C 5000<Amount
$C_3$	AddPenalty SendForCreditCollec.	5000<Amount Resource=Admin	4973<Amount Resource=Admin	5000<Amount ! Resource=Police
$C_4$	AddPenalty SendForCreditCollec.	Amount<4951 Resource=Police	Amount<4973 Resource=Police	! 5000<Amount Resource=Police

**response(InsertFineNotification, AddPenalty):** Observations regarding the quality of the redescrptions discovered from the respective constraint (cf. Fig. 3):

1. The algorithms in general discover more rules from the positive traces, however RF-SplitT has discovered in general more, thus depicting different deviant behaviors.
2. In general, all algorithms have reached a good accuracy as part of the quality of the redescrptions.
3. The discovered redescription from ReReMi and RF-SplitT have no correlation with each other which is a good point, since we do not want to discover many rules that explain this behaviour. However, that is this not the case for the SplitT algorithm where one can see small negative correlation between its rules.

**response(AddPenalty, SendForCreditCollection):** Observations regarding the quality of the redescrptions discovered from the Credit Application positive event log (cf. Fig. 4):

1. The ratio of discovered rules discovered from RF-SplitT is 2:1 compared to other SIREN algorithms.

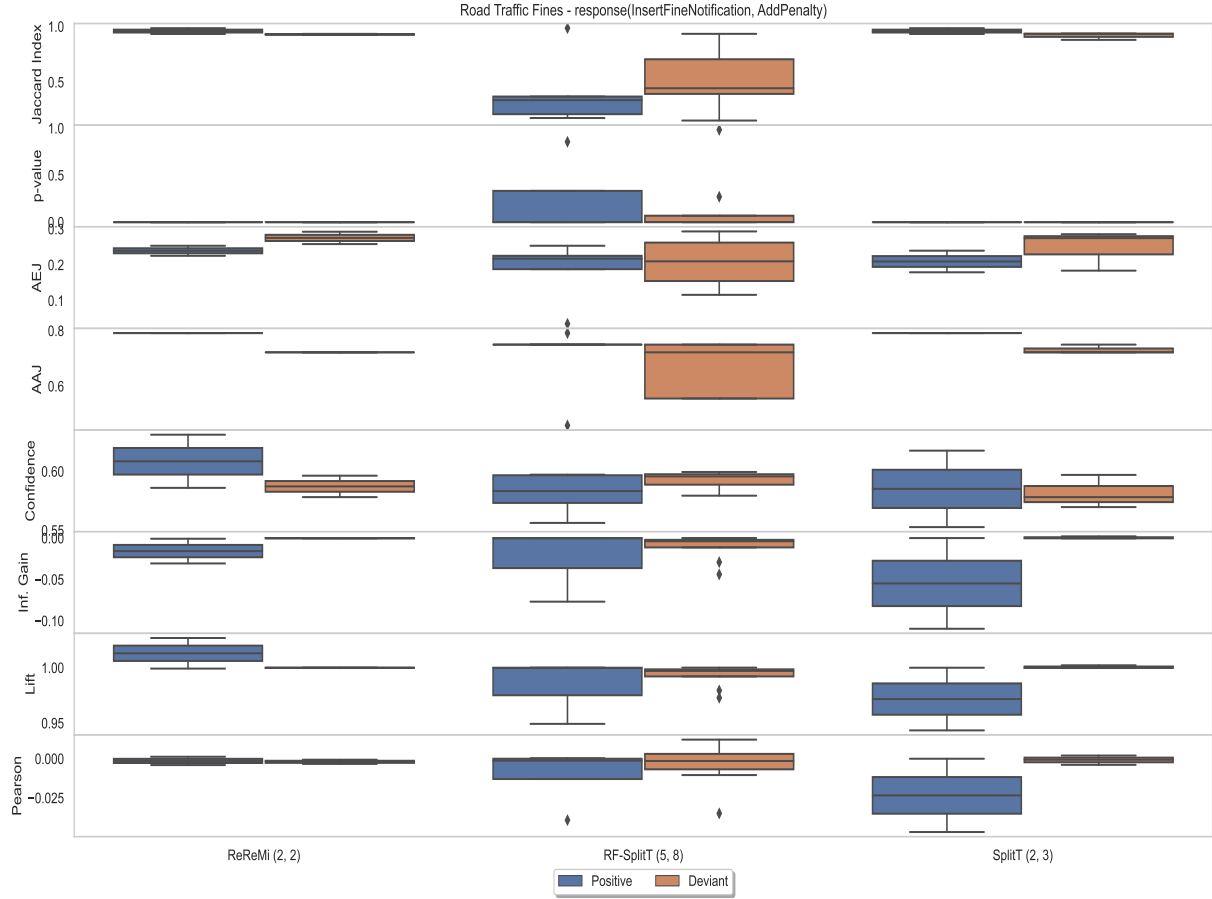


Figure 3: Credit Application - response(InsertFineNotification, AddPenalty)

