SPARK in an automotive context

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ZENUITY

Who is Zenuity?

- AD and ADAS software company owned by Veoneer and Volvo
- Customers:
  1. Volvo
  2. Through Veoneer: Geely, an American OEM, a German OEM, etc.
- Offices in Göteborg, München, Detroit, Santa Clara, and Shanghai
- Primary priority is safety

Why is AD so hard?

Technical issues

Safety critical, and:

- Complex environment (roads, road users, etc.)
- No obvious fail-safe architecture
- Nobody knows how to do it
- Large safety-critical code base (compared to other industries)

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- Large safety-critical code base (compared to other industries)
- Will contain neural networks
  - Effective validation approach unclear
  - Verification is a research problem

Why is AD so hard?

Process issues

- No experience with large safety-critical software in automotive
- Feature engineers, not programmers (in classical OEMs and suppliers)
- Unsuitable processes (what works in ADAS won't work here)

ISO 26262

- Key safety standard in automotive

ISO 26262

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- Defines integrity levels, precise mapping is up to interpretation

IEC 61508	DO-178C	ISO 26262	
–	DAL-E	QM	QM
SIL-1	DAL-D	ASIL-A	ASIL-A
SIL-2	DAL-C	ASIL-B/C	ASIL-B
SIL-3	DAL-B	ASIL-D	ASIL-C
SIL-4	DAL-A	–	ASIL-D

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- Defines verification objectives
- Suggests minimal approach to meet them

ISO 26262

Verification objectives

Demonstrate that the software units achieve:

- compliance with the software unit design specification
- compliance with the specification of the hardware-software interface
- the specified functionality
- confidence in the absence of unintended functionality
- robustness
- sufficient resources to support their functionality

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ISO 26262

Software robustness

It can mean a lot of things:

- no dead code?
- error detection effective?
- error handling effective?
- code does not crash?
- signal noise?

ISO 26262

Robustness - “obvious”

This objective is classically hard through testing:

- Trivial to find “bugs”

```
result = (previous_speed + current_speed) * 0.5f;
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  ```

  What about if our car goes at $1.13 \times 10^{30} * c$?
- These bugs are "not helpful" and "obviously" irrelevant
- Often the only way to fix them is defensive code or justification
  - Defensive code further increases testing effort (coverage)
  - Justifications are often wrong, outdated, or fail to grasp the big picture

ISO 26262

Robustness - testing is hard

- Coverage metrics helps you complete your test-suite
- Various levels exist

Level of assurance	Coverage criteria
ASIL-A	Statement
ASIL-B	Statement or Branch
ASIL-C	Branch
ASIL-D	MC/DC

ISO 26262

Robustness - testing is hard

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Level of assurance	Coverage criteria
AS[illegible]	[illegible]
ASIL-[illegible]	[illegible]

Coverage is *not* a sufficient metric for robustness tests!

ISO 26262

Robustness

