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SUPEROPT Project and Sense Constraints

SESAR Innovation Days, Toulouse, Nov/Dec 2011

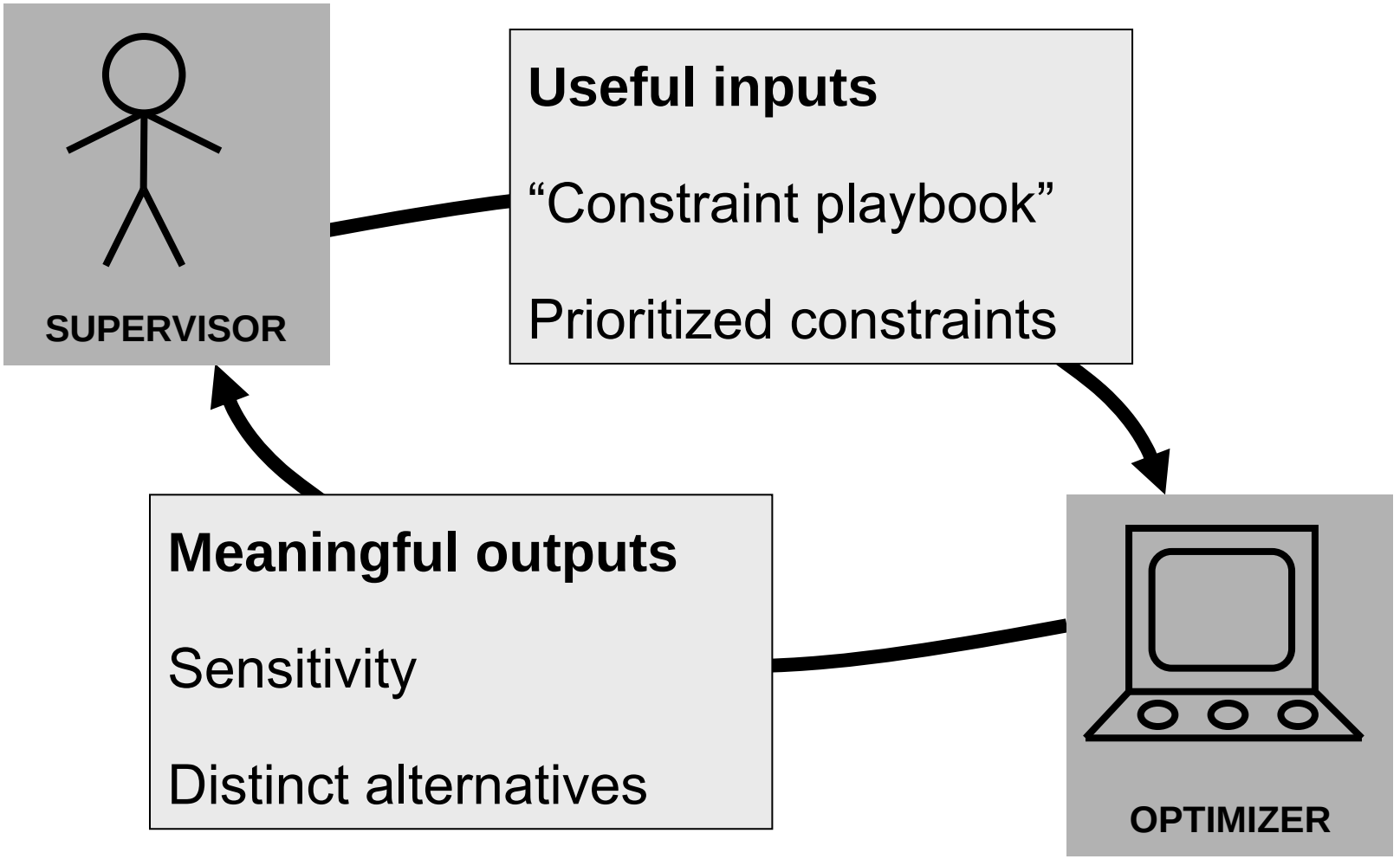
University of BRISTOL

The Project

- ***SUPEROPT*** – Supervision of Route Optimizers

- Find trajectory optimizers that are suitable for human interaction
  - Selecting and applying optimizers
  - ***Not*** developing new ones or HMI