2. The SplitT rules have a higher information gain which normally does not happen, but it has discovered for this constraint very compact rules. The Table 8 displays its rules.
3. None of the algorithms was able to discover rules from the deviant traces with respect to the constraint.

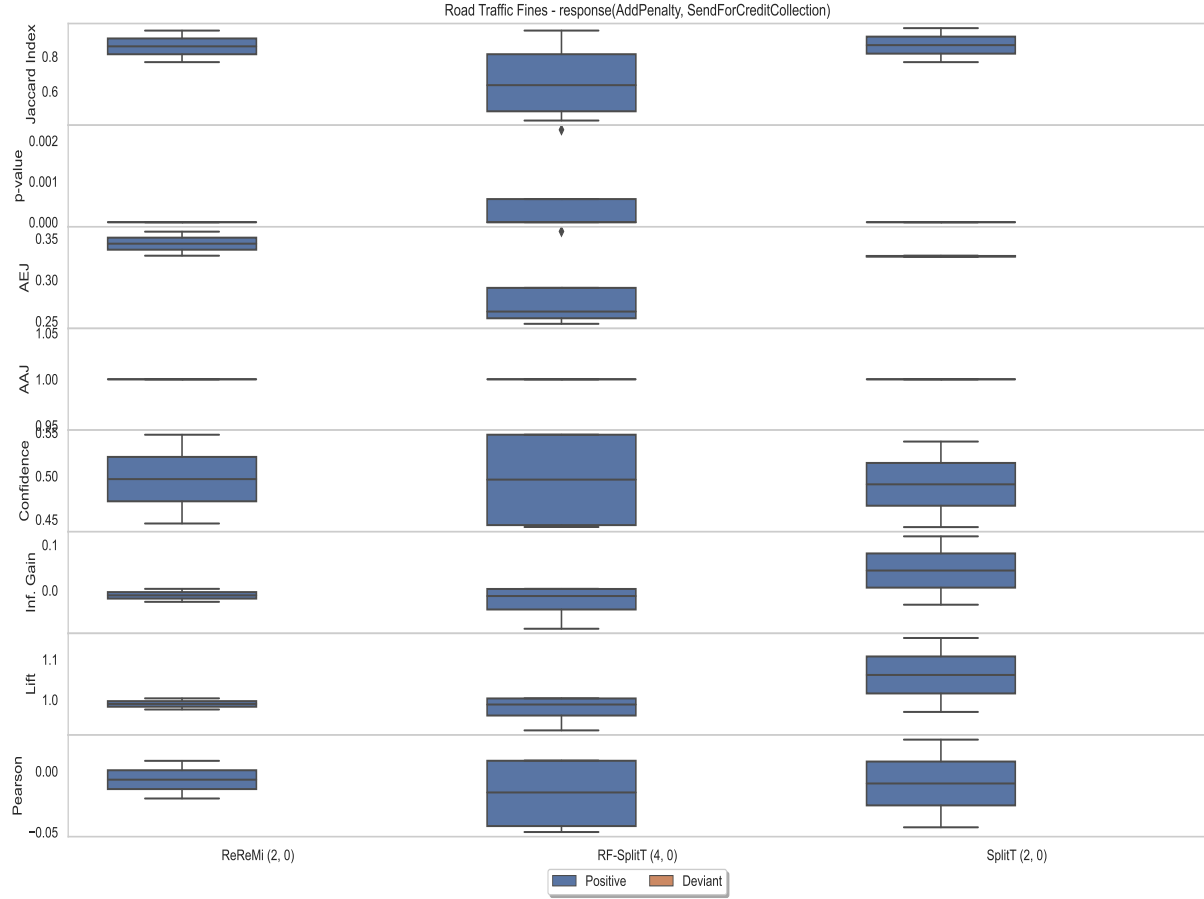


Figure 4: Credit Application - response(AddPenalty, SendForCreditCollection)

