



Enhancing Performance And Reliability of Rule Management Platforms

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Rule Management Platforms (REMPs) allow software engineers to represent programming logic as conditional sentences that relate statements of facts (i.e., **rules**) using high-level declarative languages



Rule Structure And Example

Rules Format:

when
 <conditions>
then
 <actions>

Antecedent

Consequence

Example:

```
rule simple_rule:
  When
    Student( points >= 80 )
  then
    System.out.println( "A+" );
End
```

An Interesting Question

Rule A:

When

Product (Price < 80)

Then

set(Price, 100);

Rule B:

When

Product (Price > 50)

Then

set(Price, 200);

Price = 65

An Interesting Question

Rule A:

When

Product (Price < 80)

Then

set(Price, 100);

Rule B:

When

Product (Price > 50)

Then

set(Price, 200);

Price = 65

An Interesting Question

Rule A:

When

Product (Price < 80)

Then

set(Price, 100);

Rule B:

When

Product (Price > 50)

Then

set(Price, 200);

Price = 65

If-Then Decision Points

Alternative to rules is the imperative model where sequences of if-then statements with conditionals and loops are evaluated in a strictly defined order.

```
1 C   A weird program for calculating Pi written in Fortran.
2 C   From: Fink, D.G., Computers and the Human Mind, Anchor Books, 1966.
3
4     PROGRAM PI
5     DIMENSION TERM(100)
6     N=1
7     TERM(N)=((-1)**(N+1))*(4./(2.*N-1.))
8     N=N+1
9     IF (N-101) 3,6,6
10    N=1
11    SUM98 = SUM98+TERM(N)
12    WRITE(*,28) N, TERM(N)
13    N=N+1
14    IF (N-99) 7, 11, 11
15    SUM99=SUM98+TERM(N)
16    SUM100=SUM99+TERM(N+1)
17    IF (SUM98-3.141592) 14,23,23
18    IF (SUM99-3.141592) 23,23,15
19    IF (SUM100-3.141592) 16,23,23
20    AV89=(SUM98+SUM99)/2.
21    AV90=(SUM99+SUM100)/2.
22    COMANS=(AV89+AV90)/2.
23    IF (COMANS-3.1415920) 21,19,19
24    IF (COMANS-3.1415930) 20,21,21
25    WRITE(*,26)
26    GO TO 22
27    WRITE(*,27) COMANS
28    STOP
29    WRITE(*,25)
30    GO TO 22
31    FORMAT('ERROR IN MAGNITUDE OF SUM')
32    FORMAT('PROBLEM SOLVED')
33    FORMAT('PROBLEM UNSOLVED', F14.6)
34    FORMAT(I3, F14.6)
35    END
36
```

If-Then Decision Points

Alternative to rules

is the imperative model where sequences of statements with conditionals and loops are evaluated in a strictly defined order.

