LAAS Days
Research & Technology
June 21-22 2018, Toulouse

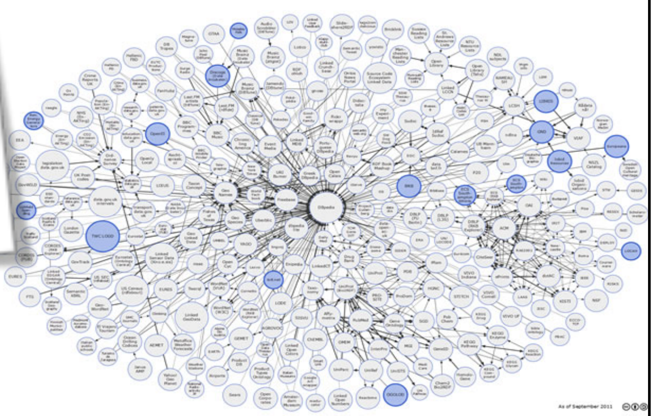
Trust Me I am Autonomous

Ambiant Intelligence axis

Jérémie Guiochet

LAAS R&T Days

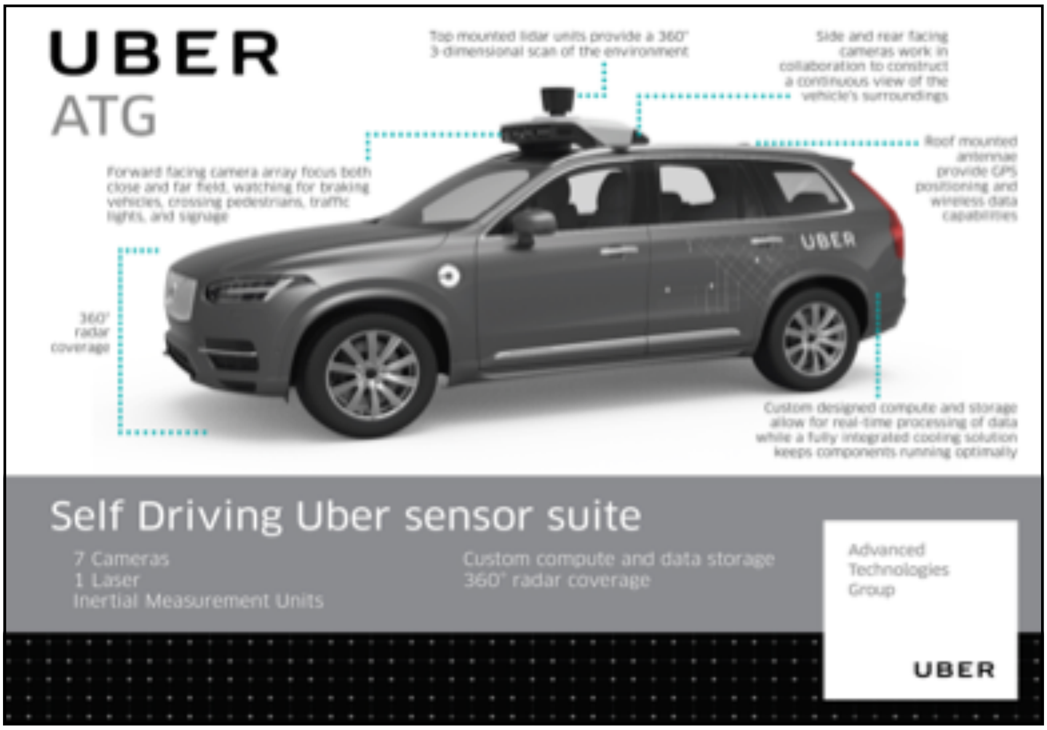
Decisional autonomy



Decisional autonomy & robotics

- Sense/plan/act paradigm
- Unstructured environment
- No human intervention

1966 – Shakey the robot

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This is it …
Tesla, 2016
Uber, 2018
Tesla X , 2018
