Software Validation via Model Animation

Aaron Dutle, César Muñoz, Anthony Narkawicz, Ricky Butler

NASA Langley Research Center,
Hampton, Virginia, US

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Stratway

Prototype software for Air Traffic Management research:

- Generates trajectories from waypoints.
- Determines if aircraft are in conflict.
- Finds manuevers to resolve conflicts.
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Used at NASA, by industry, academia, and others. Needs to be easy to read, use and extend (Java, C++), but with strong assurance of correctness (PVS).

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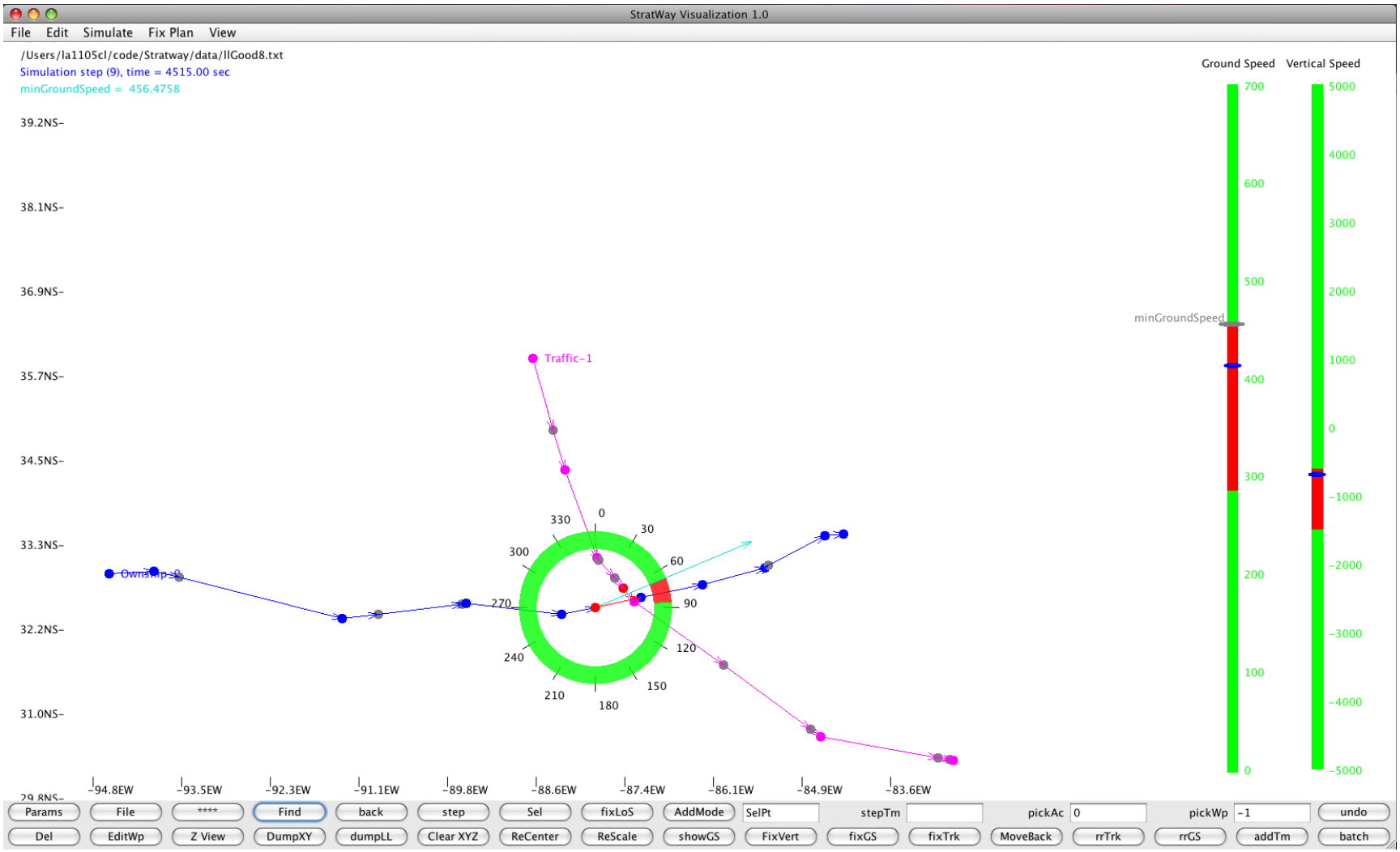
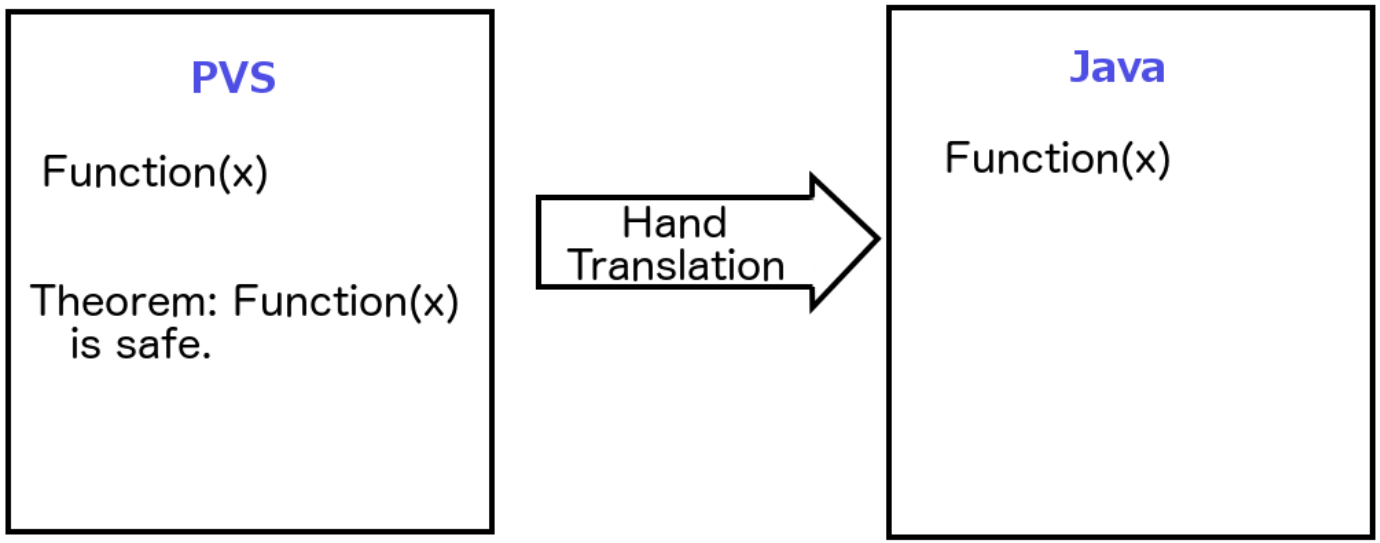