Hard to maintain and inefficient code that is not adaptable to frequent changes in business requirements

```
1 C A weird program for calculating Pi written in Fortran.  
2 C From: Fink, D.G., Computers and the Human Mind, Anchor Books, 1966.  
3  
4 PROGRAM PI  
5 DIMENSION TERM(100)
```

```
6 N=1  
7 TERM(N)=((-1)**(N+1))*(4./(2.*N-1.))  
8  
9 SUM98=0.  
10  
11 DO 10 N=1,100  
12   SUM98=SUM98+TERM(N)  
13  
14   WRITE(+,28) N,TERM(N)  
15  
16   SUM99=SUM98+TERM(N)  
17  
18   IF (SUM99-3.141592) 14,23,23  
19  
20   SUM100=SUM99+TERM(N+1)  
21  
22   IF (SUM100-3.141592) 15,23,15  
23  
24   AV89=(SUM98+SUM99)/2.  
25  
26   AV90=(SUM99+SUM100)/2.  
27  
28   COMANS=(AV89+AV90)/2.  
29  
30   WRITE(+,27) COMANS  
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32   GO TO 22  
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REMPS Are Widely Used

According to market report from Forrester, the estimated revenue of business rules management systems (BRMS) increased from \$265 million in 2008 to over \$600 million in 2011. It is one of the fastest growing markets.