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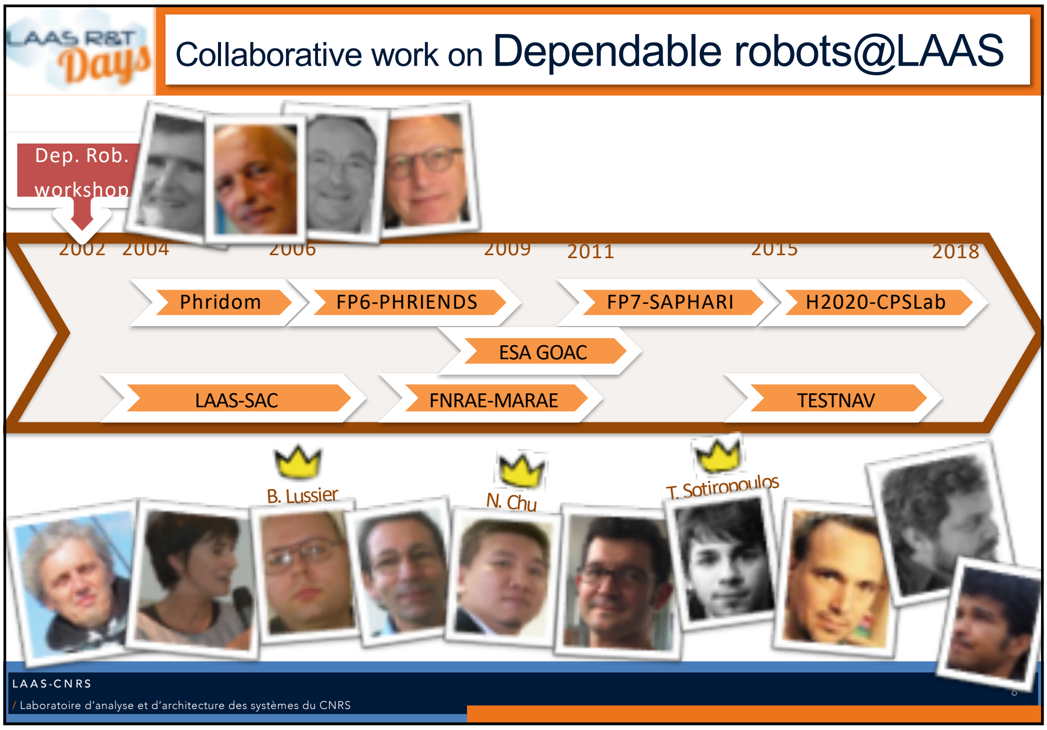
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Collaborative work on Dependable robots@LAAS
Dep. Rob. workshop
2002
2004
2006
2009
2011
2015
2018
Phridom
FP6-PHRIENDS
FP7-SAPHARI
H2020-CPSLab
ESA GOAC
LAAS-SAC
FNRAE-MARAE
TESTNAV
B. Lussier
N. Chu
T. Sotiropoulos
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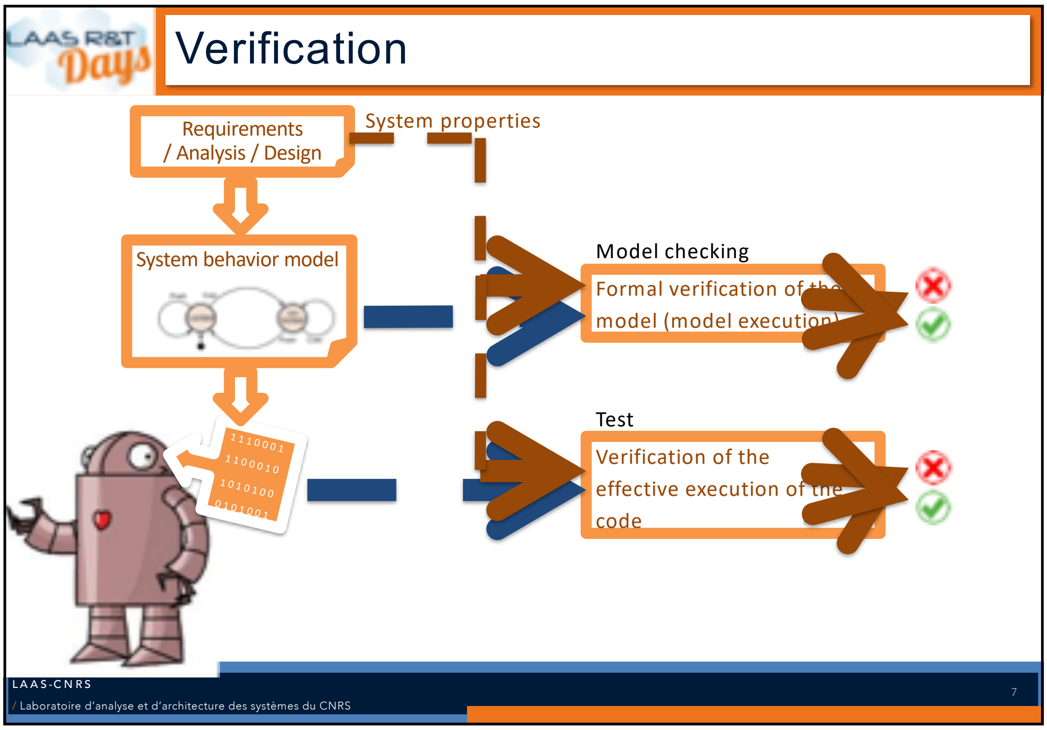
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Verification
