prepare for...

Mutation Testing

..from jUnit to Mutation-Testing

@SvenRuppert

has been coding java since 1996

Fellow / Head of R&D

reply Group

Germany - Munich

@SvenRuppert

has been coding java since 1996

@SvenRuppert

has been coding java since 1996

Projects in the field of:

- Automobile-industry
- Energy
- Finance / Leasing
- Space- Satellit-
- Government / UN / World-bank

Where?

- Europe
- Asia - from India up to Malaysia

Save harbor statement

Save harbor statement

The following is intended for information purposes only. I can not be held responsible for the overuse of effects and animations in this presentation. If any person in this room has a medical condition that is triggered by fast moving objects on the screen and/or explosions, he/she should probably better leave now...

(I got carried away by the topic.)

The Environment

Codebase is > 13 years old

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no test coverage

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no dedicated refactoring budget

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decrease complexity

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but... lets start with the basics

TDD with jUnit

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TDD with jUnit

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are you using jUnit?

TDD with jUnit

are you using jUnit?

assume that the following would make sense.. ;-)

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assume that the following would make sense.. ;-)

```
public class Service {
    public int add(int a, int b){
        if(a<2){
            return (a+b) * -1;
        } else {
            return a+b;
        }
    }
}
```

are you using jUnit?

assume that the following would make sense.. ;-)

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How many tests you will need ?

TDD with jUnit

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it depends ;-)

TDD with jUnit

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it depends ;-)

for line 100% coverage

TDD with jUnit

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How many tests you will need ?

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for line 100% coverage 2

TDD with jUnit


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public class Service {
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    }
  }
}
```

How many tests you will need ?

it depends ;-)

for line 100% coverage 2

but will this be enough?

TDD with jUnit


```
public class Service {
  public int add(int a, int b){
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  }
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```

How many tests you will need ?

it depends ;-)

for line 100% coverage 2

but will this be enough? **No**

TDD with jUnit


```
public class Service {
  public int add(int a, int b){
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How many tests you will need ?

it depends ;-)

for line 100% coverage 2

but will this be enough? **No**

TDD with jUnit

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How many tests you will need ?

it depends ;-)

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but will this be enough? **No**

how to find out, what will be enough?

TDD with jUnit


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public class Service {
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How many tests you will need ?

it depends ;-)

for line 100% coverage 2

but will this be enough? **No**

how to find out, what will be enough?

how to find the right tests?

TDD with jUnit

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```
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    } else {
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    }
  }
}
```

```
@Test
public void testAdd001() throws Exception {
  final int add = new Service().add(0, 0);
  Assertions.assertThat(add).isEqualTo(0);
}
```

How many tests you will need ?

TDD with jUnit

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How many tests you will need ?