StratWay Visualization 1.0
File Edit Simulate Fix Plan View
/Users/la1105cl/code/Stratway/data/llGood8.txt
Simulation step (9), time = 4515.00 sec
minGroundSpeed = 456.4758
Ground Speed
Vertical Speed
minGroundSpeed
Traffic-1
39.2NS
38.1NS
36.9NS
35.7NS
34.5NS
33.3NS
32.2NS
31.0NS
94.8EW
93.5EW
92.3EW
91.1EW
89.8EW
88.6EW
87.4EW
86.1EW
84.9EW
83.6EW
Params File **** Find back step Sel fixLoS AddMode SelPt stepTm pickAc 0 pickWp -1 undo
Del EditWp Z View DumpXY dumpLL Clear XYZ ReCenter ReScale showGS FixVert fixGS fixTrk MoveBack rrTrk rrGS addTm batch

Stratway

Kinematics library: Provides basic functions for simulating motion.

- Constant acceleration vertical maneuvers,
  `vsAccelUntil`
  `vsAccelUntilWithRampUp`
  `vsLevelOut`
- Constant acceleration ground speed maneuvers,
  `gsAccelUntil`
- Circular arc turn maneuvers,
  `turnOmega`
- ...

Current Workflow



Solution: **Software Validation via Model Animation**. Compare the outputs of the two implementations on an appropriate collection of test points.

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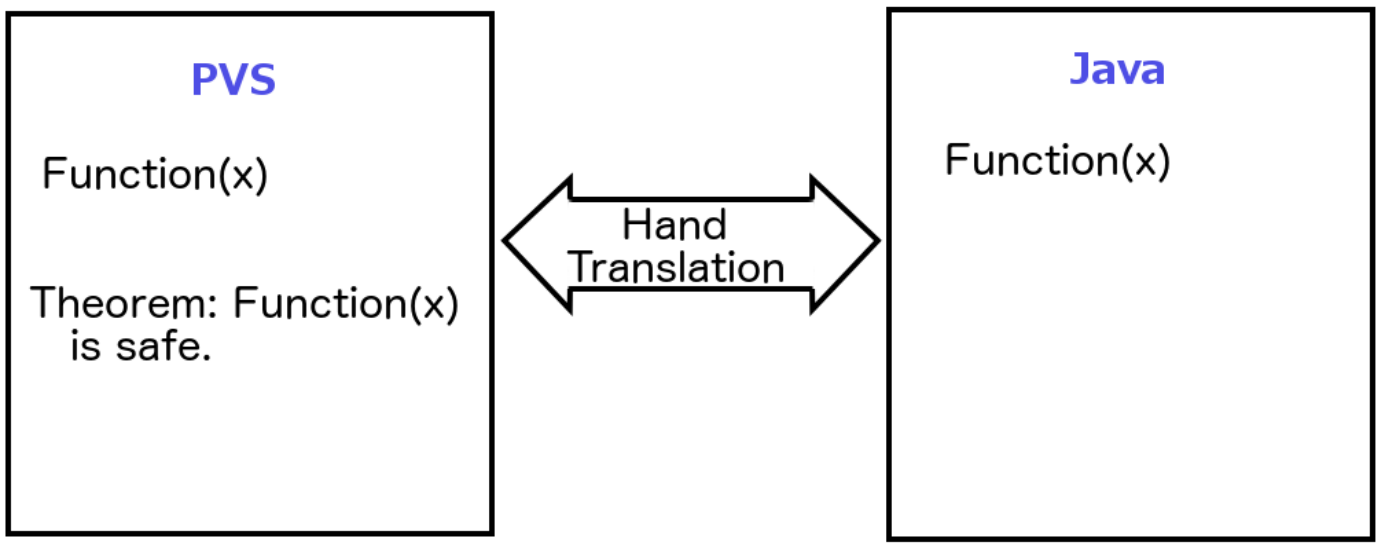