Requirements / Analysis / Design
System properties
System behavior model
Model checking
Formal verification of the model (model execution)
Test
Verification of the effective execution of the code
1110001
1100010
1010100
0101001
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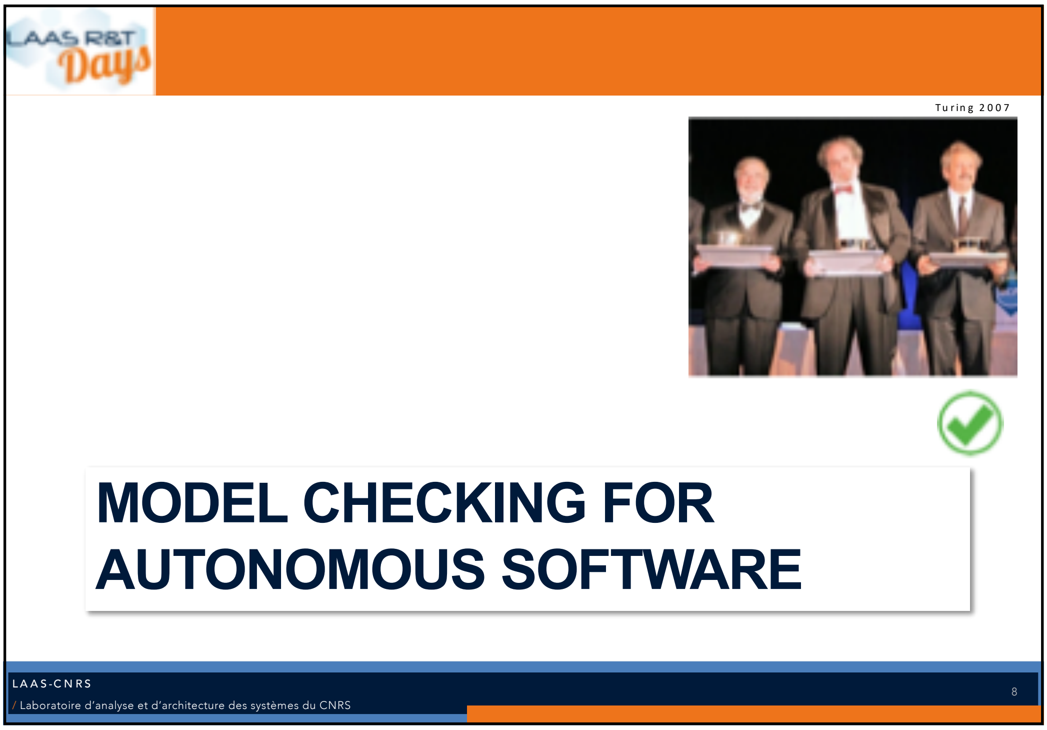
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Turing 2007
MODEL CHECKING FOR AUTONOMOUS SOFTWARE
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Model checking of autonomous software