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@Test
public void testAdd001() throws Exception {
  final int add = new Service().add(0, 0);
  Assertions.assertThat(add).isEqualTo(0);
}
@Test
public void testAdd002() throws Exception {
  final int add = new Service().add(3, 0);
  Assertions.assertThat(add).isEqualTo(3);
}
```

Mutation Testing

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Mutation Testing

Mutation Testing is a structural testing method

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we want to find a way to write "good" tests

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let the machine find the targets

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let the machine find the targets

let´s mutate it.... but how?

Mutation Testing - the Idea

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a mutation is a small change in the code

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.. small enough to be a small defect

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P will be the program

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T will be the collection of all tests / Test Suite

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we will create a sequence of mutations / **P1**,**P2**,**P3**...

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... **Px** will have only one mutation compared to **P**

Mutation Testing - the Idea

P will be the program

T will be the collection of all tests / Test Suite

we will create a sequence of mutations / **P1**,**P2**,**P3**...

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running all tests from **T** against **Px**

Mutation Testing - the Idea

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green: **T** will kill the mutation

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.. at leased one test from **T** will fail

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.. **Px** will have only one mutation compared to **P**

running all tests from **T** against **Px**

green: **T** will kill the mutation

.. at leased one test from **T** will fail

red: if all tests are green

Mutation Testing - the Idea

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if we kill **k** out of **n** mutants

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.. the good thing..

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if we kill **k** out of **n** mutants

-> we are not good enough ;-)

we are **perfect** enough if we are reaching : **k == n**

how to create all versions of Px ?

.. the good thing..

we could almost generate/ automate everything

practical TDD with Mutation Testing

Mutation Testing

practical TDD with Mutation Testing

generating the mutants and

Mutation Testing

practical TDD with Mutation Testing

generating the mutants and
running all junit tests

Mutation Testing

practical TDD with Mutation Testing

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check the reports

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generating the mutants and
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write more / better tests

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practical TDD with Mutation Testing

generating the mutants and

running all junit tests

check the reports

write more / better tests

loop until quality target reached

Mutation Testing

mutants are a good approach / model to estimate the default rate of defects per 1k lines of the **P**

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the defects are independent

Mutation Testing

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estimate that:

the defects are independent normaly ;-)

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.. how to find YOUR barrier you have to reach?

Mutation Testing

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.. how to find YOUR barrier you have to reach?

but.. what is a mutation?

Mutation Testing - Kinds of Mutation

but.. what is a mutation?

Value Mutation

changing constants,
loop bounds (adding/subtracting values)

Mutation Testing - Kinds of Mutation

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but.. what is a mutation?

Value Mutation

Decision Mutation

for example **<** will be changed to **<=**

Mutation Testing - Kinds of Mutation

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but.. what is a mutation?

Value Mutation Decision Mutation

Statement Mutation

for example swapping/deleting/duplicating
lines of code

Mutation Testing - Kinds of Mutation

but.. what is a mutation?

Value Mutation Decision Mutation
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for **Java** you could think about more language spec. mutations

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.. changing between static / non static

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.. delete member initialization

Mutation Testing - Kinds of Mutation

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.. delete this.

Mutation Testing - Kinds of Mutation

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for **Java** you could think about more language spec. mutations

.. changing modifiers

.. changing between static / non static

.. delete member initialization

.. delete this.

.. argument order change

Mutation Testing - in short words

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mutation testing is an add on to normal jUnit TDD

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but most important

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will effect your project structure

Mutation Testing - Frameworks

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muJava

Mutation Testing - Frameworks

muJava

2003. First released as JMutation (Java Mutation System).
2004. The name was changed to MuJava (Mutation System for Java).
2005. Software Copyright Registration, ALL RIGHTS RESERVED.
2005. Version 2 released with several fault fixes and modified mutation operators.
2008. Version 3 released with minimal support for Java 1.5 and 1.6.
2013. Version 4 released to support JUnit tests and Java 1.6 language features, including generics, annotations, enumerations, varargs, enhanced for-each loops, and static imports.
2015. Additional and improved error messages. Bug fixes for OpenJava. Licensing changed to the Apache license.

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https://cs.gmu.edu/~offutt/mujava/

https://github.com/jeffoffutt/muJava/graphs/contributors

Mutation Testing - Frameworks

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Mutation Testing - Hello World

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Mutation Testing - Hello World

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how many test you will need for..

Mutation Testing - Hello World


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how many test you will need for..

100% Line Coverage... and...

Mutation Testing - Hello World


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how many test you will need for..

100% Line Coverage... and... **to be save ?**

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how many test you will need for..

100% Line Coverage... and...

2 for Line Coverage

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```

how many test you will need for..

100% Line Coverage... and...

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to be save ?

we will see ;-)

Mutation Testing - Hello World

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100% Line Coverage... and...

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```

100% Line Coverage... and...

we have one if statement

Mutation Testing - Hello World


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100% Line Coverage.... and...

we have one if statement with an else branch

Mutation Testing - Hello World


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    }
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```

100% Line Coverage.... and...

we have one if statement with an else branch

this will lead to 2 jUnit Tests to get 100 %

Mutation Testing - Hello World

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public class Service {
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    if (a<2) { return (a+b) * -1; }
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100% Line Coverage.... and....

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100% Line Coverage.... and....

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@Test
public void testAdd001() throws Exception {
  final int add = new Service().add(0, 0);
  Assertions.assertThat(add).isEqualTo(0);
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100% Line Coverage.... and....

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@Test
public void testAdd001() throws Exception {
  final int add = new Service().add(0, 0);
  Assertions.assertThat(add).isEqualTo(0);
}
  @Test
  public void testAdd002() throws Exception {
    final int add = new Service().add(3, 0);
    Assertions.assertThat(add).isEqualTo(3);
  }
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final int add = new Service().add(0, 0);
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 6. public class Service {
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12.     }
13.   }
```

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final int add = new Service().add(3, 0);
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we got 100% Line Coverage

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How good these tests are?

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we got 100% Line Coverage

How good these tests are?

How to measure if these test are good?

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we got 100% Line Coverage

How good these tests are?

How to measure if these test are good?

How to find the good tests?

