mbeddr
C the Difference. C the Future.

# Robust C Code through language extensions and model checking

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SICK Sensor Intelligence. fortiss itemis

# What if…

you could change languages like you can change programs?

```
module WriteATestCase from cdesignpaper.unittest imports nothing {

  var int8_t failedTests;

  int32_t main(int32_t argc, int8_t*[ ] argv) {
    testMultiply();
    return failedTests;
  } main (function)

  void testMultiply() {
    if ( times2(21) != 42 ) { failedTests++; } if
  } testMultiply (function)

  int8_t times2(int8_t a) {
    return 2 * a;
  } times2 (function)
}
```

```
module UnitTestDemo from cdesignpaper.unittest imports nothing {

  int32_t main(int32_t argc, int8_t*[ ] argv) {
    return test testMultiply;
  } main (function)

  exported test case testMultiply {
    assert(0) times2(21) == 42;
  } testMultiply(test case)

  int8_t times2(int8_t a) {
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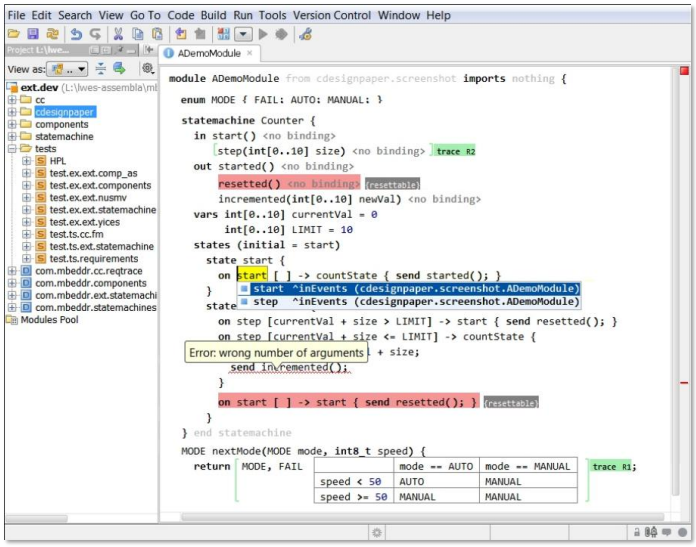
  int8_t times2(int8_t a) {
    return 2 * a;
  } times2 (function)
}
```