One leading vendor, IBM ILOG Optimization is used by over 50% of the world's largest companies, 1000's of Universities, and 1000's of application providers.

CLIPS

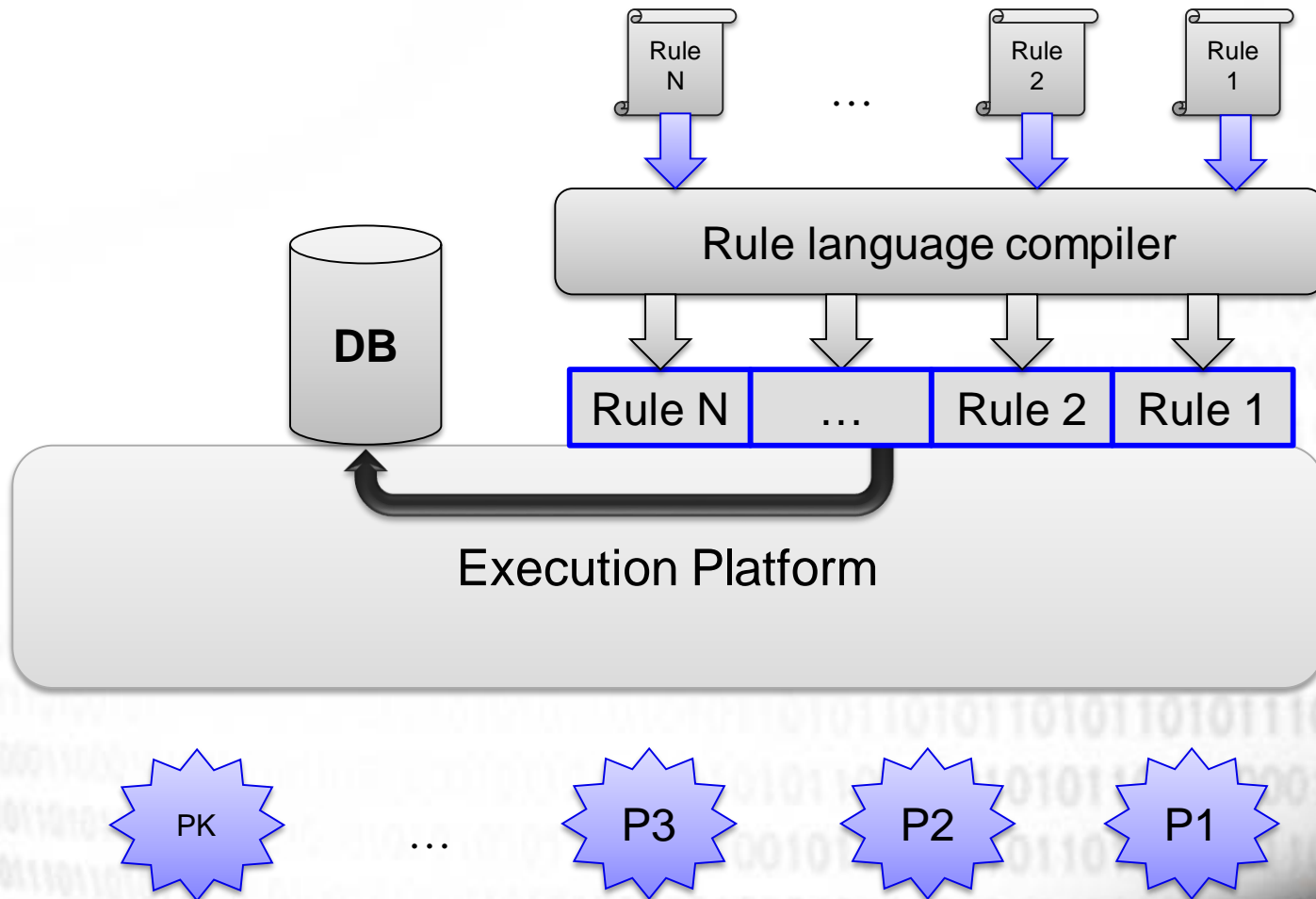
JBoss Drools

BizTalk

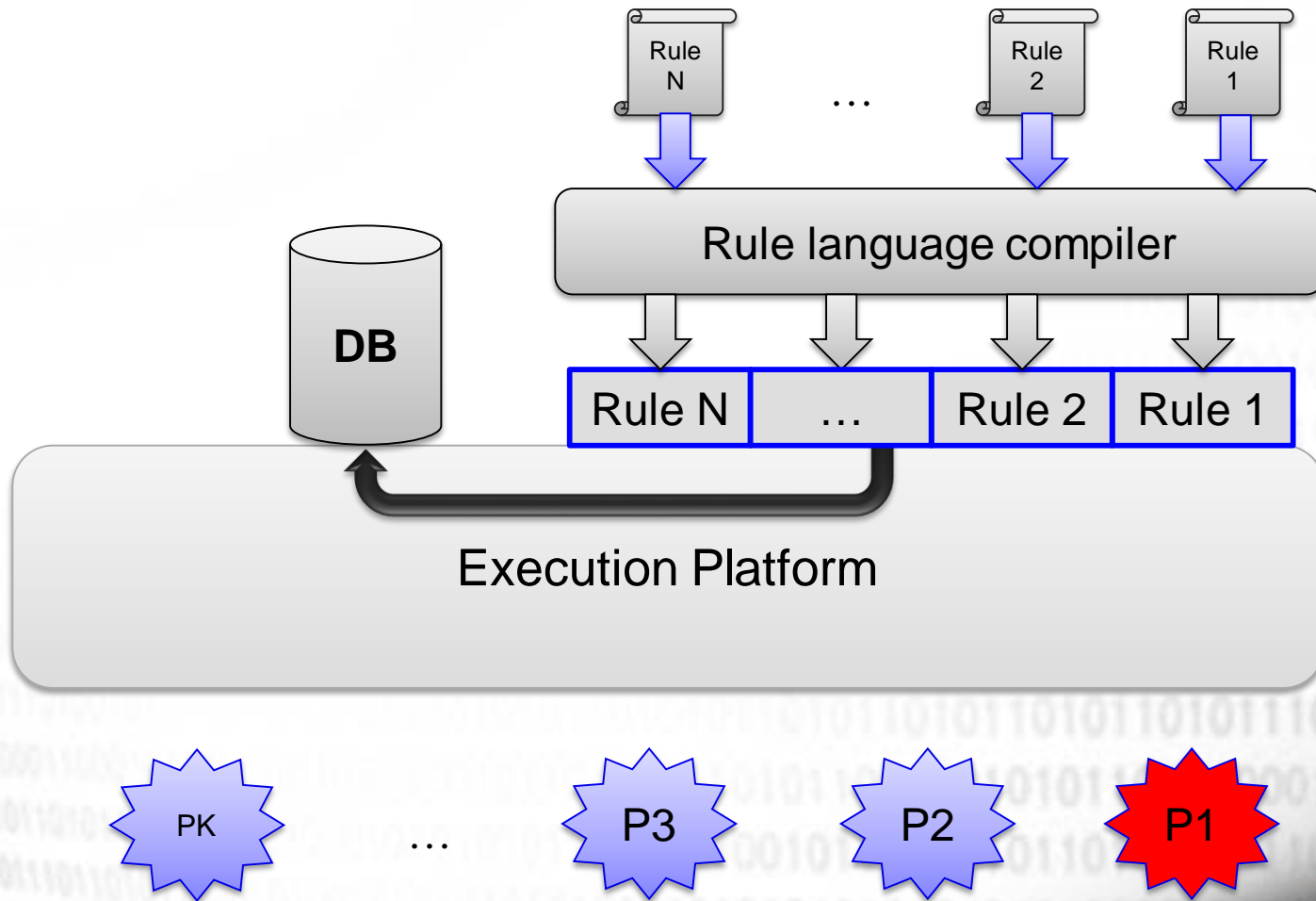
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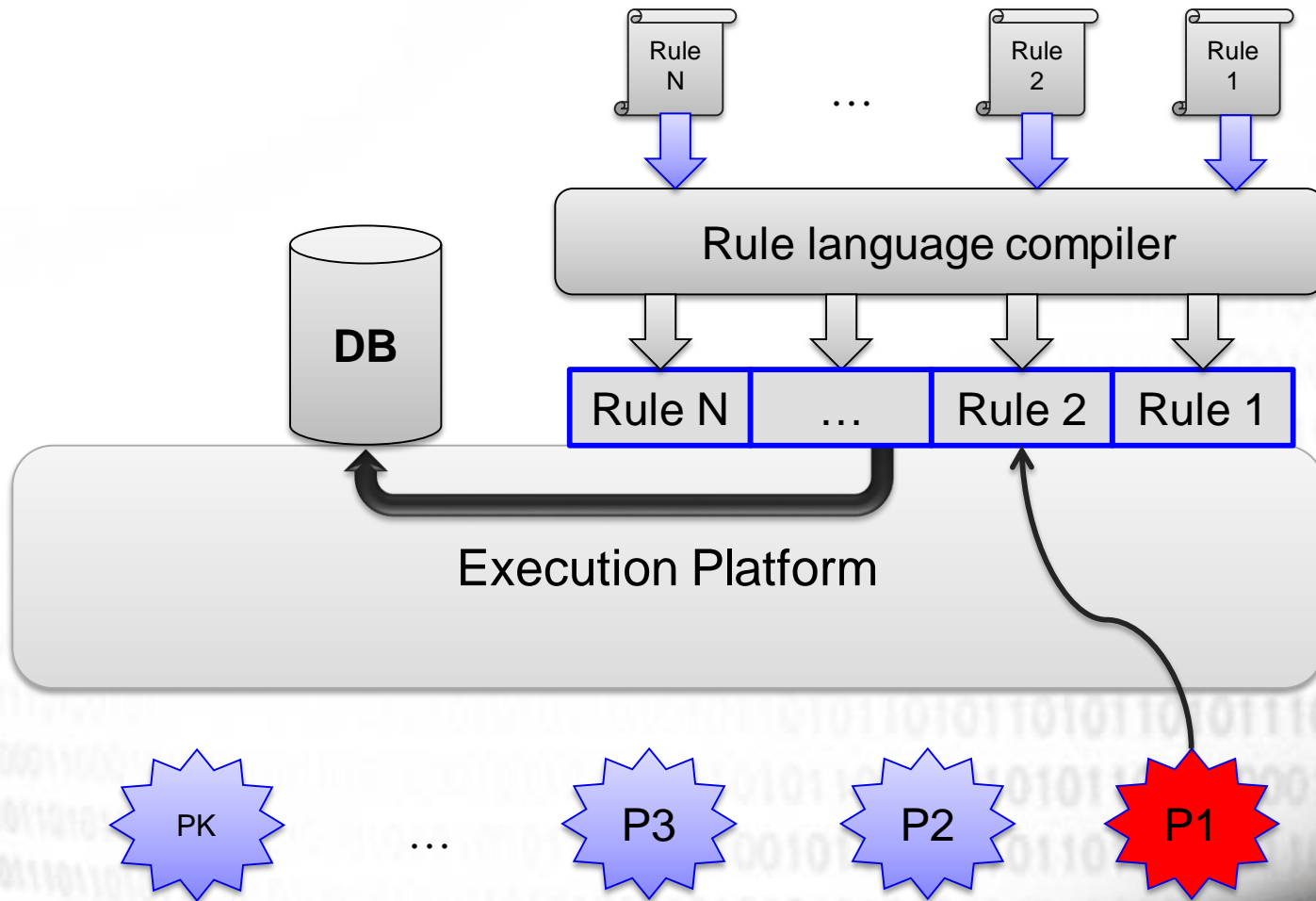
How REMPs Work



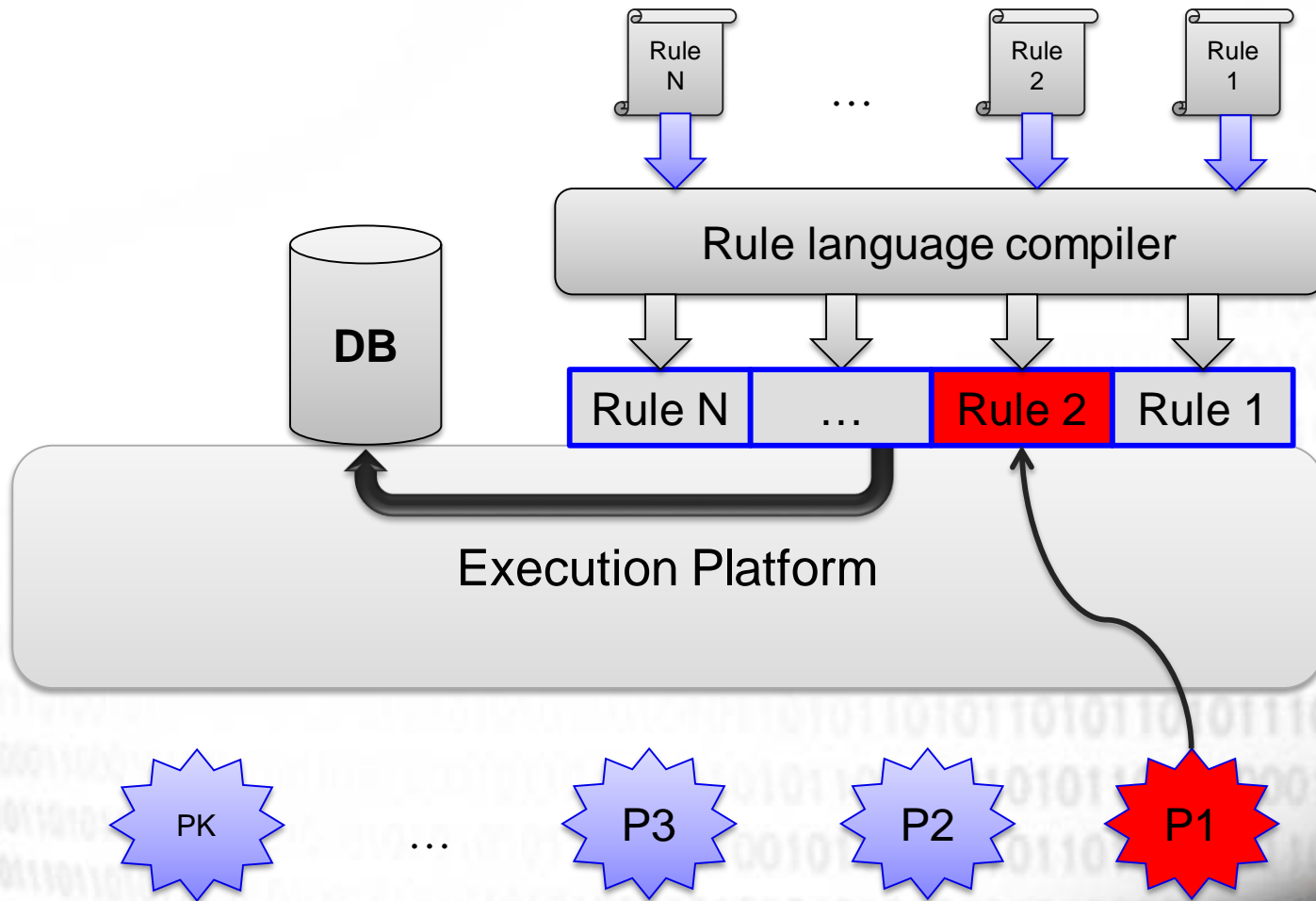
How REMPs Work