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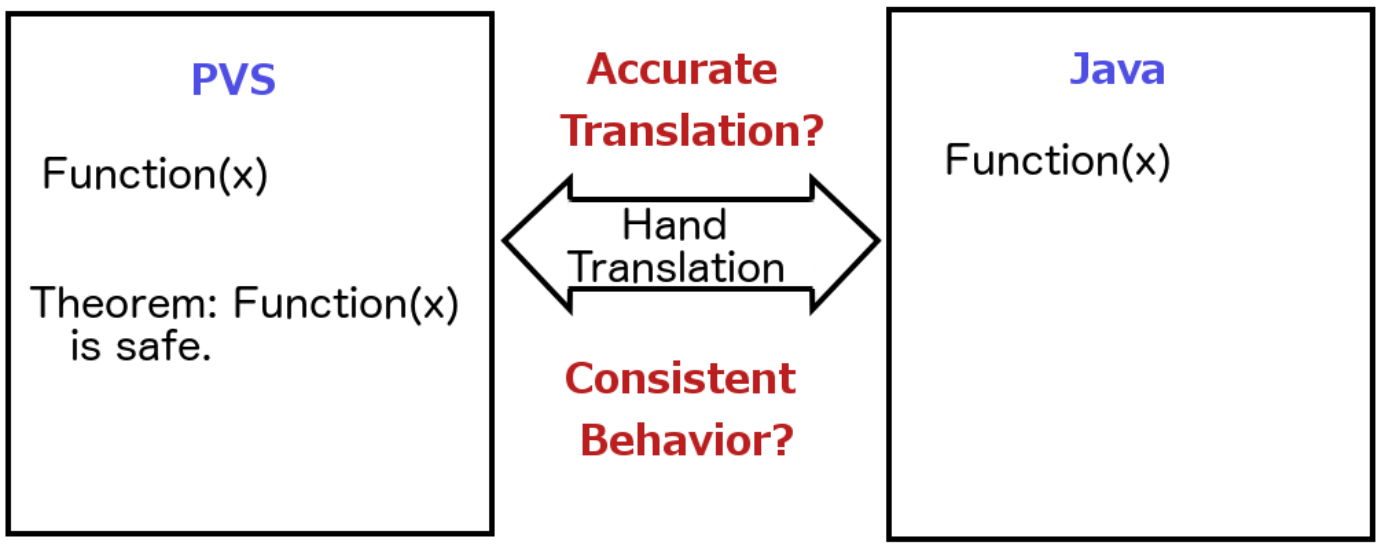

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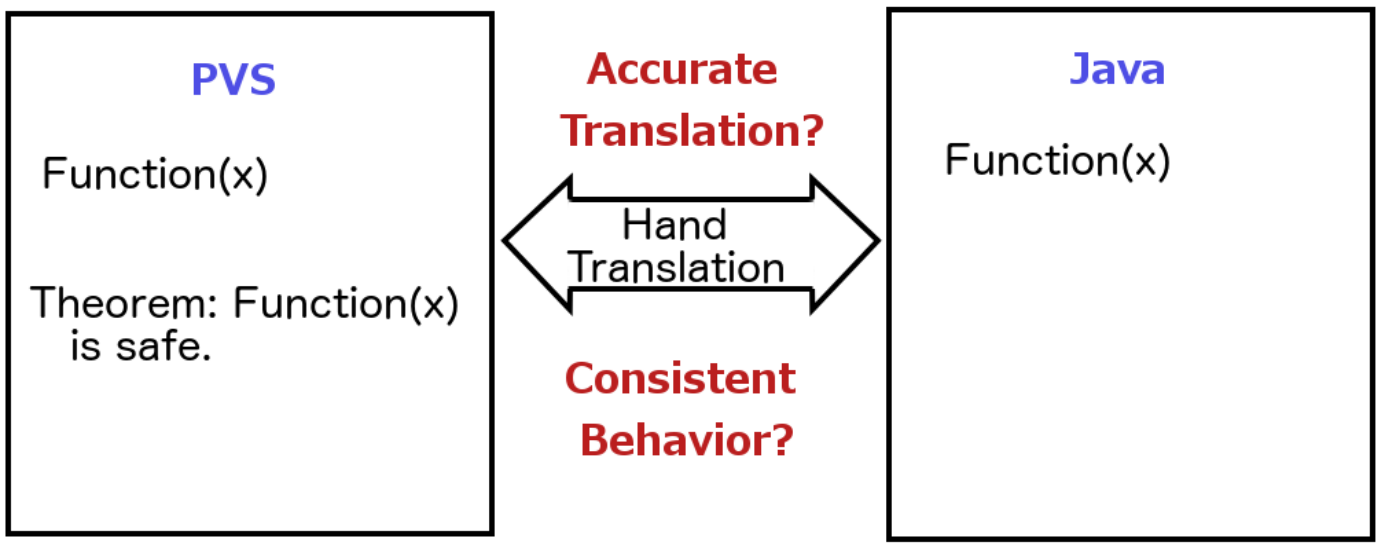