# mbeddr C Approach

# An extensible C with support for formal methods, requirements and PLE.

## IDE for Everything



# A debugger for all of that

# SDK for building your own Language Extensions!

IDE for Everything

JetBrains
MPS
Open Source
Language Workbench

# Challenges

## in embedded software development

# Abstraction without Runtime Cost

# C considered unsafe

# Program Annotations

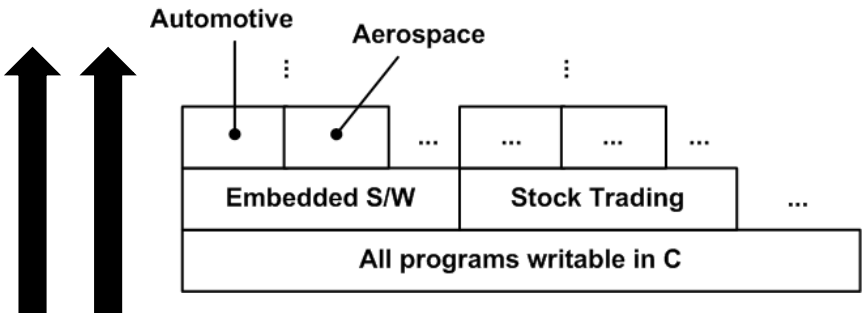
# Static Checks and Verification

# Product Lines and Requirement Traces

Separate, hard to integrate Tools

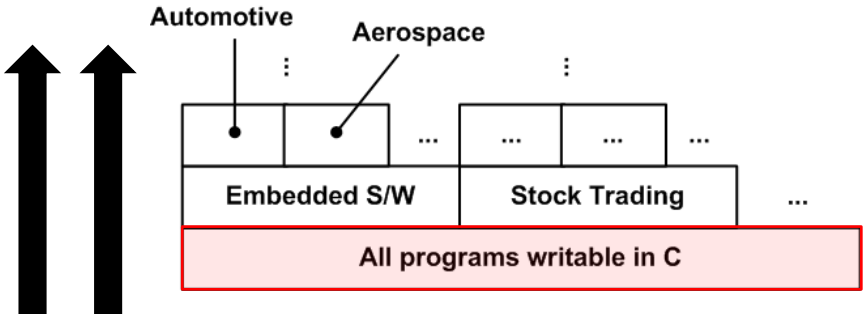
# mbeddr C Solution Philosophy

# Extension




more specialized domains
more specialized languages

# Extension

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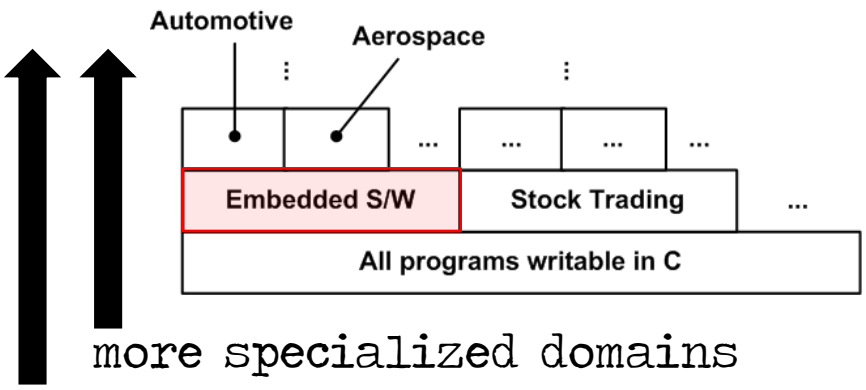


more specialized domains
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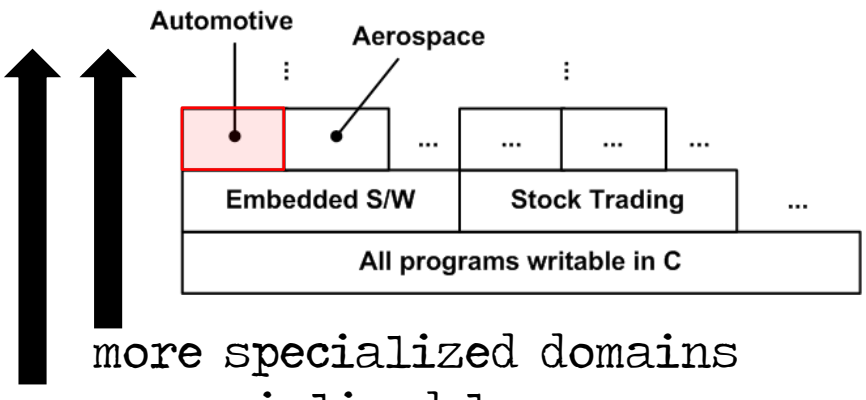
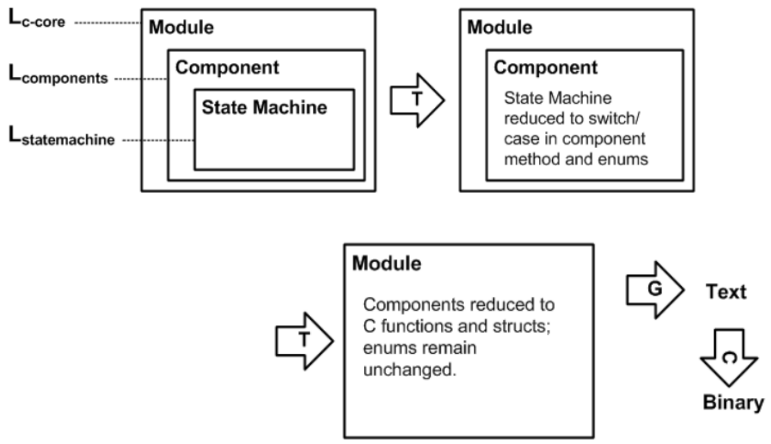



more specialized domains
more specialized languages

# Incremental Trafo



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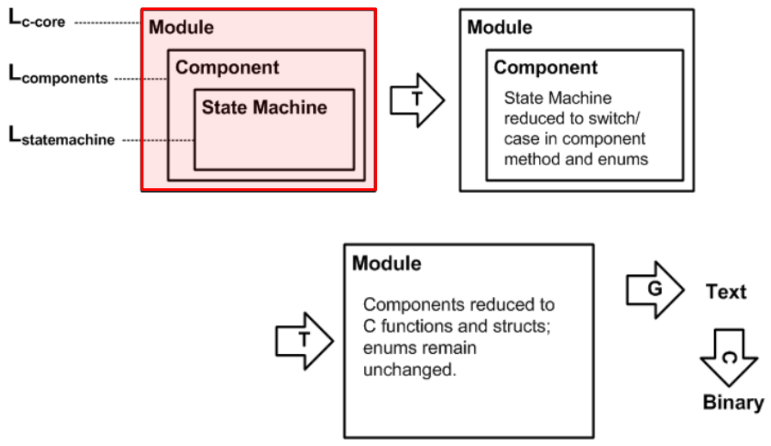