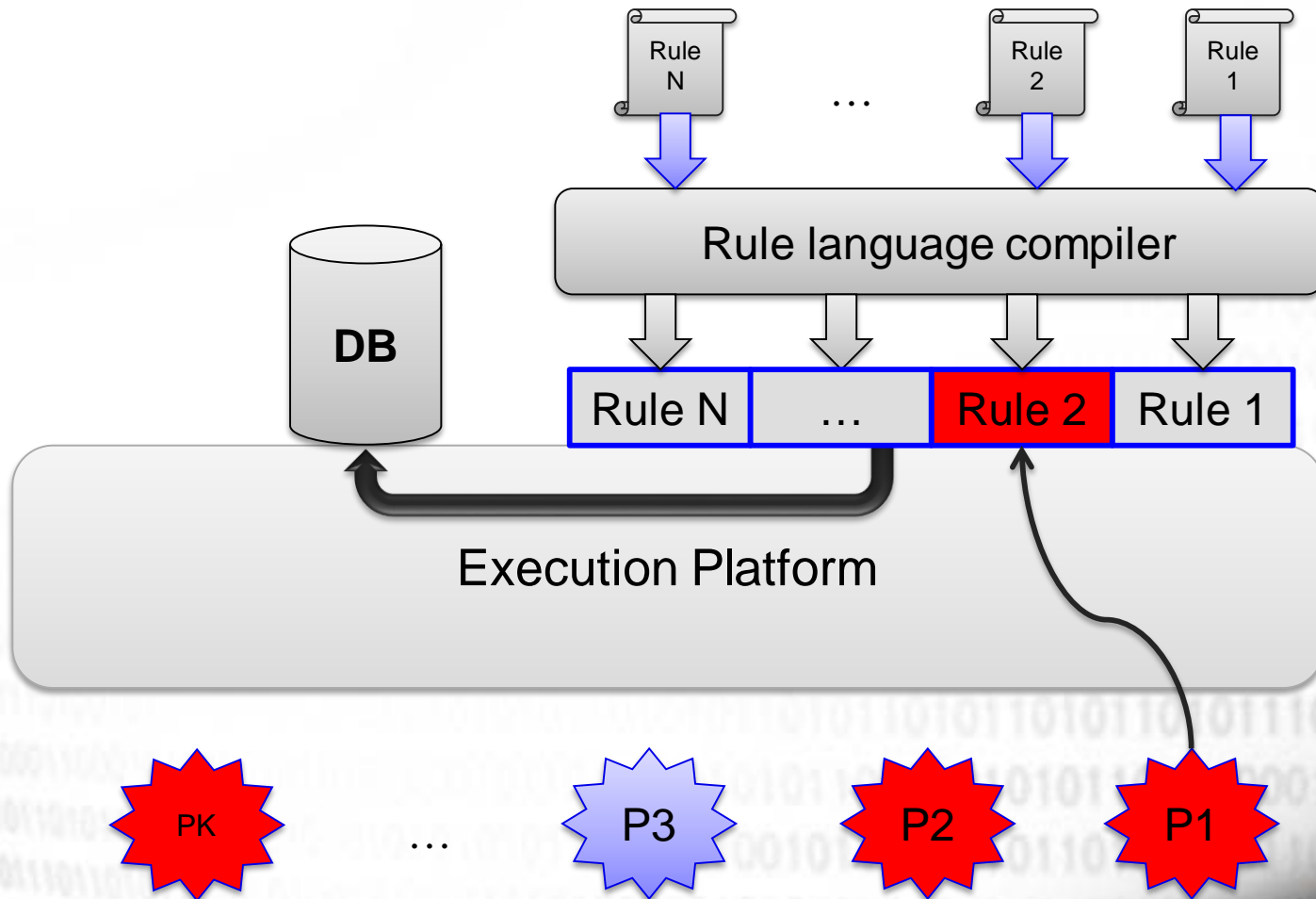
How REMPs Work



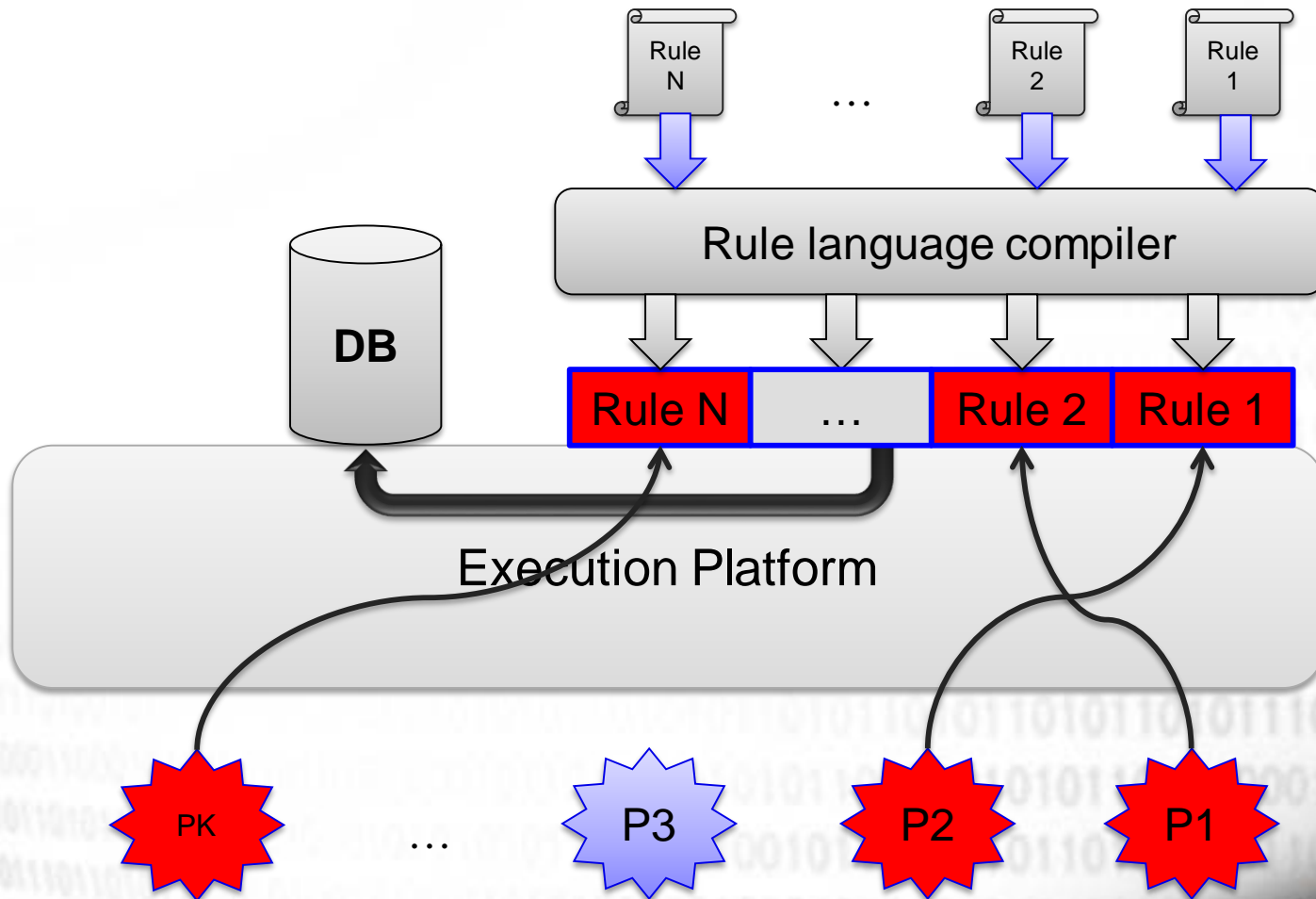
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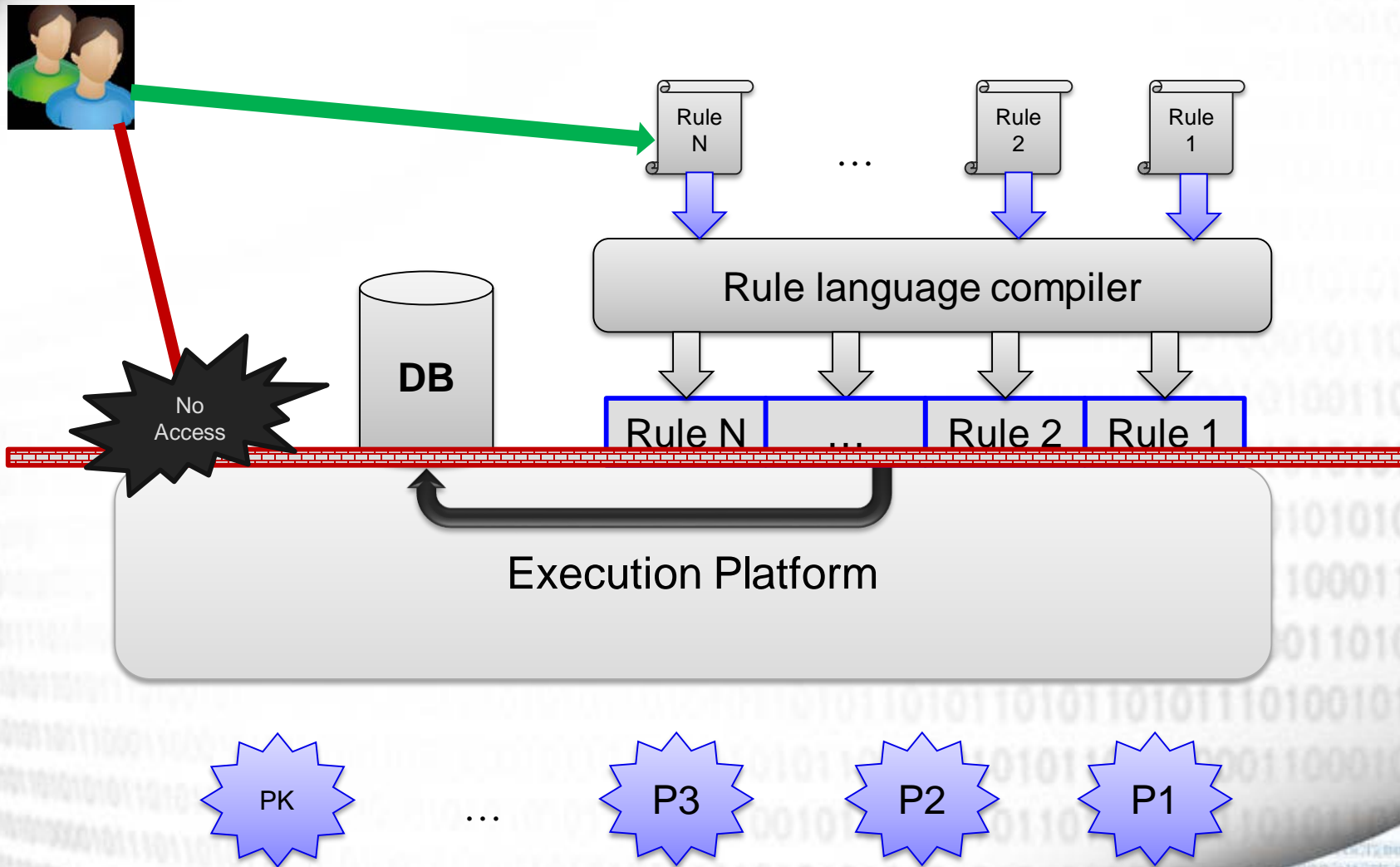
How REMPs Work



How REMPs Work



How REMPs Work



Separation of Concerns

A key property of REMPs is that they encapsulate the control flow that includes fact inference and rule firing logics

- It is a fundamental separation of concerns of the control flow and the rule business logic.