The Project



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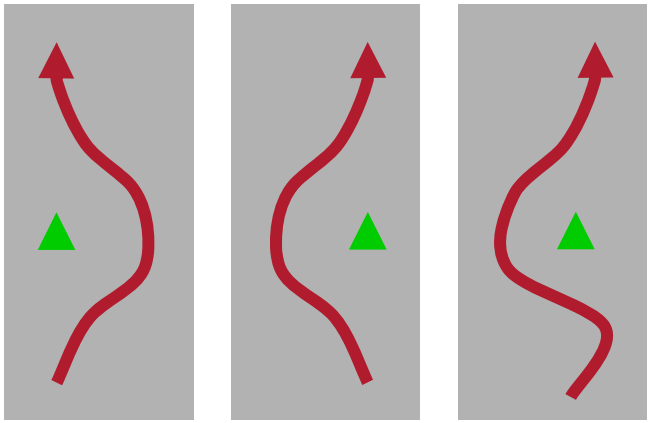
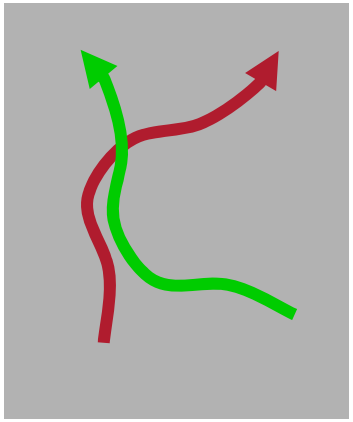
So Far

- Main body of work just about to start
- Today: initial results
  - Constraining the sense of a conflict resolution
- Who is the supervisor?
  - Big question: for now, executive controller

Constraining the Sense

- Tricky to formulate
- Constraint: integrated angular change ≥ 0
  - Or < 0 for opposite
- Angle change robustly captures the sense
  - Independent of direction or aircraft ordering





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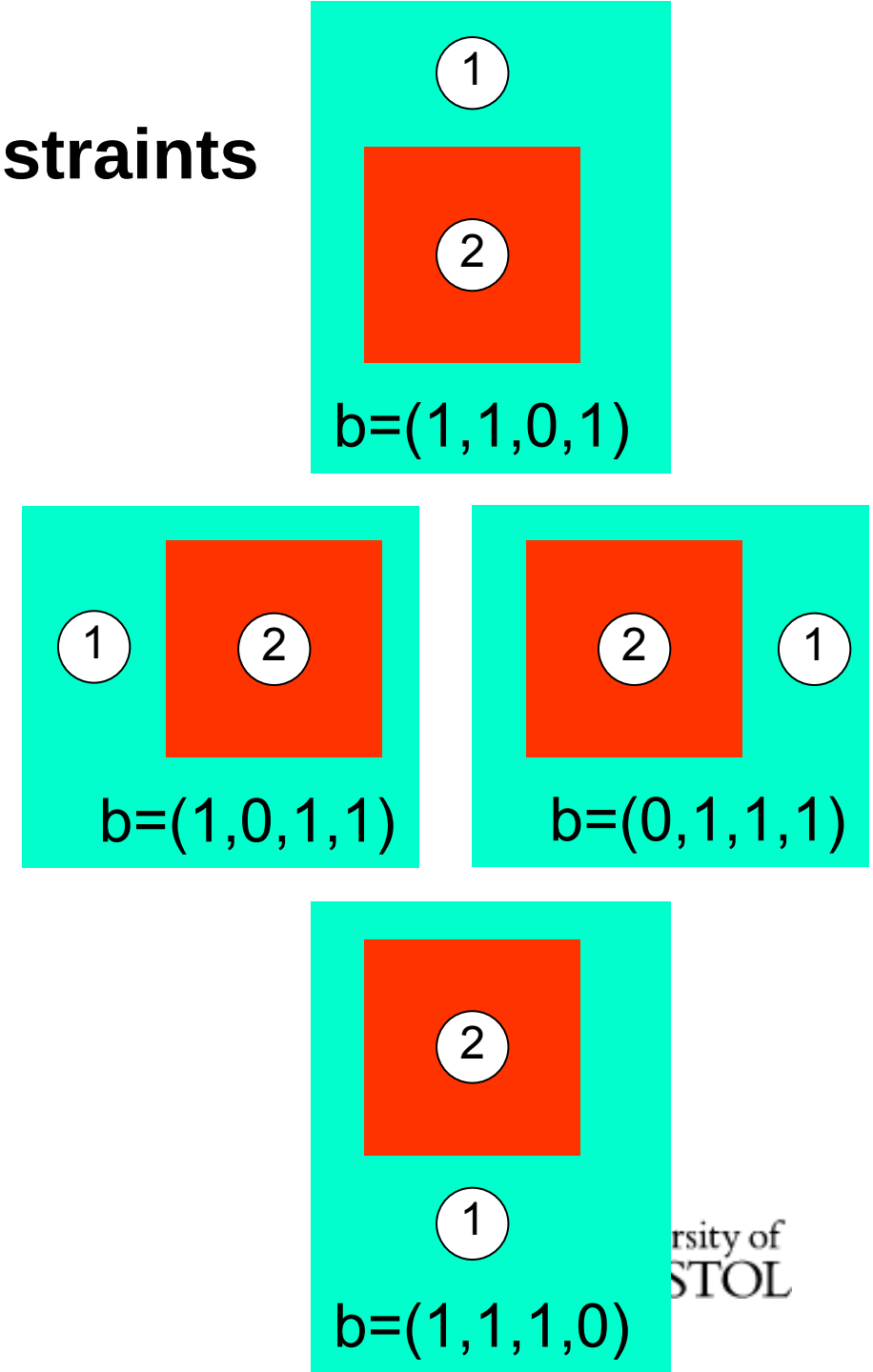
MILP Separation Constraints