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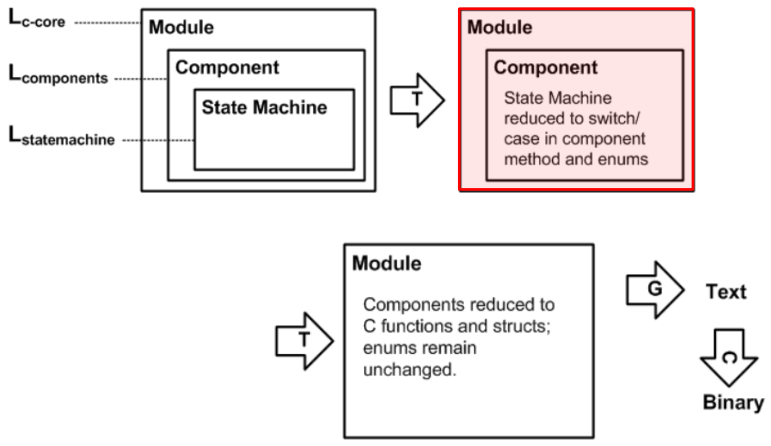

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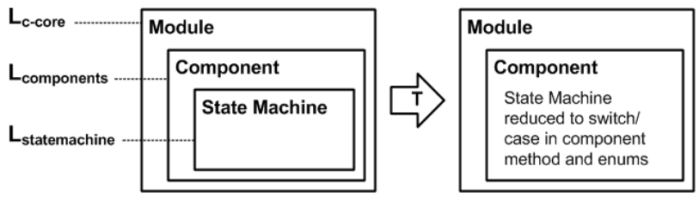
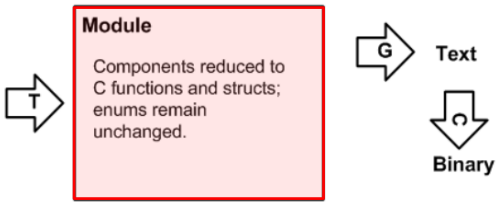
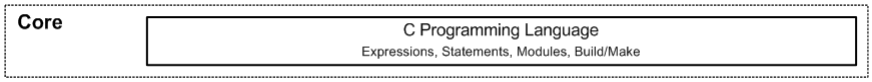


# Language Extension

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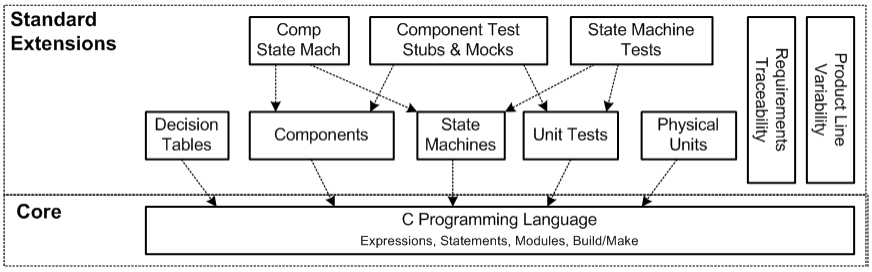

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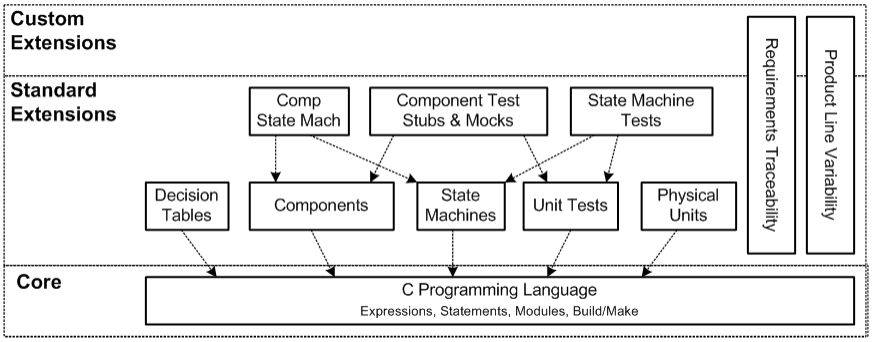