Software engineers concentrate on reasoning about higher-level business logic that they encode in rules without worrying about low-level details of rule invocations by effectively delegating this job to REMP engines

- Rule-driven APplications (RAPs) are highly adaptable to changing requirements, since stakeholders simply add new rules as independent modules to RAPs

Benefits of REMPs And RAPs

Easy to maintain & evolve

Rules are easy to comprehend and highly modular

RAPs are highly adaptable

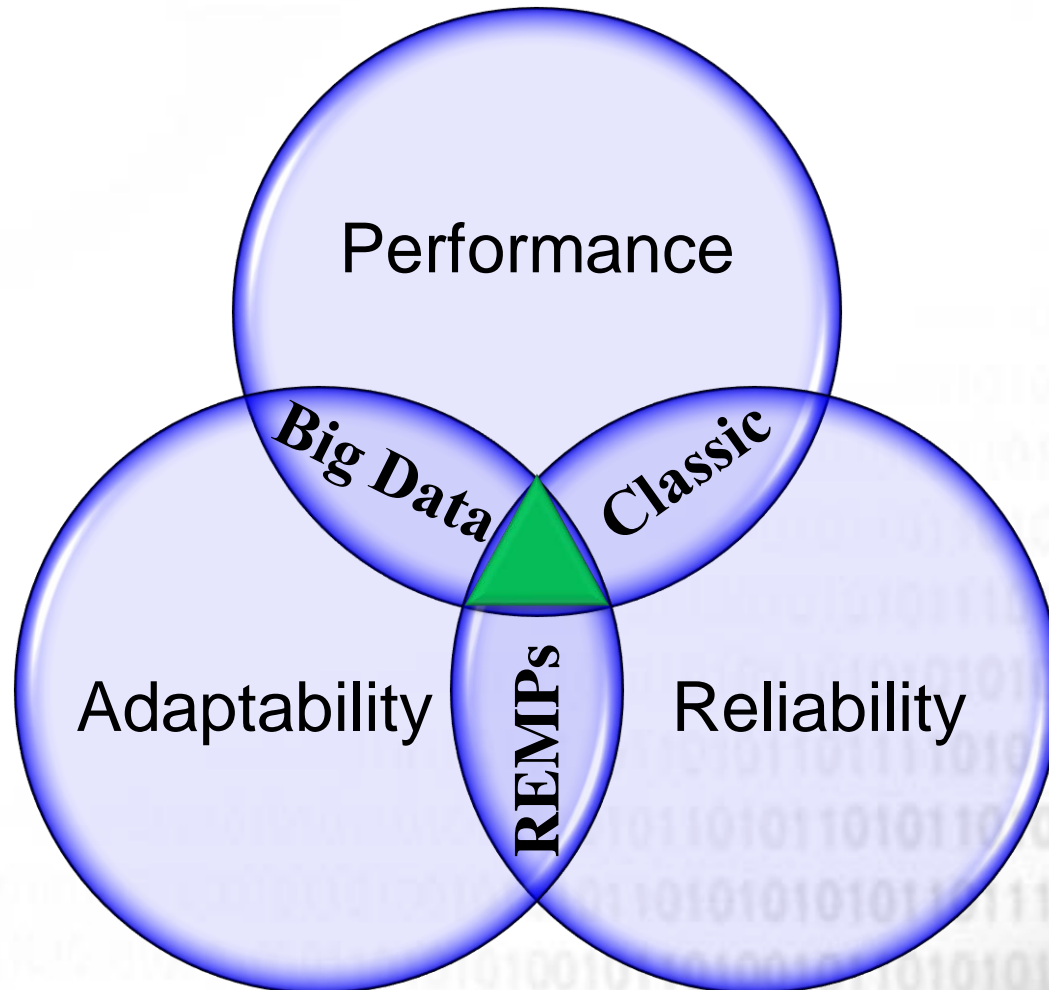
Constraints of REMPs And RAPs

RAPs may contain tens of thousands of rules

Detection of conflicting rules is difficult

Dependencies should not be introduced among rules

The PAR Model For REMPs



Fundamental Problem

Many REMPes execute RAPs sequentially.

Locks introduce complex dependencies among rules, thereby defeating the separation of concerns and eventually the adaptability of RAPs.

How to enhance the performance of RAPs without sacrificing their adaptability and reliability?

Motivating Example: Credit