## 2.3 Redescription Execution Time Analysis

In order to estimate the time required for deviance analysis in practice, we performed a runtime measurement for the different redescription algorithms. The results obtained are shown in Table 9. To allow a fair comparison, we run all algorithms on the same data models. Our measurements handle the time that an algorithm requires to discover the respective rules on a given input dataset. For the Road Traffic Fines example, we found that the SplitT algorithm has the lowest execution time, while the RF-SplitT algorithm is the worst one. The

reason why the ReReMi algorithm is slightly faster than RF-SplitT is because the discovered rules from ReReMi are singleton queries meaning there was no need for much computations. We know from the paper that singleton queries are the base queris of the algorithm. The, SplitT algorithm, on the other hand, is a decision tree based algorithm where the trees grow based on the entropy calculation, resulting in faster tree discovery. The RF-SplitT algorithm is ranked third. This was also to be expected since it is an ensemble of decision trees and therefore takes more time than the SplitT algorithm.

Table 9: Execution times for Road Traffic Fines Process

Execution time for Road Traffic Fines Process							
	C <sub>1</sub> ,C <sub>2</sub>		C <sub>3</sub> ,C <sub>4</sub>		Time (s)		Rank
	P	N	P	N	P	N	
<b>ReReMi</b>	6.77	0.74	5.32	0.13	12.09	0.87	2
<b>RF-SplitT</b>	9.99	5.98	3.5	0.42	13.49	6.4	3
<b>SplitT</b>	0.82	0.58	0.81	0.17	1.63	0.75	1

## 2.4 Comparisons and Analysis of Discovered Redescriptions Evaluation

The final result of the deviance analysis pipeline is a detailed report in form of a human-readable text that explains the reasons of the deviance in general, as well as the causes for the deviance of the single process execution (cf. ReReMi (Table 10), RF-SplitT (Table 11) and SplitT (Table 12)). The tables have two sections, the '*Deviances of the event logs in general:*' and '*Analysing traces in detail:*'. In the '*Deviances of the event logs in general:*' section, the comparisons and analysis of deviant redescrptions with positive ones are handled. For example, in the Table 11 is detected that deviant traces that have a penalty amount smaller than 6,393 euros, then the insertion of the fine is done by a person from an admin staff. However, in a positive traces the insertions of fines with an amount smaller than 6,393 euros are done from the police staff. Moreover, as part of providing reasons on why particular deviant traces occurred, we can see that in Table 11 the trace with ID 8999 has deviated because the notification type is not C and therefore not executed by a police staff.

Table 10: Excerpt of the deviance report in natural language text (Road Traffic Fines Process - ReReMi)

**Deviances of the event logs in general:**

The first mined negative rule is 'If the notification type is C that implicates that the penalty amount is lesser than 4950. (r0)' and its subrules comparisons to the positive subrules are below:

- The amount for the event 'Add Penalty' is lesser than 4950 in the negative rule, while in the positive rule r2, it is bigger than 5000.
- The notification type for the event 'Insert Fine Notification' is C in the negative rule, while in the positive rule r3, it is equal to P.
- The amount for the event 'Add Penalty' is lesser than 4950 in the negative rule, while in the positive rule r3, it is below 4909.

The second mined negative rule is 'If the notification type is P that implicates that the penalty amount exceeds 5000. (r2)' and its subrules comparisons to the positive subrules are below:

- The notification type for the event 'Insert Fine Notification' is P in the negative rule, while in the positive rule r2, it is equal to C.
- The amount for the event 'Add Penalty' exceeds 5000 in the negative rule, while in the positive rule r3, it is lesser than 4909.

**Analysing traces in detail:**

- The process execution with 'Case No. 50' is deviant because the process is not executed by Police (r7), the notification type is unequal to P (r3) and the penalty amount doesn't exceed 5000 (r2).
- The process execution with 'Case No. 84' is deviant because the notification type is unequal to P (r3), the penalty amount is smaller than 5000 (r2) and the process is not executed by Police (r7).
- The process execution with 'Case No. 891' is deviant because the process is not executed by Admin (r6) and the penalty amount is not below 4951 (r7).

Table 11: Excerpt of the deviance report in natural language text (Road Traffic Fines Process - RF-SplitT)

#### **Deviances of the event logs in general:**

The first mined negative rule is 'If the notification type is equal to C or the notification type is c and the process is executed by Admin or the notification resource is System that implies that the penalty amount is smaller than 6393. (r0)' and its subrules comparisons to the positive subrules are below:

- The resource for the event 'Insert Fine Notification' is executed by Admin in the negative rule, while in the positive rule r1, it is executed by Police.
- ...