```
function Absolute_Value (N : Integer)
                        return Integer
is
begin
   if N >= 0 then
      return N;
   else
      return -N;
   end if;
end Absolute_Value;
```

Tests for MC/DC:

- -42, 123

ISO 26262

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ISO 26262

Robustness - escalating complexity

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$a > 0$

$\boxed{\text{foo}}$

ISO 26262

Robustness - escalating complexity

$0 \leq b < 128$

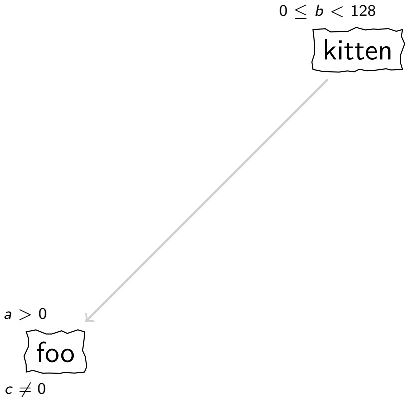
kitten

$a > 0$

foo

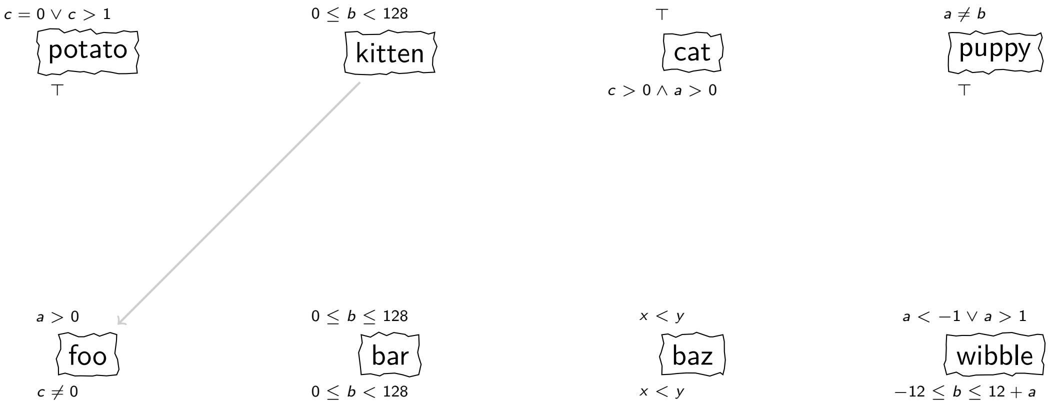
ISO 26262

Robustness - escalating complexity



ISO 26262

Robustness - escalating complexity



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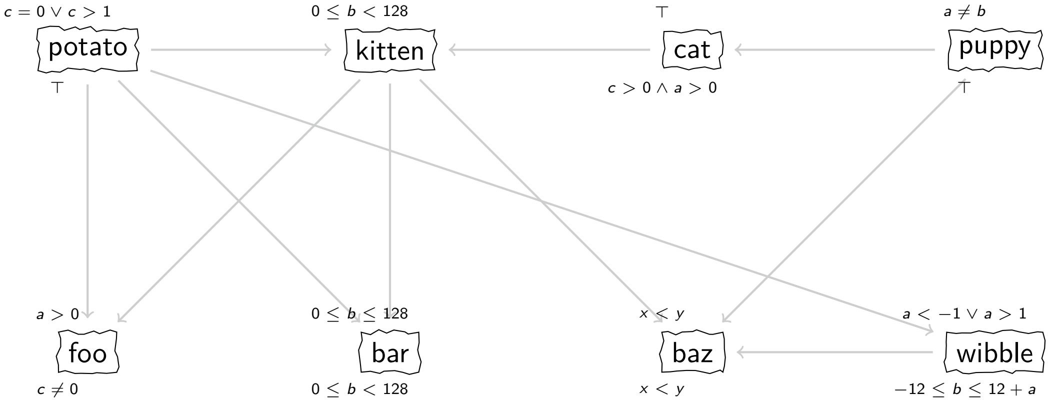

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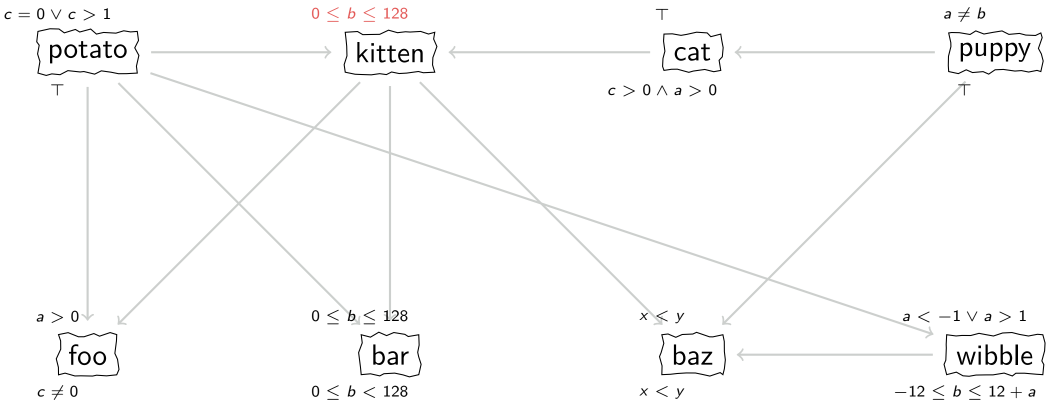

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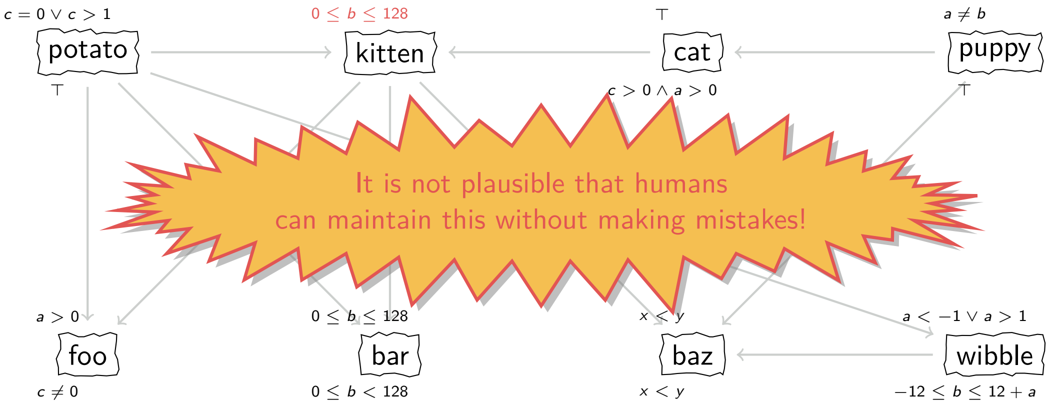


Software failure modes are non-obvious and system complexity is vast!

ISO 26262

Robustness

SPARK can help here, even if you just do the absolute basics:

- Absence of run-time error proof
- Guarantee for type ranges
- Preconditions replace defensive code

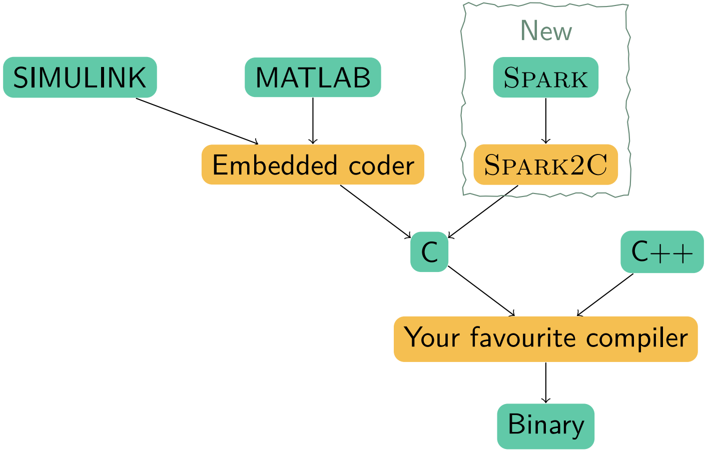
Challenges

What makes adopting SPARK difficult?

- C and C++ is very established
- Emphasis on validation over verification
- Model-based design is sometimes seen as a magic bullet
- Platform issues (i.e. SPARK compiler availability)

How to make it work in automotive?

Generate C code!



Interfacing

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- Interfacing SPARK / SIMULINK?

Interfacing

SIMULINK

What we have:

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procedure Potato (Thing : in out Potato_Bus_T;
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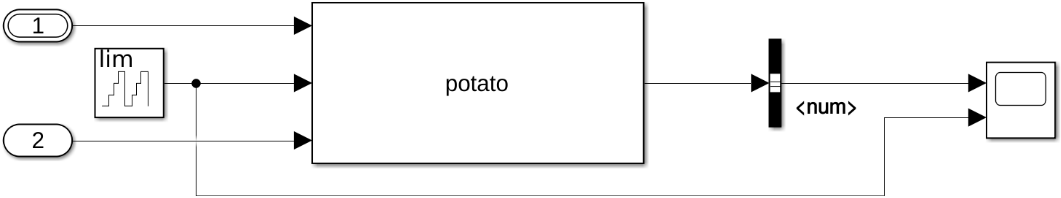

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Where to start?

Read the docs...

- There used to be an Ada binding (deprecated and dead)
- Bind to SIMULINK C API from Ada?
- Generate C code, bind to that from SIMULINK?
- Try something else...

Interfacing

Compatible header files

Annotate interface spec:

```ada
type Potato_Bus_T is record
   Arr     : Int_Array_T;
   Num     : Integer;
   Bus_Arr : Bus_Array_T;
   Kitten  : Kittens;
end record
with Convention => C_Pass_By_Copy;
```

```c
typedef struct {
  int arr[25];
  int num;
  point bus_arr[25];
  kittens kitten;
} potato_bus;
```

Ideally generate both from a neutral format.

Interfacing

A thin binding

Create a small C wrapper for SIMULINK:

```
void my_fun(potato_bus *u1, int u2, kittens u3, potato_bus *y1)
{
  memcpy(y1, u1, sizeof(potato_bus));
  ada__potato(y1, u2, u3);
}

void my_init()
{
  potatoinit();
}

void my_finish()
{
  potatofinal();
}
```

Interfacing

Glue code

Use the SIMULINK legacy code binding generator setup glue code:

```
Simulink.importExternalCTypes('src/potato_bus.h');

def = legacy_code('initialize');
def.Options.language = 'C';
def.Options.isVolatile = false;
def.SFunctionName = 'potato';
def.SourceFiles = {'my_fun.c'};
def.HeaderFiles = {'potato_bus.h'};
def.OutputFcnSpec = ['void my_fun(potato_bus u1[1], uint8 u2, ' ...
    'kittens u3, potato_bus y1[1])'];
def.StartFcnSpec = ['void my_init()'];
def.TerminateFcnSpec = ['void my_finish()'];

legacy_code('sfcn_cmex_generate', def);
movefile('potato.c', 'src/potato.c');
```

Interfacing

Building

Build it all via gprbuild:

- Don't use the mex utility function
- Works on Windows and Linux
- Build DLL / SO
  - Without auto init section
  - With a special linker script
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  - With a special linker script
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- Result is a mixed language .mexw64 / .mexa64 plugin that "just works".
- A lot of this can be automated!

Interfacing

Automation

Now all you need to do is this:

```
procedure Potato (Thing : in out Potato_Bus_T;
                  A     : in Integer;
                  B     : in Kittens)
with
  Export,
  Convention => C,
  External_Name => "ada__potato",
  Annotate => Simulink_Block;
```

- Python script based on gnat2xml works out data types and a list of subprogram to build bindings for
- Other script generate both C header and Ada type definitions
- No manual work involved!

Conclusion

SPARK in the automotive industry:

- Great fit with ISO 26262 (especially robustness)
- Interfacing with existing tools and environments is possible
- Incremental adoption possible: integrates well with existing environments and systems

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Thank you for listening.
Questions?

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