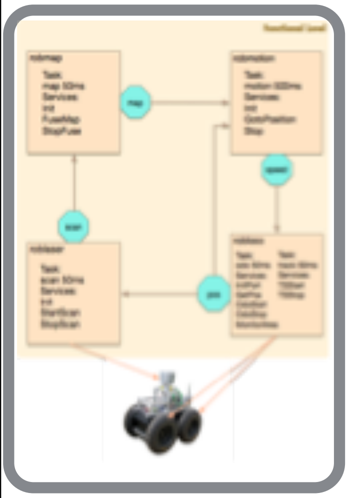
> Objectives : what do robotic software developers want ?

- Check that the robot behave safely (e.g. stop in time when an obstacle has been detected, speed remain in bound, etc.)
- Check that the robot has a consistent perception/action loop (e.g., laser scan freq and range, speed control, freq and value, time for an emergency stop, etc)

> Issues : why not use basic model checkers ?

- No formal specifications of autonomous systems
- No behavior models of autonomous software
- Semantic gap between robot software and model checker tools

The proposed approach



Robot software with Genom @ Laas

```
process Manager (&tick: bool, ...) is
states start, manage
from start
wait [0,0];
on tick;
tick := false;
if (...) /* no active activity */
then to start
else to manage end
from manage
wait [0,0];
... /* execute one active activity */
if (...) /* no more activities */
then to start
else to manage end
```

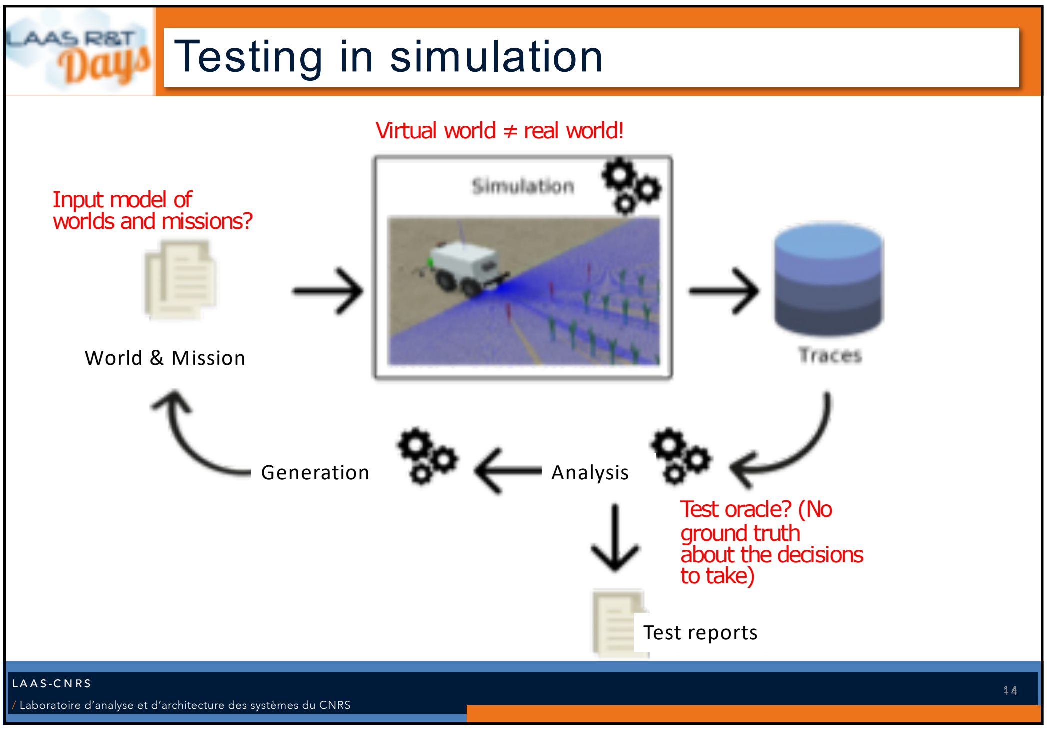
```
process timer (&tick:
bool) is
states start
from start
wait [0.5,0.5];
tick := true;
to start
```