The second mined negative rule is 'If the notification type is C that implies that the penalty amount is lesser than 4975. (r9)' and its subrules comparisons to the positive subrules are below:

- The notification type for the event 'Insert Fine Notification' is C in the negative rule, while in the positive rule r2, it is P.
- ...

The third mined negative rule is 'If the notification type is P that implies the penalty amount exceeds 4974. (r8)' and its subrules comparisons to the positive subrules are below:

- The notification type for the event 'Insert Fine Notification' is P in the negative rule, while in the positive rule r1, it is equal to C.
- ...

The fourth mined negative rule is 'If the notification type is P and the process is executed by Admin or the process is executed by System that implies that the penalty amount is smaller than 6393. (r1)' and its subrules comparisons to the positive subrules are below:

- The notification type for the event 'Insert Fine Notification' is P in the negative rule, while in the positive rule r1, it is C.
- ...

The fifth mined negative rule is 'If the notification type is P and the notification resource is Police that implies the penalty amount exceeds 6515. (r3)' and its subrules comparisons to the positive subrules are below:

- The notification type for the event 'Insert Fine Notification' is P in the negative rule, while in the positive rule r1, it is equal to C.
- ...

...

#### **Analysing traces in detail:**

- The process execution with 'Case No. 305' is deviant because the process is not executed by Police (r1), the process is not executed by System (r5) and the process is not executed by System (r3).
- The process execution with 'Case No. 882' is deviant because the process is not executed by Admin (r10), the process is not executed by Admin (r2) and the process is not executed by Police (r1).
- The process execution with 'Case No. 899' is deviant because the notification type differs from C (r7), the process is not executed by Police (r1) and the process



Table 12: Excerpt of the deviance report in natural language text (Road Traffic Fines Process - SplitT)

**Deviances of the event logs in general:**

The first mined negative rule is 'If the notification type is unequal to P that implicates that the penalty amount is lower than 4950. (r1)' and its subrules comparisons to the positive subrules are below:

- The notification type for the event 'Insert Fine Notification' is unequal to P in the negative rule, while in the positive rule r28, it is equal to C.
- The amount for the event 'Add Penalty' is lower than 4950 in the negative rule, while in the positive rule r28, it exceeds 5000.
- The amount for the event 'Add Penalty' is lower than 4950 in the negative rule, while in the positive rule r32, it is smaller than 5000.

The second mined negative rule is 'If the notification type is equal to P that implicates that the penalty amount is bigger than 5000. (r5)' and its subrules comparisons to the positive subrules are below:

- The notification type for the event 'Insert Fine Notification' is equal to P in the negative rule, while in the positive rule r28, it is C.

**Analysing traces in detail:**

- The process execution with 'Case No. 17' is deviant because the penalty amount is smaller than 5000 (r57), the notification type is unequal to P (r32) and the process is not executed by Police (r61).
- The process execution with 'Case No. 41' is deviant because the notification type differs from P (r32), the process is not executed by Police (r61) and the penalty amount is smaller than 5000 (r57).
- The process execution with 'Case No. 893' is deviant because the process is not executed by Police (r57) and the penalty amount is above 5000 (r61).

### 3 Repair Example

#### 3.1 Process model

Table 13: Repair Example Declare Constraints

ID	Constraint	A/T	Payload
1	response	Register InformUser	Resource=Tester Resource=System
2	response	Register InformUser	Resource=Solver ComplexityOfRepair=Complex
3	response	InformUser ArchiveRepair	Resource=Tester NumberRepairs > 2 & DefectFixed=false & Resource=Solver
4	response	InformUser ArchiveRepair	Resource=System NumberRepairs <= 2 & DefectFixed=true
5	response	InformUser ArchiveRepair	ComplexityOfRepair=Complex NumberRepairs = 3

To build this process model, we took the event log <sup>2</sup> and mined a declarative process model out of it. A subset of the mined model which is also used in this paper is shown in Table. 13. The constraints (including the additional data constraints) of the process model mean that:

- $C_1$ : *response(Register, InformUser)*: If an activity for registering a repair is executed by a Tester, then the informing of the user will be done by System.
- $C_2$ : *response(Register, InformUser)*: If an activity for registering a repair is executed by a Solver, then the complexity of the repair will be Complex.
- $C_3$ : *response(InformUser, ArchiveRepair)*: If the informing of the user will be done by a Tester, then an archive of repair will occur where number of repairs are higher than two, defect is not fixed and the activity is executed by a Solver.
- $C_4$ : *response(InformUser, ArchiveRepair)*: If the informing of the user will be done by System, then an archive of repair will occur where number of repairs are smaller or equal to two and defect is fixed.
- $C_5$ : *response(InformUser, ArchiveRepair)*: If the a repair is complex, then the number of repairs will be three.