Mutation Testing - Hello World

@SvenRuppert

```
final int add = new Service().add(0, 0);
final int add = new Service().add(3, 0);
```

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How to find the good tests?

let´s generate a the mutation report

Mutation Testing - Hello World


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with maven : **`pitest: mutationCoverage`**

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Mutation Testing - Hello World

@SvenRuppert

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>> Generated 54 mutations Killed 3 (6%)

Mutation Testing - Hello World


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`org.pitest……mutators.`**`ConditionalsBoundaryMutator`**

Mutation Testing - Hello World


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```
org.pitest……mutators.ConditionalsBoundaryMutator
org.pitest……mutators.IncrementsMutator
```

Mutation Testing - Hello World


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org.pitest……mutators.MathMutator
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Breakdown by Class

Name	Line Coverage		Mutation Coverage	
Service.java	100%	4/4	43%	3/7

Mutation Testing - Hello World

@SvenRuppert

```
final int add = new Service().add(0, 0);
final int add = new Service().add(3, 0);
```

>> Generated 54 mutations Killed 3 (6%)

```
6     public class Service {
7       public int add(int a, int b) {
8   2       if (a < 2) {
9   3           return (a + b) * -1;
10          } else {
11  2           return a + b;
12          }
13      }
```

Mutation Testing - Hello World

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Mutation Testing - Hello World

@SvenRuppert

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```

>> Generated 54 mutations Killed 5

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Mutation Testing - Hello World

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>> Generated 54 mutations Killed 5

killed 9:1

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```

>> Generated 54 mutations Killed 6

killed 9:1

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```

>> Generated 54 mutations Killed 6

killed 11:1

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Mutation Testing - Lesson Learned

@SvenRuppert

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mutation tests are often leading to

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mutation tests are often leading to

....cleaner code compared to jUnit only

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.... smaller modules (shorter mutation runtime)

Mutation Testing - Lesson Learned

mutation tests are often leading to

....cleaner code compared to jUnit only

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and something nice....
helps to find useless code

Example of useless Code

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@SvenRuppert

```
12  public class ReflectionUtils extends org.reflections.ReflectionUtils {
13
14    public boolean checkInterface(final Type aClass, Class targetInterface) {
15 2    if (aClass.equals(targetInterface)) return true;
16
17     final Type[] genericInterfaces = ((Class) aClass).getGenericInterfaces();
18 2    if (genericInterfaces.length > 0) {
19 3      for (Type genericInterface : genericInterfaces) {
20 2        if (genericInterface.equals(targetInterface)) return true;
21
22         final Type[] nextLevBackArray = ((Class) genericInterface).getGenericInterfaces();
23 2        if (nextLevBackArray.length > 0)
24 3          for (Type type : nextLevBackArray) {
25 2            if (checkInterface(type, targetInterface)) return true;
26           }
27       }
28     }
29     final Type genericSuperclass = ((Class) aClass).getGenericSuperclass();
30 1    if (genericSuperclass != null) {
31 2      if (checkInterface(genericSuperclass, targetInterface)) return true;
32     }
33
34
35 1    return false;
36   }
```

Example of useless Code

@SvenRuppert

```
18 2     if (genericInterfaces.length > 0) {
19 3         for (Type genericInterface : genericInterfaces) {
```

Mutation Testing - How to start

@SvenRuppert

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you need jUnit - to generate the reference

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run **`pitest: mutationCoverage`**

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you need jUnit - to generate the reference

add the pitest-plugin to the build section

configure the plugin

generate the reference -> clean , install

run **`pitest: mutationCoverage`**

report will be under **target/pit-reports**

Mutation Testing - How to start

pom.xml - example - build

```
<plugin>
  <groupId>org.pitest</groupId>
  <artifactId>pitest-maven</artifactId>
  <configuration>
    <outputFormats>
      <outputFormat>XML</outputFormat>
      <outputFormat>HTML</outputFormat>
    </outputFormats>
    <targetClasses>
      <param>org.rapidpm.*</param>
    </targetClasses>
    <targetTests>
      <param>org.rapidpm.*</param>
      <param>junit.org.rapidpm.*</param>
    </targetTests>
  </configuration>
</plugin>
```

Mutation Testing - How to start

pom.xml - example - reporting

```
<reporting>
  <plugins>
    <plugin>
      <groupId>org.pitest</groupId>
      <artifactId>pitest-maven</artifactId>
      <reportSets>
        <reportSet>
          <reports>
            <report>report</report>
          </reports>
        </reportSet>
      </reportSets>
    </plugin>
  </plugins>
</reporting>
```

Mutation Testing - practical usage

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Start with some tests

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generate the pitest report

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Mutation 001 **Survived**

Mutation 002 **Survived**

Mutation 003 **Survived**

Mutation 004 **Survived**

Mutation Testing - practical usage

Start with some tests

generate the pitest report

write more tests to kill mutations

if you have time, eliminate useless tests

do it one by one

Mutation 001 **Survived ⇢ Killed**

Mutation 002 **Survived ⇢ Killed**

Mutation 003 **Survived ⇢ Killed**

Mutation 004 **Survived ⇢ Killed**

Summary

If you are interested...

have a look at **RapidPM** on github

rapidpm-proxybuilder

rapidpm-dynamic-cdi

rapidpm-microservice

or contact me ;-) @SvenRuppert

Summary

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have a look at **RapidPM** on github

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Thank You !!!

rapidpm-dynamic-cdi

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