Fiacre + TINA @ Laas

Results

- Properties successfully checked with Fiacre/TINA (e.g, Schedulability of execution tasks, no deadlock, position port update bounded in time)
- GenoM specifications were good for verification
  - *Codel* granularity
  - Internal and external shared data access is fully specified
  - Automata specification provides execution sequence and time/period management
  - Task are clearly specified (how many, periodic, sporadic)
- Limits
  - Based on the hypothesis that specifications are correct (verification is not validation)
  - Verification limited to properties of the software modules (not including operating system and hardware artefacts)
  - Genom *Codels* still need to be validated
- A complementary approach… testing

TESTING NAVIGATION IN VIRTUAL WORDS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Testing in simulation
Virtual world ≠ real world!
Input model of worlds and missions?
Simulation
World & Mission
Traces
Generation
Analysis
Test oracle? (No ground truth about the decisions to take)
Test reports
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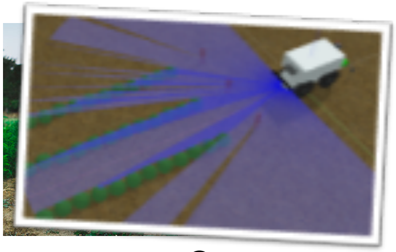
Two case studies (outdoor navigation)

Mana

- Outdoor experiments @LAAS
- Generic navigation missions
- Path planning similar to NASA's GESTALT algorithm for Mars exploration rovers
- 35 KLOC including 3D mapping, localisation, path planning
- MORSE simulator (based on the Blender game engine)



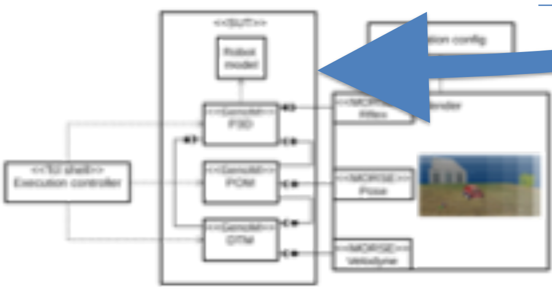
Oz

- Agricultural robots developed and commercialized by Naïo Technologies
- Weeding missions
- Proprietary and mission-specific software
- 151 KLOC (also including modules we do not test: control of weeding tools & user interface)
- Gazebo simulator

Can robot navigation bugs be reproduced in simulation?

In-depth analysis of identified bugs in the *Mana* navigation software and analysis of their reproductibility in simulation (2005-2015 history of code)

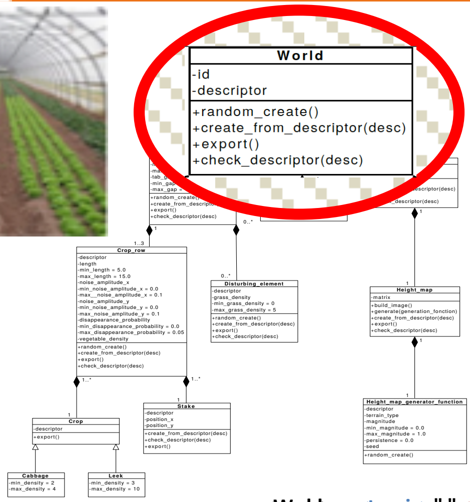
P3D	69 commits	12 bugs
LibP3D	154 commits	14 bugs
DTM	50 commits	3 bugs
POM	83 commits	4 bugs
Total	**356 commits**	**33 bugs**