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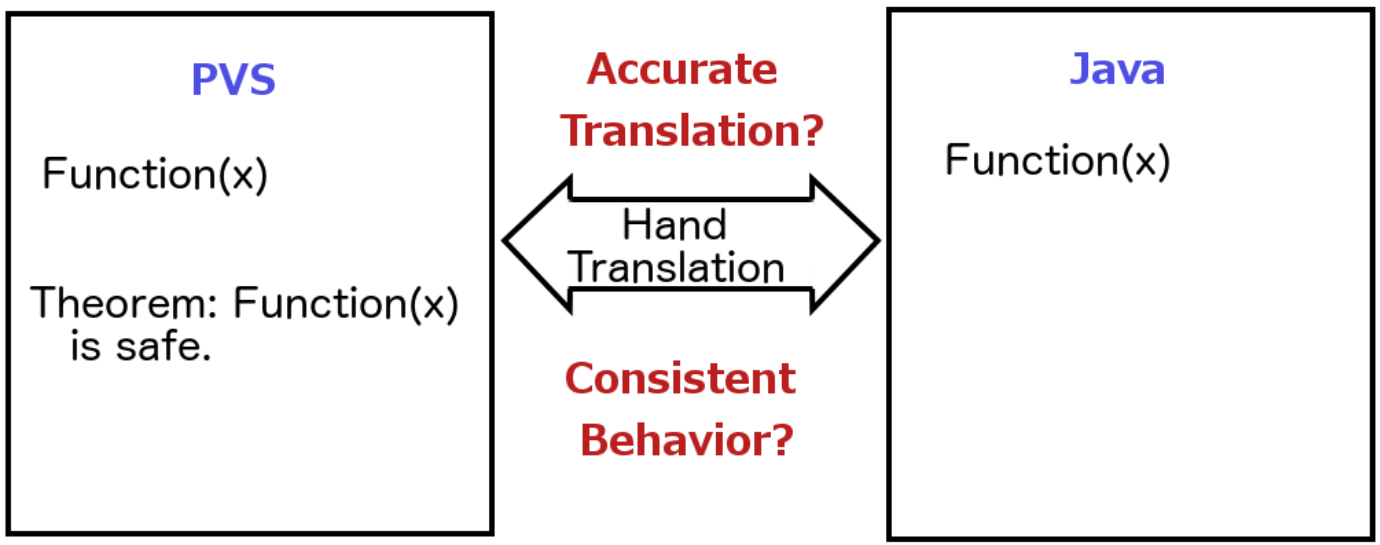

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Model Animation

Bring specifications to life by evaluating them on concrete inputs.

PVSio = PVS ground evaluator + Semantic attachments.
New semantic attachments for square root, sine, cosine, and arctangent that have

$$|f(x) - \mathtt{f}_{sa}(x)| \leq \epsilon$$

for any user specified ϵ.
Future Goal: Provide guaranteed *output* precision, or upper and lower bounds.

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Model Animation

PVSioChecker Automates common tasks for model animation

- Reading and writing of files,
- Converting inputs to exact rationals,
- Comparison of values to user-specified precision,
- Aggregating and printing error, timing, and other information.

Test Generation

- Test cases can be any set based on the situation, generated by any means.
- Three methods used, each implemented for each function with a Java program.