<sup>2</sup>DOI: [10.4121/uuid:31a308ef-c844-48da-948c-305d167a0ec1](https://doi.org/10.4121/uuid:31a308ef-c844-48da-948c-305d167a0ec1)

### 3.2 Redescription Quality Evaluation

In Table 14, we have displayed the discovered redescription rules from every algorithm with respect to the MP-Declare Constraints that they correspond to. It can be seen from the table that for this process algorithms are unable to discover redescrptions that relate to the Declare constraints that were used to generate the respective event logs. Note that RF-SplitT covers most of the Declare constraints. In the paragraphs below, we discuss the quality of the redescrptions:

Table 14: Repair Example Process redescription rules

C	A/T	ReReMi	RF-SplitT	SplitT
C <sub>1</sub>	Register InformUser	Resource=Tester Resource=Tester	Resource=Tester Resource=Tester	Resource=Tester Resource=Tester
C <sub>2</sub>	Register InformUser	-	Resource=Solver Complexity=Simple	-
C	A/T	ReReMi	RF-SplitT	SplitT
C <sub>1</sub>	Register InformUser	-	Resource=Tester Resource=System	-
C <sub>2</sub>	Register InformUser	Resource=Solver Complexity=Complex	Resource=Solver Complexity=Complex & Resource=Solver	Resource=Solver Complexity=Complex
C <sub>3</sub>	InformUser ArchiveRepair	-	-	-
C <sub>4</sub>	InformUser ArchiveRepair	Resource=System DefectFixed	Resource=System ( Resource=System — Resource=Tester) & DefectFixed & 1<NumberRepairs	-
C <sub>5</sub>	InformUser ArchiveRepair	-	-	-

**response(Register, InformUser):** Observations regarding the quality of the redescrptions discovered from the respective constraint (cf. Fig. 5):

1. The RF-SplitT has discovered in general more redescrptions, thus depicting different deviant behaviors.
2. In general, all algorithms have reached a good accuracy as part of the quality of the redescrptions.