# Subset of Available Extensions

All of C
(cleaned-up)

```
module Calculator from cdesignpaper.helloWorld imports nothing {

  exported int8_t add(int8_t x, int8_t y) {
    return x + y;
  } add (function)

  exported int8_t multiply(int8_t x, int8_t y) {
    return x * y;
  } multiply (function)
}
```

```
module HelloWorld from cdesignpaper.helloWorld imports Calculator {

  int32_t main(int32_t argc, int8_t*[ ] argv) {
    return add(2, 2) + multiply(10, 2);
  } main (function)
}
```

# Native Support for Unit Testing and Logging

```
module UnitTestDemo from cdesignpaper.unittest imports nothing {

  int32_t main(int32_t argc, int8_t*[ ] argv) {
    return test testMultiply;
  } main (function)

  exported test case testMultiply {
    assert(0) times2(21) == 42;
    if ( 1 > 2 ) {
      fail(1);
    } if

  } testMultiply(test case)

  int8_t times2(int8_t a) {
    return 2 * a;
  } times2 (function)
}
```

```
module ARealHelloWorld from cdesignpaper.helloWorld imports nothing {

  message list HelloWorldMessages {
    INFO hello(string name) active: Hello World
    ERROR wrongNumberOfArguments(int8_t expected, int8_t actual) active: Wrong number of Arguments
  }

  int32_t main(int32_t argc, int8_t*[ ] argv) {
    report(0) HelloWorldMessages.wrongNumberOfArguments(1, argc) {
      if ( argc != 1 ) {
        report;
        return 1;
      } if
    };
    report(0) HelloWorldMessages.hello(argv[0]) on/if;
    return 0;
  } main (function)
}
```

```
message list HelloWorldMessages {
  INFO hello(string name) active: Hello World
  ERROR wrongNumberOfArguments(int8_t expected, int8_t actual) inactive: Wrong number of Arguments
}
```

# Components
# Interfaces
# Contracts
# Instances
# Mocks & Stubs

```
exported c/s interface Orienter on contract error MultibotMessages.prePostconditionFailed {
  int16_t heading()
    post(0) result >= 0 && result <= 359
  void orientTowards(int16_t heading, uint8_t speed, DIRECTION dir)
    pre(0) heading >= 0 && heading <= 359
}
```

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exported c/s interface Orienter on contract error MultibotMessages.prePostconditionFailed {
  int16_t heading()
    post(0) result >= 0 && result <= 359
  void orientTowards(int16_t heading, uint8_t speed, DIRECTION dir)
    pre(0) heading >= 0 && heading <= 359
}
```

```
exported component OrienterImpl extends nothing {
  ports:
    provides Orienter orienter
    requires EcRobot_Compass compass
    requires EcRobot_Motor motorLeft
    requires EcRobot_Motor motorRight
  contents:
    field int16_t[5] headingBuffer

    void orienter_orientTowards(int16_t heading, uint8_t speed, DIRECTION dir) <-
        op orienter.orientTowards {
      int16_t currentDir = compass.heading();
      if ( dir == COUNTERCLOCKWISE ) {
        motorLeft.set_speed(-1 * ((int8_t) speed));
        motorRight.set_speed(((int8_t) speed));
        while ( currentDir != heading ) { currentDir = compass.heading(); } while
      } else {
        motorLeft.set_speed(((int8_t) speed));
        motorRight.set_speed(-1 * ((int8_t) speed));
        while ( currentDir != heading ) { currentDir = compass.heading(); } while
      } if
      motorLeft.stop();
      motorRight.stop();
    }

    int16_t orienter_heading() <- op orienter.heading {
      return compass.heading();
    }
}
```

```
exported test case testDriveTrain {
  initialize instances;
  assert(0) dt.currentSpeed() == 0;
  dt.driveContinouslyForward(50);
  dt.stop();
  validate mock motorLeft;
  validate mock motorRight;
} testDriveTrain(test case)
```

```
instance configuration instances extends nothing {
  instances:
  instance MotorLeftMock motorLeft
  instance MotorRightMock motorRight
  instance DriveTrainImpl driveTrain
  instance EcUtil util
  connectors:
  connect driveTrain.motorLeft to motorLeft.motor
  connect driveTrain.motorRight to motorRight.motor
  connect driveTrain.util to util.util
  adapter:
  << ... >>
}
```

```
mock component MotorLeftMock {
  report messages: true
  ports:
    provides EcRobot_Motor motor
  expectations:
    total no. of calls is 2
    sequence {
      0: motor.set_speed {
          0: parameter speed: speed == 50
        }
      1: motor.stop
    }
}
```

```
mock component MotorRightMock {
  report messages: true
  ports:
    provides EcRobot_Motor motor
  expectations:
    total no. of calls is 2
    sequence {
      0: motor.set_speed {
          0: parameter speed: speed == 50
        }
      1: motor.stop
    }
}
```

# Physical Units