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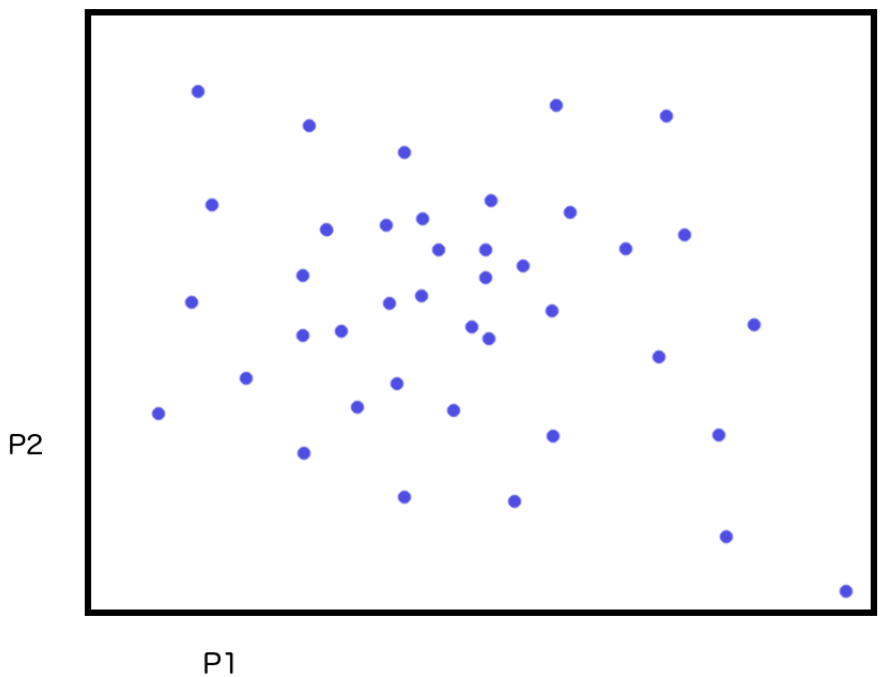

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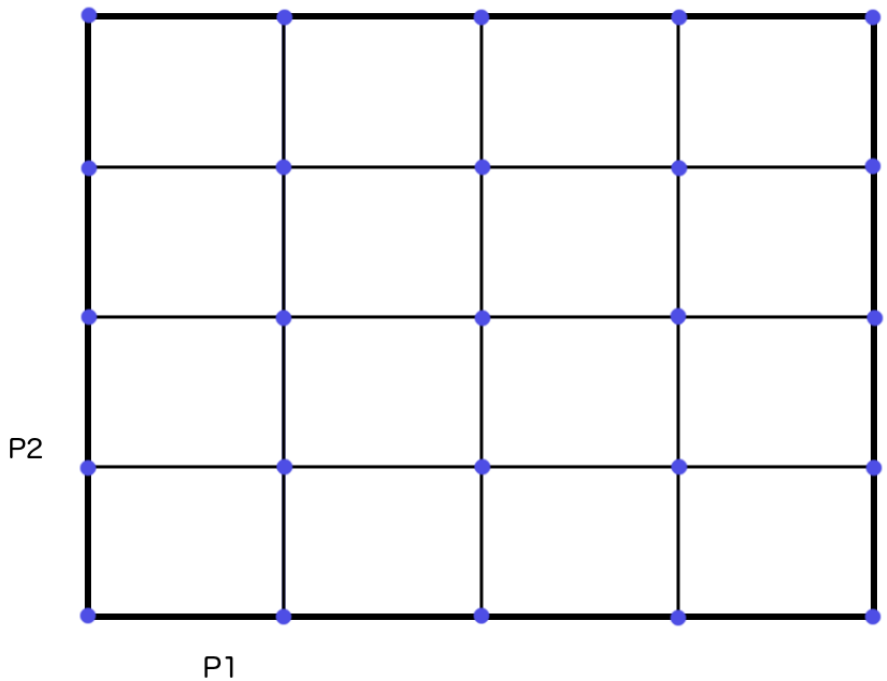
Grid