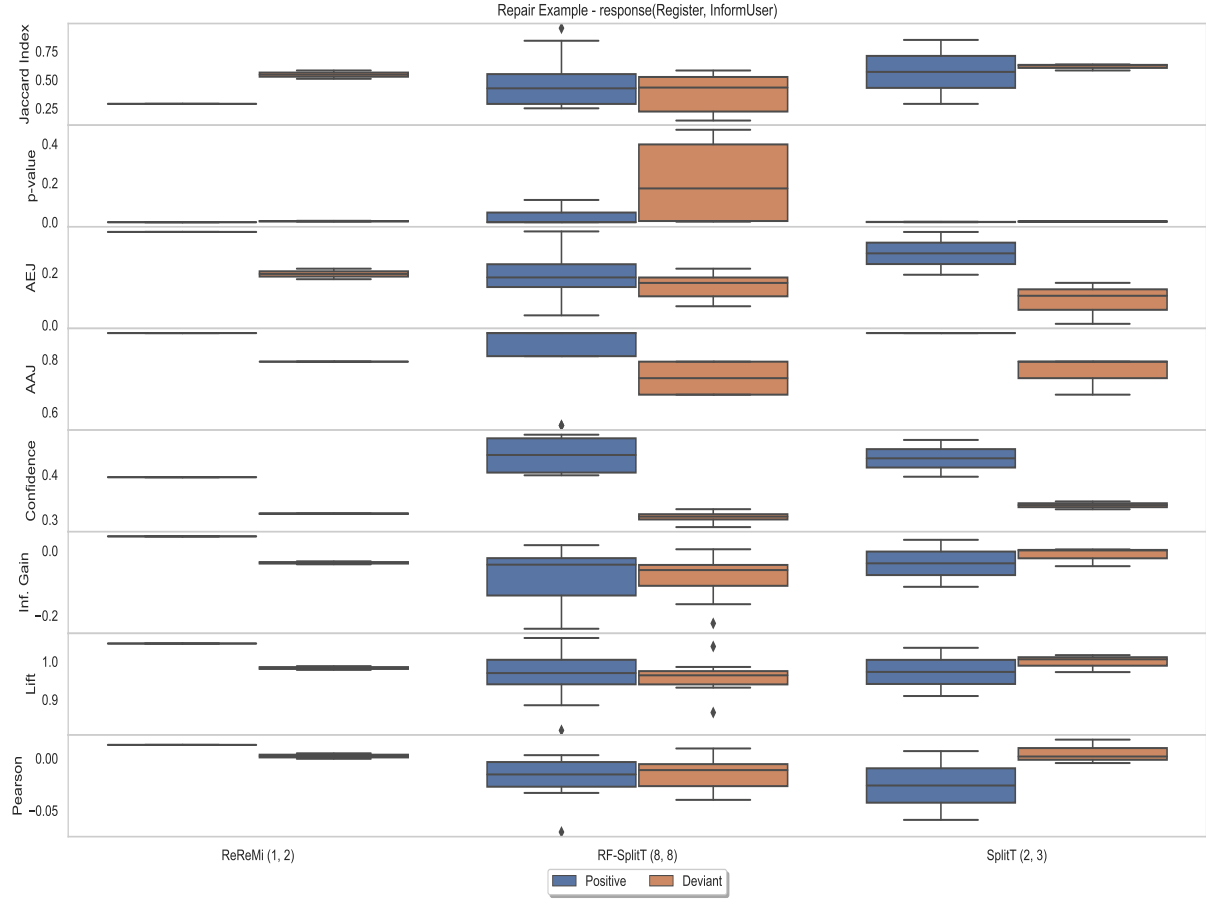


Figure 5: Repair Example - response(Register, InformUser)

3. The discovered rules from the RF-SplitT are high in amount and the p-value in some cases very high in which case we can not ignore the null hypothesis. That implies that our data would have occurred by random chance. This is a good thing that RF-SplitT was able to discover rule for such random behaviors.

**response(AddPenalty, SendForCreditCollection):** Observations regarding the quality of the redescrptions discovered from the Credit Application