```
void testBasicUnits() {
  int8_t/N n = 3 N;
                      -2
  int8_t/N n3 = 3 kg m s ;

  int8_t/m length;
  int8_t/s time;
          -1
  int8_t/[m s ] speed = length / time;

  int8_t/v thisShouldNotWork = length + time;

  length l1 = length + length;
  length l2 = length * 33;
  length l3 = length / 3;
  length l4 = length + 3;
} testBasicUnits (function)
```

# State Machines
# +
# Model Checking

```
verifiable
statemachine Counter {
  in start() <no binding>
     step(int[0..10] size) <no binding>
  out someEvent(int[0..100] x, boolean b) => handle_someEvent
      resetted() => resetted
  vars int[0..100] currentVal = 0
       int[0..100] LIMIT = 10
  states (initial = initialState)
    state initialState {
      on start [ ] -> countState { send someEvent(100, true && false || true); }
    }
    state countState {
      on step [currentVal + size > LIMIT] -> initialState { send resetted(); }
      on step [currentVal + size <= LIMIT] -> countState { currentVal = currentVal + size; }
      on start [ ] -> initialState {  }
    }
} end statemachine
```

Can I do proofs, and not just "trial and error" testing?

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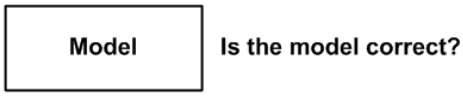
Yes. Formal Methods.

# Model Checking

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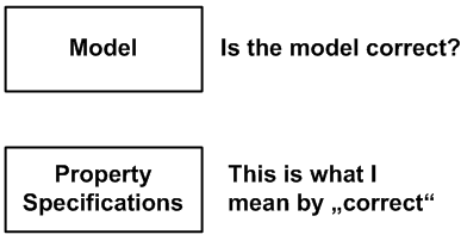

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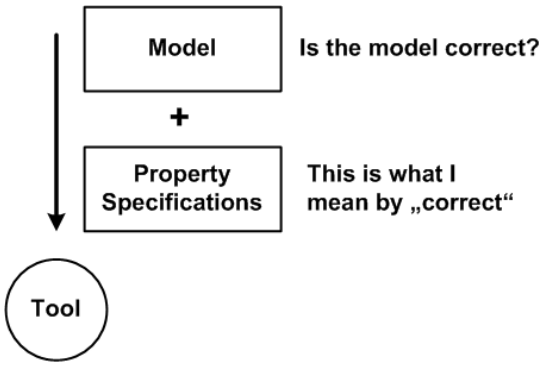


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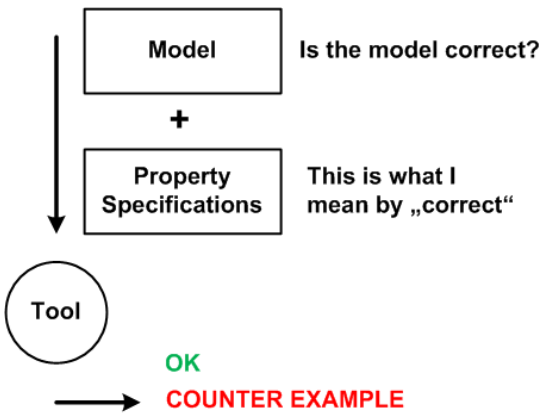

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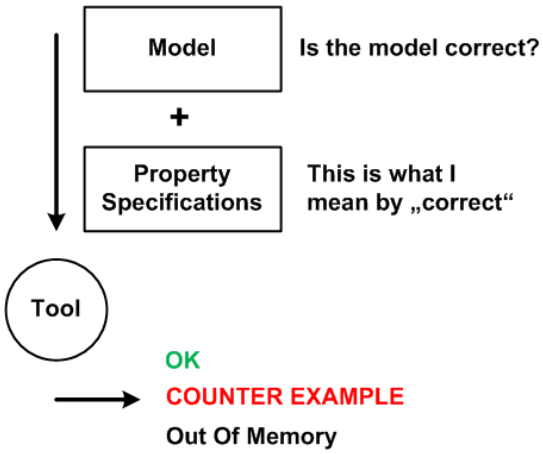
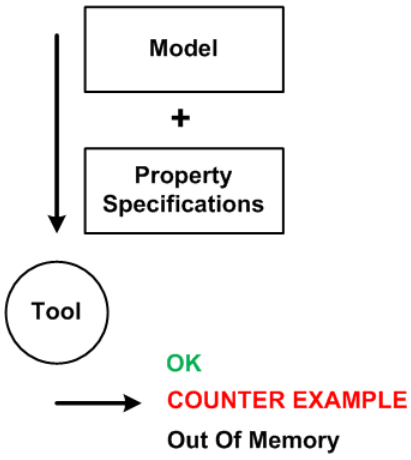
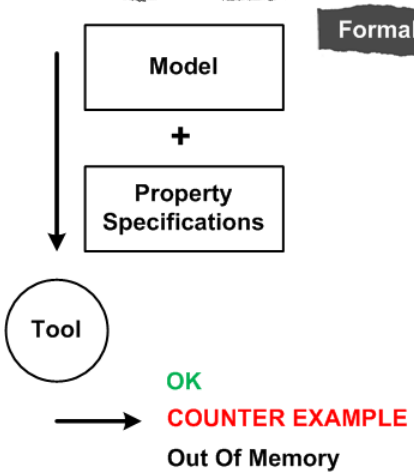


# Challenges




# Challenges

Formalism



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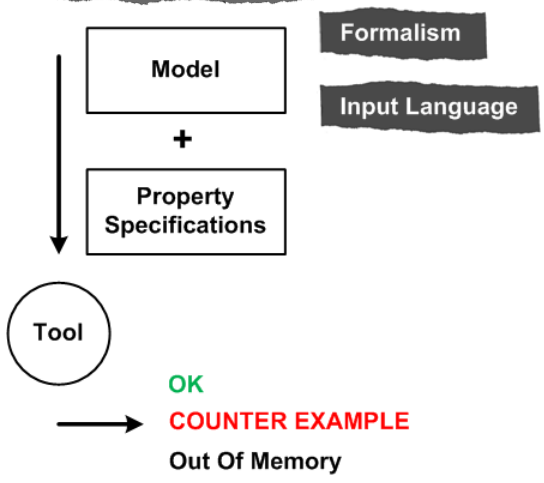


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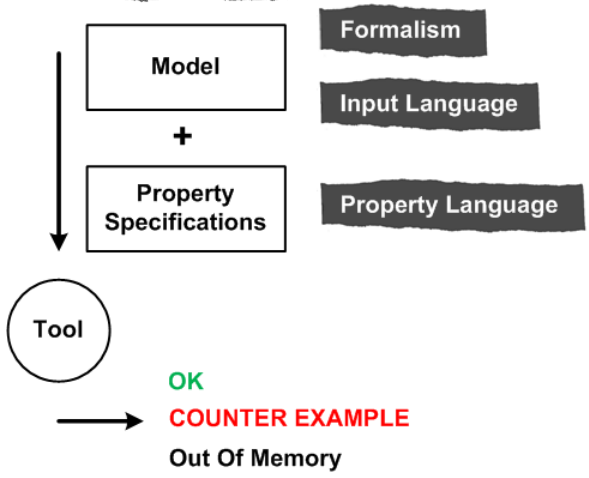

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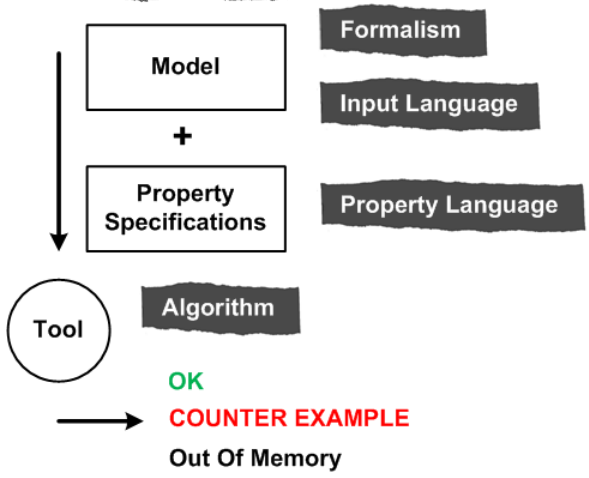


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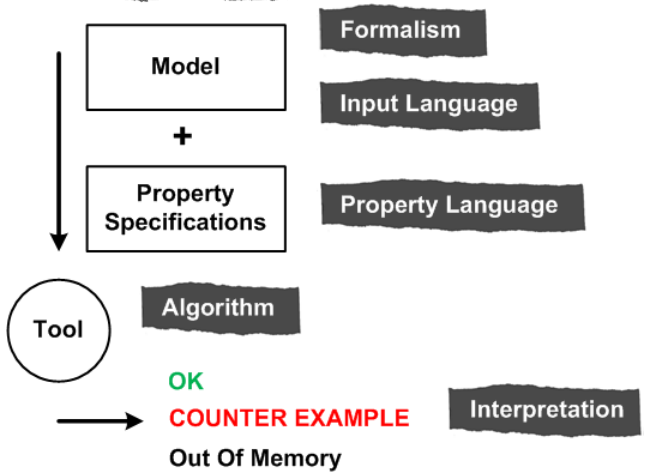
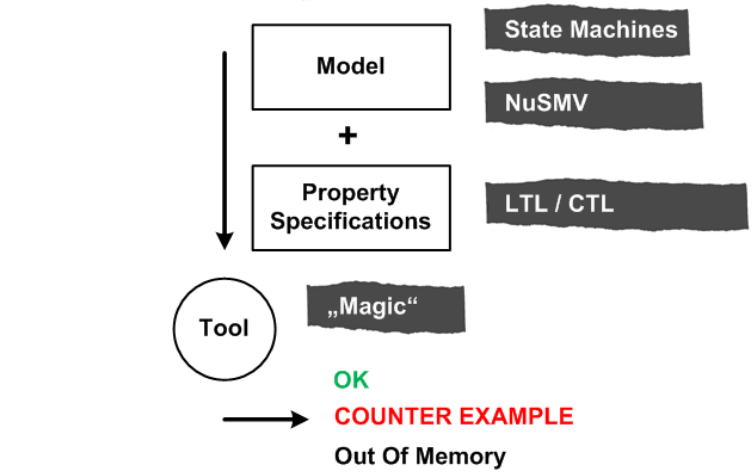


# State Based