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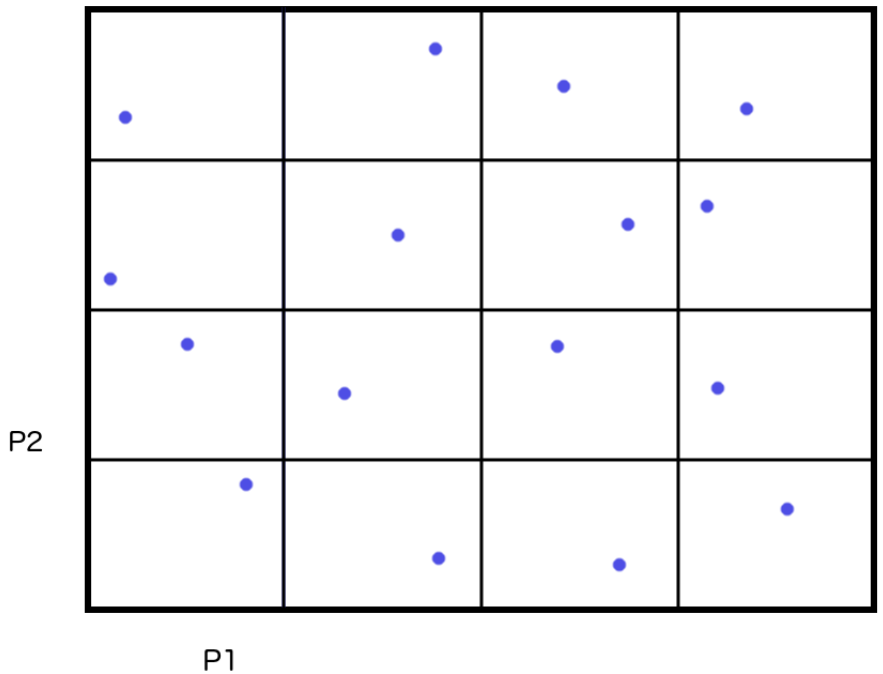
Grid-Random



Results

`vsAccelUntil`

	Records	Fails	CPU time
Rand	1,000,000	0	11.32 hr
Grid	622 ,080	0	4.11 hr
G-R	332,659	0	2.88 hr
totals	1,954,739	0	18.31 hr

`vsAccelUntilWithRampUp`

	Records	Fails	CPU time
Rand	960,000	0	11.7 hr
Grid	340,416	0	2.45 hr
G-R	665,429	0	6.48 hr
totals	1,965,845	0	20.63 hr

`vsLevelOut`

	Records	Fails	CPU time
Rand	810,000	0	11.53 hr
Grid	518,400	0	4.88 hr
G-R	915,000	8	11.42 hr
totals	2,243,400	8	27.83 hr

`gsAccelUntil`

	Records	Fails	CPU time
Rand	330,000	0	12.29 hr
Grid	315,000	0	11.8 hr
G-R	340,000	0	11.7 hr
totals	985,000	0	35.79 hr

`turnOmega`

	Records	Fails	CPU time
Rand	615,000	225	13.06 hr
Grid	504,000	300	7.89 hr
G-R	436,066	309	8.4 hr
totals	1,555,066	834	29.35 hr

Global Totals

	Records	Fails	CPU time
Rand	3,715,000	225	59.9 hr
Grid	2,299,896	300	31.13 hr
G-R	2,689,154	317	40.88 hr
totals	8,704,050	842	131.91 hr

Failure tolerance $= 10^{-8}$, attachment precision $= 10^{-15}$. Less than 0.01% failure rate, concentrated in `turnOmega`.

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Conclusion

Model animation

- A practical way to show that an implementation agrees with its specification.
- Bridges the semantic gap between theorem provers and common programming languages.
- Mitigates concerns over numerical (floating point) errors in software implementations.

Thanks for your attention!