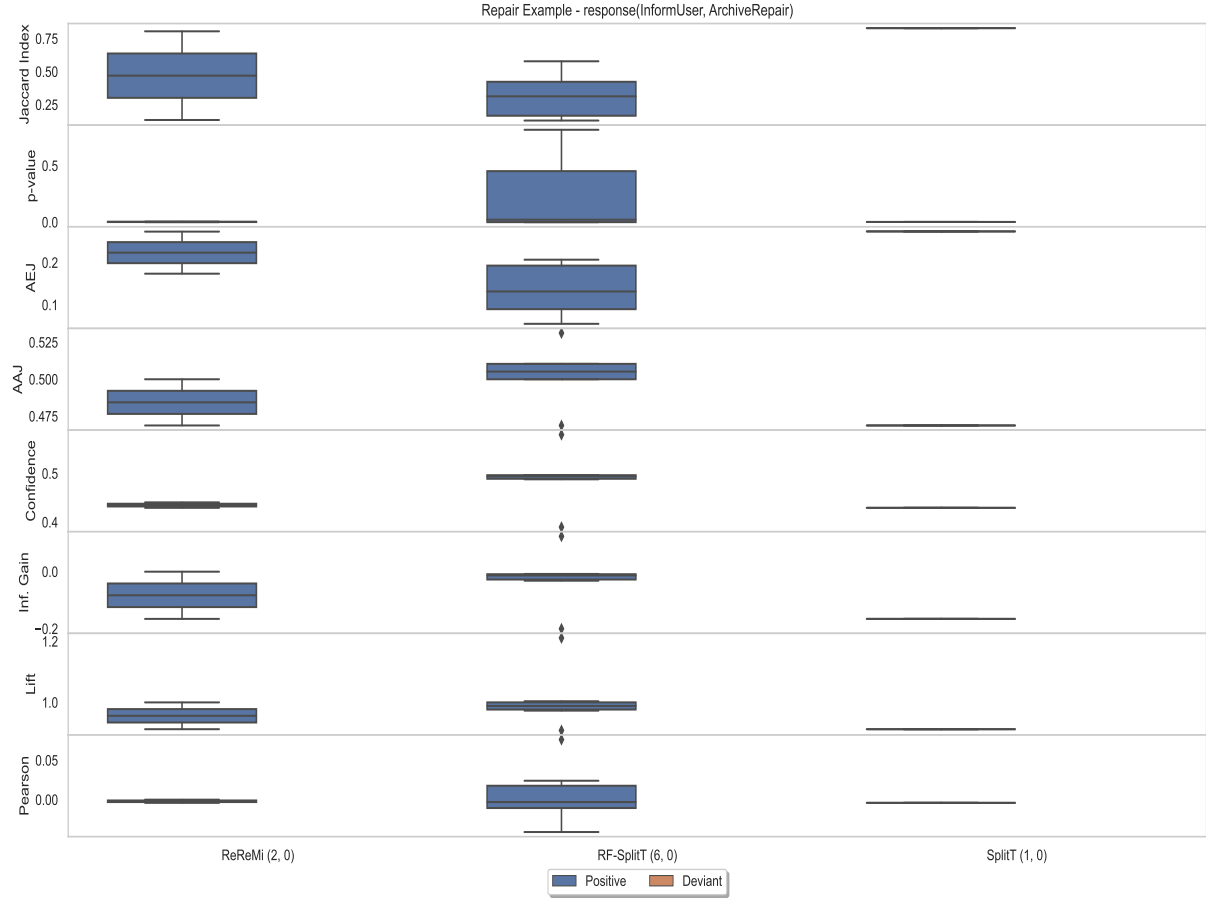


Figure 6: Repair Example - response(InformUser, ArchiveRepair)

positive event log (cf. Fig. 6):

1. The ratio of discovered rules discovered from RF-SplitT is 3:1 compared to other SIREN algorithms.
2. The ReReMi and SplitT rules have a higher accuracy (Jaccard index).
3. None of the algorithms was able to discover rules from the deviant traces with respect to the constraint.
4. Also, for this constraint the discovered rules from the RF-SplitT are high

in amount, but the p-value has a high value which means that our data have occurred by random chance. However, this is a good thing that RF-SplitT was able to discover rule for such random behaviors.

### 3.3 Redescription Execution Time Analysis

In order to estimate the time required for deviance analysis in practice, we performed a runtime measurement for the different redescription algorithms. The results obtained are shown in Table 15. To allow a fair comparison, we run all algorithms on the same data models. Our measurements handle the time that an algorithm requires to discover the respective rules on a given input dataset. For the Repair Example, we found that the SplitT algorithm has the lowest execution time, while the ReReMi algorithm is the worst one. The reason why the ReReMi algorithm was slower than the other algorithms is its greedy behavior to go through each attribute therefore needing more computations. The SplitT algorithm, on the other hand, is a decision tree based algorithm where the trees grow based on the entropy calculation, resulting in faster tree discovery. The RF-SplitT algorithm is ranked third. This was also to be expected since it is an ensemble of decision trees and therefore takes more time than the SplitT algorithm.

Table 15: Execution times for Repair Example Process

Execution time for Repair Example							
	C <sub>1</sub> ,C <sub>2</sub>		C <sub>3</sub> ,C <sub>4</sub> ,C <sub>5</sub>		Time (s)		Rank
	P	N	P	N	P	N	
<b>ReReMi</b>	0.18	0.2	0.32	0.09	0.5	0.29	1
<b>RF-SplitT</b>	6.34	5.62	12.65	1.41	18.99	7.03	3
<b>SplitT</b>	0.41	0.31	0.45	0.15	0.86	0.46	2

### 3.4 Comparisons and Analysis of Discovered Redescriptions Evaluation

The final result of the deviance analysis pipeline is a detailed report in form of a human-readable text that explains the reasons of the deviance in general, as well as the causes for the deviance of the single process execution (cf. ReReMi (Table 16), RF-SplitT (Table 17) and SplitT (Table 18)). The tables have two sections, the *'Deviances of the event logs in general:'* and *'Analysing traces in detail:'*. In the *'Deviances of the event logs in general:'* section, the comparisons and analysis of deviant redescrptions with positive ones are handled. For example, all algorithms have detected that traces are deviant when the activity register is not executed by a tester and inform the user is not executed by a test. However, in positive traces, the execution of activity inform user is done by the solver. Moreover, as part of providing reasons on why particular deviant

traces occurred, we can see that in Table 16 the trace with ID 935 has deviated because the repair is not complex and the process is not executed by solver.