32 reproducible

1 non reproducible

World & mission Models (2)



- Oz model : 31 generation parameters (some with interdependancies)
- Grammar-based approach to manage the parameters

  Descriptor: genotype of a world or a world element
- Descriptors can have wildcards

  R (= any random world)

  f+0.0+0-R-R (flat terrain, any mission and field)

```
<World> ::= <terrain> "-" <mission> "-" <field>
<terrain> ::= <terrain_type> "+" <magnitude> "+" <seed>
<field> ::= <nb_crop_row> "+" <gap_list> "+" <crop_row_list> "+" <disturbing_element_list>
```

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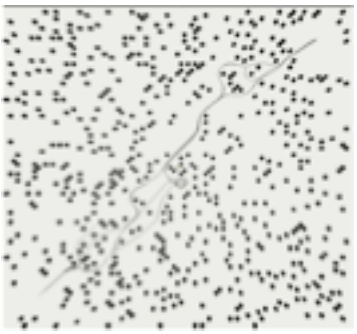
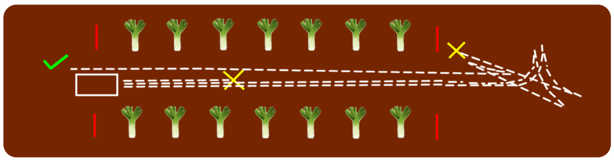
Oracle ? A navigation system is not deterministic!





Oz experiment : 30% of the test cases do not yield a consistent verdict for 5 repeated runs

> Non deterministic trajectory -> non deterministic verdict

> No ground truth for decisional functions (Mission Failure ≠ Fail verdict)

➔Definition of measures and classes of properties

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Results for robot testing under simulation

> Results
- Preliminary validation of procedural 3D world generation with a grammar, reproducibility, and measures for oracle
- Successful application to an industrial case study (full code access)

> Limits / perspectives
- only random testing -> search-based testing (fitness, evolutionary algorithms, etc.)
- only static situations -> dynamic situations (e.g. mobile obstacles at the right time and location)
- confidence in virtual test results (statistics), e.g. how to use them in certification ?

To conclude

> Trust in autonomous system could be achieved through 3 activities:
- Social acceptance criteria elicitation (not presented here)
- Structured arguments : how to argue that acceptability objectives are reached / combine assurance building blocks (not presented here)
- Assurance building blocks, based on dependability techniques (presented here)

> Verification is part of assurance building blocks (e.g. model checking and test in simulation)
- What is the confidence level ? (still open issues, e.g. verification of machine learning algorithms)
- What is the contribution in a structured argumentation ?

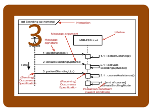
> Work in progress at LAAS (not exhaustive):
- Several running phds (safety monitoring, testing, model checking, etc.) and starting in september/october 2018 (safety argumentation, verification, etc.)
- A European project SAS (Safer Autonomous Systems) nov2018-nov2022
- A RTRA chantier "TrustMeIA" led by the LAAS
- Contracts/PhDs in verif/decisional : eHorizon (Continental) , FURIOUS (Safran), etc.
- …

> Thank you, questions ?

A path for trusting autonomous systems

Social acceptability criteria elicitation
- E.g.: Is an autonomous vehicle able to avoid an obstacle or just try to stop ?

How to argue that acceptability objectives are reached / combine assurance building blocks
- E.g.: combining virtual testing and operational testing on 1 million miles is sufficient ?



Argumentation building blocks / risk treatment / dependability techniques
- E.g.: verification of AI components ?