```
verifiable
statemachine Counter {
  in start() <no binding>
     step(int[0..10] size) <no binding>
  out someEvent(int[0..100] x, boolean b) => handle_someE
      resetted() => resetted
  vars int[0..100] currentVal = 0
       int[0..100] LIMIT = 10
  states (initial = initialState)
    state initialState {
      on start [ ] -> countState { send someEvent(100, tr
    }
    state countState {
      on step [currentVal + size > LIMIT] -> initialState
      on step [currentVal + size <= LIMIT] -> countState
      on start [ ] -> initialState {  }
    }
} end statemachine
```

NuSMV Tool

| Property | Status | Trace Size |
|---|---|---|
| State 'initialState' can be reached | SUCCESS | |
| State 'countState' can be reached | SUCCESS | |
| Variable 'currentVal' is always between its defi... | SUCCESS | |
| Variable 'LIMIT' is always between its defined ... | SUCCESS | |
| State 'initialState' has deterministic transitions | SUCCESS | |
| State 'countState' has deterministic transitions | SUCCESS | |
| Transition 0 of state 'initialState' is not dead | SUCCESS | |
| Transition 0 of state 'countState' is not dead | SUCCESS | |
| Transition 1 of state 'countState' is not dead | SUCCESS | |
| Transition 2 of state 'countState' is not dead | SUCCESS | |
| Condition 'currentVal == 8' can be true | FAIL | 4 |

| Node | Value |
|---|---|
| **State initialState** | |
| LIMIT | 10 |
| currentVal | 0 |
| **State initialState** | |
| in_event: start | star) |
| LIMIT | 10 |
| currentVal | 0 |
| **State countState** | |
| in_event: step | step(8) |
| out_event:someEvent | someEvent(100, true) |
| LIMIT | 10 |
| currentVal | 0 |
| **State countState** | |
| LIMIT | 10 |
| currentVal | 8 |

# Requirements Tracability

```
requirements HighLevelRequirements
  show traces true

functional Main: Program has to run from the command line ...
  functional Arg2: Argument Count must be 2 ...
    functional FailOtherwise: Otherwise it should return -1 ...
functional Add: The program should return the sum of the two arguments ...
  functional AddFct: Adding should be a separate function for reuse ...
```


```
requirements HighLevelRequirements
  show traces true

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functional Add: The program should return the sum of the two arguments ...
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```


```
requirements modules: HighLevelRequirements
module ExampleCode from test.ts.requirements.code imports StrUtil {

  int8_t add(int8_t a, int8_t b) {  trace AddFct
    return a + b;
  } add (function)

  int8_t main(string[ ] args, int8_t argc) {                                  trace Main
    if ( argc == 2 ) {                                                        trace Arg2
      return add(str2int(args[0]), str2int(args[1]));  trace Add;
    } else {
      return -1;  trace FailOtherwise
    } if
  } main (function)
}
```

```
requirements HighLevelRequirements
  show traces false

functional Main: Program has to run from the command line ...
  functional Arg2: Argument Count must be 2 ...
    functional FailOtherwise: Otherwise it should return -1 ...
functional Add: The program should return the sum of the two arguments ...
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module ExampleCode from test.ts.requirements.code imports StrUtil {

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    return a + b;
  } add (function)

  int8_t main(string[ ] args, int8_t argc) {
    if ( argc == 2 ) {
      return add(str2int(args[0]), str2int(args[1]));
    } else {
      return -1;
    } if
  } main (function)
}
```

