



DCL Decision and Control Laboratory



Semantics of Optimization for Real Time Intelligent Embedded Systems (SORTIES)

Pr. Behcet Acikmese, University of Texas, Austin
Pr. Eric Feron, Georgia Institute of Technology
Pr. John Hauser, University of Colorado, Boulder
Dr. Pierre-Loïc Garoche, Guillaume Davy, ONERA, France

Situation:

Optimization algorithms used in a real-time and safety-critical context offer the potential for considerably advancing robotic and autonomous systems by improving their ability to execute complex missions. However, this promise cannot happen without proper attention to the considerably stronger operational constraints that real-time, safety-critical applications must meet, unlike their non-real-time, desktop counterparts. Advanced real-time algorithms are growing in complexity and **length**, related to the growth in autonomy, which allows aircraft, automobile, and medical devices to plan paths of their own.

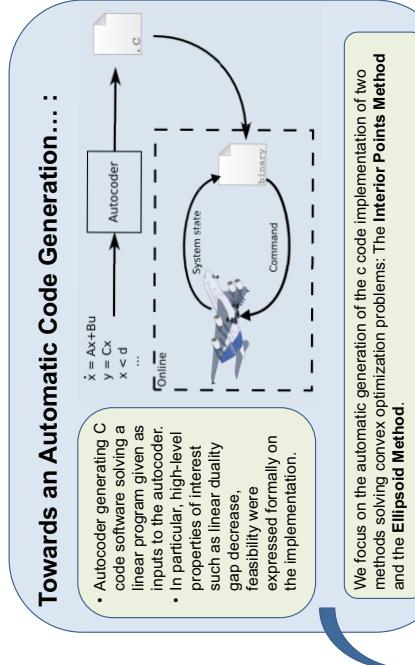
On the other hand, the productivity of safety-critical software developers remains fairly constant at 0.6 to 1 line of code per hour. Knowing that software verification and validation represent fifty percent of their entire engineering development budget, it is then obvious that unless something is done soon, advanced real-time and safety-critical cost development using today's technologies will be unsustainable, if not impossible in the years to come.

Towards an Automatic Code Generation ... ;

- Autocoder generates code software solving linear program giving inputs to the autocoder.
 - In particular, linear properties of interest such as linear dual gap decrease, feasibility were expressed formally, the implementation

Real Time Convex Optimization: Mars Lander guidance

- A photograph showing a yellow and white test rocket launching vertically against a clear blue sky. The rocket has a single large engine at the base and a smaller one on top. A white cylindrical fairing covers the upper part of the rocket. It is mounted on a mobile launch platform with hydraulic arms extending downwards.

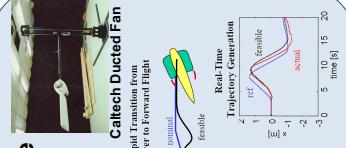


Goals.

- Demonstrate the relevance and feasibility of embedding modern optimization (and control) algorithms in real-time applications, with strong theoretical guarantees.
 - Support the expression of proof elements (including on-line optimization modules) to compile those enriched models down to code, carrying along proof elements.
 - Develop the capability to re-check this information of proof elements for other purposes, such as verification and documentation.

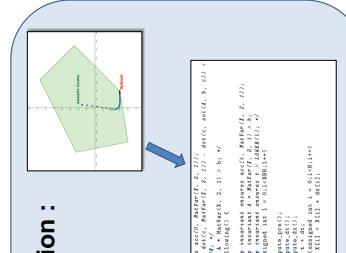
High Confidence Reconfigurable Distributed Control

- Develop and validate an optimization-based, hierarchical control architecture for motion control systems.
 - Exploit new theoretical results in the development of receding horizon optimization objectives to provide guaranteed stability for aggressive flight vehicles.
 - Employ geometric methods to drastically reduce online computational requirements.



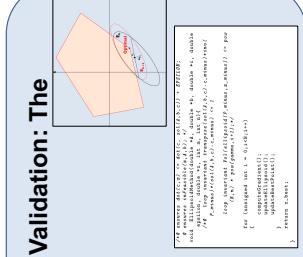
Linear Program Solver Validation : The Interior Points Method

- Generation of a primal interior point method using a convex barrier function along with annotations.
 - Expressing the semantics of the main algorithm (feasibility and optimality of the solution returned).
 - Expressing other low level semantics at the code level (pathfollowing).



Convex Optimizat
Ellipsoid Method

- Generation of a C code implementation of the Ellipsoid Method solving LP.
 - Expressing the semantics of the main algorithm feasibility and optimality of the solution returned.
 - Expressing low level properties as well such as the decrease of the ellipsoids volume
 - Future work: Numerical Stability Analysis.



Project's Tasks and Output:

- Proof-Carrying automatic code generation:
 - Floating point arithmetic management
 - Nonconvex optimization routines

Output : - “Credible Autocoding of Convex Optimization Algorithms”
accepted article in *Optimization Engineering, Implementation of Convex Optimization Algorithms and Credible Implementations for Model Predictive Control*