```
rule "Rule-Credit" salience 10
```

```
when
```

```
    $cashflow : Cashflow( $account:account,
```

```
    $date : date, $amount : amount,
```

```
    type==Cashflow.CREDIT )
```

```
    not Cashflow(account==$account,date<$date)
```

```
then
```

```
    //some code
```

```
    $account.setBalance(
```

```
        $account.getBalance()+$amount);
```

```
    retract($cashflow);
```

```
end
```

Motivating Example: Debit

rule "Rule-Debit" salience 1

when

```
$cashflow : Cashflow( $account : account,  
$date : date, $amount : amount,  
type==Cashflow.DEBIT )  
not Cashflow(account==$account,date<$date)
```

then

```
//some code
```

```
if($account.getBalance()>$amount){  
    $account.setBalance(  
        $account.getBalance()-$amount); }  
else { new BlockedAccount($cashflow); }  
retract($cashflow);
```

end

Parallelism Interferes With Saliences

Let us assume that a REMP engine executes rules in parallel and lock objects are used to synchronize concurrent accesses.

Using a lock object effectively overrides the intention of the programmer to give the priority to the rule with a higher salience.

Given the large number of possible interleavings among tens of thousands of rules in a RAP, it is very difficult to reason about interactions between saliences and synchronization lock mechanisms.

Reliability Meets Performance

In fully parallelized REMP's, loss of reliability comes from two sources:

- different orders in which rules are executed by the REMP engines;
- races between parallelized executions of rules.

When the system produces different results consecutively for the same computational task using the same input data, it is a serious problem, since it reduces the confidence of the user in the RAP and it impacts negatively the perception of the user about the business value that the company or organization delivers.

- the execution order for different instructions can be affected by multiple factors beyond the control of stakeholders
- sometimes even slight changes in the non-functional parameters of the environment (e.g., paging on demand) for executing RAPs result in different orders of instruction interleavings that lead to different results, hence the loss of reliability

The Problem Statement

Enable REMPes to execute rules in RAPs in parallel

Do not violate the separation of concerns in REMPes by requiring programmers to use synchronization lock mechanisms for concurrent accesses to shared resources

Prevent races in parallelized RAPs without explicit using of locking mechanisms by programmers

Choose a better schedule for executing rules that share the same lock objects to improve the overall performance of RAPs

Core Ideas



- 1) Find all concurrent access to resources from rules where one of the accesses is write.
- 2) Define synchronizations around these accesses.
- 3) Impose a complete ordering among all rules that are fired in working memory.

Our Solution - PERLATO

Performance and Reliability for ruLe-driven Applications (PERLATO) connects separate layers or REMP's in a way that enable us to solve the fundamental problem of REMP.

- we obtain a rule execution model from a RAP that approximate different execution scenarios by using the if-then structure of rules by analyzing their antecedents and consequents
- the obtained rule execution model is used in PERLATO to detect races statically among these rules effectively and efficiently
- the rule execution model and locking strategies for a given RAP are passed to the REMP engine, so that it can precompute an execution schedule for rules in a RAP to optimize the performance of the RAP.
- **We implemented PERLATO for JBoss Drools, an open-source enterprise-level REMP and we evaluated PERLATO on three RAPs. The results suggest that PERLATO is effective and efficient, since we achieved up to 225% speedup on average without observing any races.**

Map fo PERLATO

Massive Parallel Computing

Parallelize

Schedule

Optimize

Performance

Reliability

Rule Management Platform

Knowledge Base

Reasoning Engine

Event Processing

Enterprise
Infrastructure

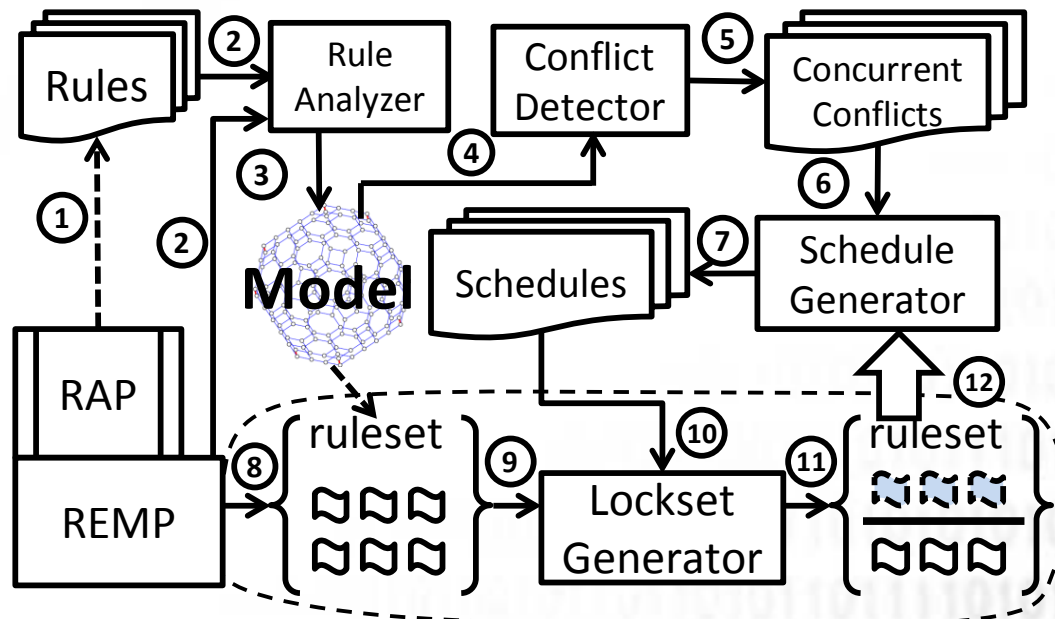
Rule Execution Model

Key Concepts of Rule-based Engineering

Implicit Rule
Invocations

Rule Independence
And Modularity

The Architecture of PERLATO



Research Questions

Is PERLATO effective in achieving higher speedups for subject RAPs?

Is finer granularity locking strategy more effective in obtaining higher speedup for RAPs?

Is symbiotic scheduling effective in obtaining higher speedup for RAPs?

Result for Subject RAPs

| Application | Input Set | Facts | Rules Fired | Approach | Type | Avg | Med | Min | Max | σ^2 |
|-------------|-----------|--------|-------------|----------|--------|--------|--------|--------|--------|------------|
| EEWS | 1 | 246896 | 1088 | DROOLS | Seq | 32.22 | 32.08 | 31.559 | 35.358 | 0.4 |
| | | | | | Par | 9.52 | 9.27 | 8.267 | 11.789 | 0.87 |
| | | | | PERLATO | Rule | 13.44 | 13.6 | 10.927 | 14.911 | 0.99 |
| | Atomic | 10.85 | 10.82 | | 10.21 | 11.867 | 0.14 | | | |
| | Variable | 10.67 | 10.67 | | 10.21 | 11.359 | 0.06 | | | |
| | 2 | 334220 | 1454 | DROOLS | Seq | 42.31 | 42.12 | 41.508 | 43.322 | 0.21 |
| | | | | | Par | 11.62 | 11.53 | 10.299 | 14.126 | 0.85 |
| | | | | PERLATO | Rule | 18.86 | 19.02 | 15.794 | 21.549 | 2.07 |
| | Atomic | 15.62 | 15.58 | | 15.016 | 16.476 | 0.11 | | | |
| Variable | 15.08 | 15.02 | 14.24 | | 16.689 | 0.21 | | | | |
| 3 | 247113 | 572 | DROOLS | Seq | 19.51 | 19.44 | 18.906 | 21.115 | 0.24 | |
| | | | | Par | 6.05 | 6.19 | 3.947 | 8.242 | 1.32 | |
| | | | PERLATO | Rule | 8.33 | 8.22 | 7.025 | 9.442 | 0.42 | |
| Atomic | 7.24 | 7.13 | | 6.837 | 8.259 | 0.13 | | | | |
| Variable | 6.79 | 6.76 | 6.662 | 7.165 | 0.02 | | | | | |
| TAXC | 1 | 16 | 95 | DROOLS | Seq | 20.4 | 20.32 | 20.023 | 20.97 | 0.06 |
| | | | | | Par | 19.52 | 19.52 | 19.115 | 20.072 | 0.07 |
| | | | | PERLATO | Rule | 19.71 | 19.69 | 19.232 | 20.657 | 0.13 |
| | | | | | Atomic | 19.62 | 19.61 | 19.144 | 20.227 | 0.08 |
| | Variable | 19.55 | 19.52 | 19.077 | 20.161 | 0.08 | | | | |
| | 2 | 22 | 162 | DROOLS | Seq | 42.48 | 42.48 | 41.553 | 43.63 | 0.32 |
| | | | | | Par | 34.27 | 34.6 | 31.866 | 36.019 | 1.13 |
| | | | | PERLATO | Rule | 36.87 | 36.83 | 36.016 | 37.812 | 0.19 |
| | | | | | Atomic | 36.86 | 36.77 | 36.007 | 37.775 | 0.21 |
| | Variable | 36.8 | 36.74 | 35.972 | 37.698 | 0.23 | | | | |
| | 3 | 10 | 66 | DROOLS | Seq | 11.78 | 11.73 | 11.549 | 12.344 | 0.04 |
| | | | | | Par | 9.85 | 9.87 | 9.116 | 10.314 | 0.05 |
| PERLATO | | | | Rule | 9.93 | 9.9 | 9.641 | 10.431 | 0.03 | |
| | | | | Atomic | 9.91 | 9.92 | 9.145 | 10.342 | 0.04 | |
| Variable | 9.98 | 9.97 | 9.309 | 10.761 | 0.06 | | | | | |

Conclusions

We created a novel solution for enhancing performance and reliability of rule-driven applications.

The results suggest that PERLATO is effective, since we achieved over 225% speedup on average.



Thank You

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