# Product Line Variability

```
feature model DeploymentConfiguration
  root ? {
    logging
    test
    valueTest [int8_t value]
  }

configuration model Debug configures DeploymentConfiguration
  root {
    logging
    test
    valueTest [value = 42]
  }

configuration model Production configures DeploymentConfiguration
  root {
    << ... >>
  }
```

```
Variability from FM: DeploymentConfiguration
Rendering Mode: product line
                                                    {!test}
module ApplicationModule from test.ex.cc.fm imports SensorModule {

  {logging}
  message list messages {
    INFO beginningMain() active: entering main function
    INFO exitingMain() active: exitingMainFunction
  }

  exported test case testVar {
    {logging}
    report(0) messages.beginningMain() on/if;
    int8_t x = getSensorValue(1) replace if {test} with 42;
    {logging}
    report(1) messages.exitingMain() on/if;
    assert(2) x == 10 replace if {test} with 42;
    {valueTest}
    int8_t vv = value;
    {valueTest}
    assert(3) vv == 42;
    int8_t ww = 22 replace if {valueTest} with 12 + value;
    {!valueTest}
    assert(4) ww == 22;
    {valueTest}
    assert(5) ww == 54;
  } testVar(test case)

  int32_t main(int32_t argc, string[ ] args) {
    return test testVar;
  } main (function)
}
```


```
feature model DeploymentConfiguration
  root ? {
    logging
    test
    valueTest [int8_t value]
  }

configuration model Debug configures DeploymentConfiguration
  root {
    logging
    test
    valueTest [value = 42]
  }

configuration model Production configures DeploymentConfiguration
  root {
    << ... >>
  }
```

```
Variability from FM: DeploymentConfiguration
Rendering Mode: variant rendering config: Debug
module ApplicationModule from test.ex.cc.fm imports {

  message list messages {
    INFO beginningMain() active: entering main function
    INFO exitingMain() active: exitingMainFunction
  }

  exported test case testVar {
    report(0) messages.beginningMain() on/if;
    int8_t x = 42;
    report(1) messages.exitingMain() on/if;
    assert(2) x == 42;
    int8_t vv = value (variant Debug);
    assert(3) vv == 42;
    int8_t ww = 12 + value (variant Debug);
    assert(5) ww == 54;
  } testVar(test case)

  int32_t main(int32_t argc, string[ ] args) {
    return test testVar;
  } main (function)
}
```

```
feature model DeploymentConfiguration
  root ? {
    logging
    test
    valueTest [int8_t value]
  }

configuration model Debug configures DeploymentConfiguration
  root {
    logging
    test
    valueTest [value = 42]
  }

configuration model Production configures DeploymentConfiguration
  root {
    << ... >>
  }
```

```
Variability from FM: DeploymentConfiguration
Rendering Mode: variant rendering config: Production
module ApplicationModule from test.ex.cc.fm imports SensorModule {


  exported test case testVar {
    int8_t x = getSensorValue(1);
    assert(2) x == 10;
    int8_t ww = 22;
    assert(4) ww == 22;
  } testVar(test case)

  int32_t main(int32_t argc, string[ ] args) {
    return test testVar;
  } main (function)
}
```

```
feature model DeploymentConfiguration
  root ? {
    logging
    test
    valueTest [int8_t value]
  }

configuration model Debug configures DeploymentConfiguration
  root {
    logging
    test
    valueTest [value = 42]
  }

configuration model Production configures DeploymentConfiguration
  root {
    << ... >>
  }
```

# Status and Availability

# http://mbeddr.com

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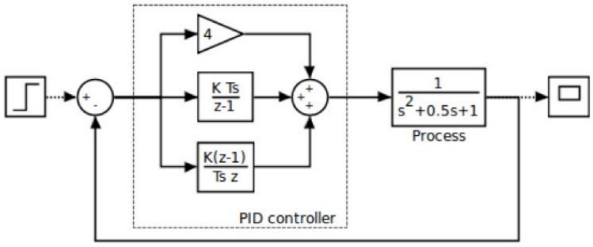
Core is
Open Source
(EPL)

Some Extensions
will be
Open Sourced
this year

# Custom Extensions and Professional Services by itemis

# integration in early 2013




# support for graphical in 2013

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