Table 16: Excerpt of the deviance report in natural language text (Repair Example Process - ReReMi)

**Deviances of the event logs in general:**

The first mined negative rule is 'If the register resource is Solver that implicates that the process is executed by System. (r2)' and its subrules comparisons to the positive subrules are below:

- The resource for the event 'Inform User' is executed by System in the negative rule, while in the positive rule r2, it is Solver.

The second mined negative rule is 'If the register resource is Tester that implicates that the user resource is Tester. (r0)' and its subrules comparisons to the positive subrules to the positive subrules are below:

- The resource for the event 'Register' is Tester in the negative rule, while in the positive rule r2, it is executed by Solver.
- The resource for the event 'Inform User' is Tester in the negative rule, while in the positive rule r2, it is Solver.

**Analysing traces in detail:**

- The process execution with 'Case No. 372' is deviant because the process is not executed by Solver (r1) and the process is not executed by Solver (r2).
- The process execution with 'Case No. 376' is deviant because the user complexity of repair differs from Complex (r1).
- The process execution with 'Case No. 935' is deviant because the user complexity of repair is not Complex (r1) and the process is not executed by Solver (r2).

Table 17: Excerpt of the deviance report in natural language text (Repair Example Process - RF-SplitT)

**Deviances of the event logs in general:**

The first mined negative rule is 'If the process is executed by Solver or the process is executed by System that implies that the user complexity of repair is Medium. (r5)' and its subrules comparisons to the positive subrules are below:

- The resource for the event 'Register' is executed by Solver in the negative rule, while in the positive rule r0, it is Tester.
- ...

The second mined negative rule is 'If the process is executed by Solver or the process is executed by System that implies the process is executed by System. (r0)' and its subrules comparisons to the positive subrules are below:

- The resource for the event 'Register' is executed by Solver in the negative rule, while in the positive rule r0, it is executed by Tester.
- ...

The third mined negative rule is 'If the process is executed by System or the register resource is Tester that implies the user complexity of repair is equal to Complex. (r4)' and its subrules comparisons to the positive subrules are below:

- The resource for the event 'Register' is executed by System in the negative rule, while in the positive rule r0, it is Tester.
- ...

The fourth mined negative rule is 'If the register resource is Solver that implicates that the user complexity of repair is equal to Simple. (r3)' and its subrules comparisons to the positive subrules are below:

- The resource for the event 'Register' is Solver in the negative rule, while in the positive rule r0, it is executed by Tester.
- ...

The fifth mined negative rule is 'If the register resource is Solver that implies that the user resource is Solver. (r1)' and its subrules comparisons to the positive subrules are below:

- The resource for the event 'Register' is Solver in the negative rule, while in the positive rule r0, it is Tester.
- ...

...

**Analysing traces in detail:**

- The process execution with 'Case No. 207' is deviant because the user complexity of repair is not Medium (r5), the process is not executed by Solver (r8) and the process is not executed by Tester (r7).
- The process execution with 'Case No. 461' is deviant because the user complexity of repair is not Simple (r3), the process is not executed by Solver (r16) and the process is not executed by Solver (r4).
- The process execution with 'Case No. 799' is deviant because the process is not executed by System (r8), the process is not executed by Solver (r1) and the process is not executed by System (r3).



Table 18: Excerpt of the deviance report in natural language text (Repair Example Process - SplitT)

**Deviances of the event logs in general:**

The first mined negative rule is 'If the register resource is not Tester that implicates that the user resource is not Tester. (r7)' and its subrules comparisons to the positive subrules are below:

- The resource for the event 'Register' is not Tester in the negative rule, while in the positive rule r37, it is not System.
- The resource for the event 'Inform User' is not Tester in the negative rule, while in the positive rule r37, it is executed by Solver.

The second mined negative rule is 'If the process is executed by Tester that implicates that the user resource is Tester. (r3)' and its subrules comparisons to the positive subrules are below:

- The resource for the event 'Register' is executed by Tester in the negative rule, while in the positive rule r37, it is not executed by System.
- The resource for the event 'Inform User' is Tester in the negative rule, while in the positive rule r37, it is Solver.

**Analysing traces in detail:**

- The process execution with 'Case No. 1' is deviant because the process is not executed by System (r17), the user complexity of repair is not Complex (r21) and the process is not executed by Solver (r37).
- The process execution with 'Case No. 375' is deviant because the process is not executed by System (r17) and the user complexity of repair is unequal to Complex (r21).
- The process execution with 'Case No. 888' is deviant because the process is not executed by System (r17), the user complexity of repair differs from Complex (r21) and the process is not executed by Solver (r37).