$$x_1 - x_2 \geq R - Mb_1$$
$$\text{and } x_2 - x_1 \geq R - Mb_2$$
$$\text{and } y_1 - y_2 \geq R - Mb_3$$
$$\text{and } y_2 - y_1 \geq R - Mb_4$$
$$\text{and } \sum_{k=1}^{4} b_k = 3$$



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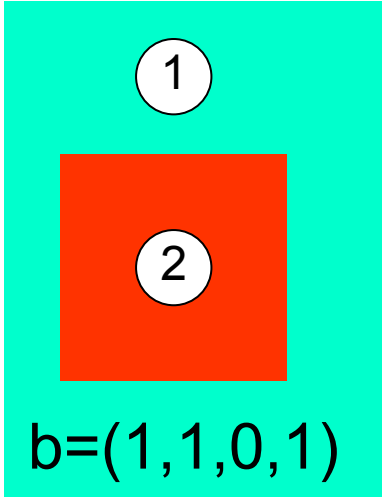
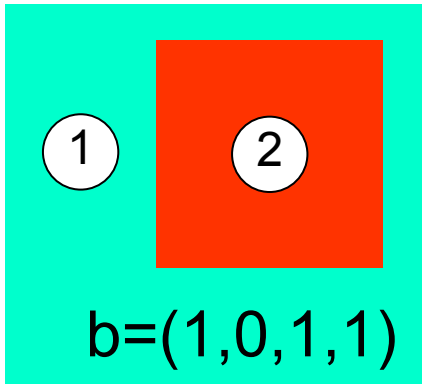
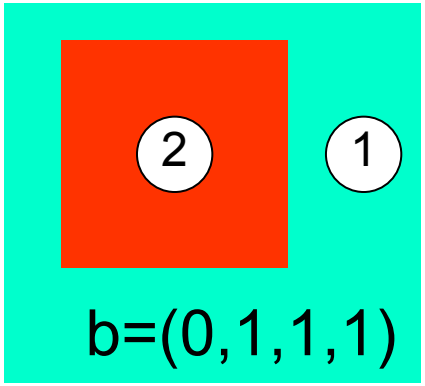
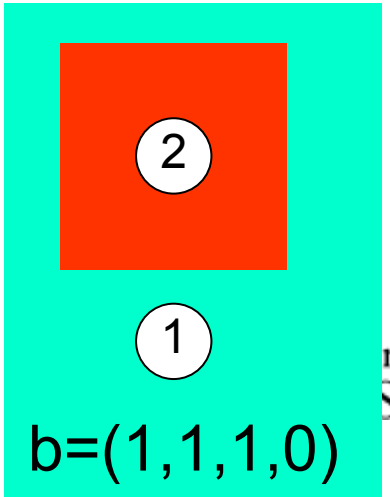
Sense can be related to the sequence of binary settings



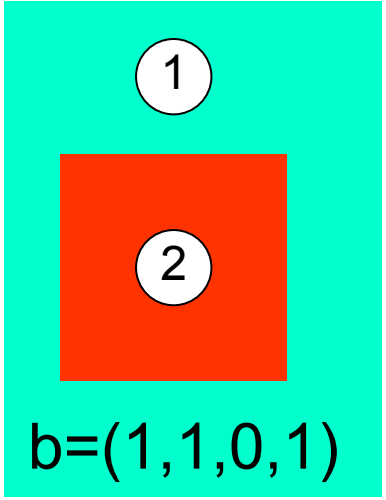


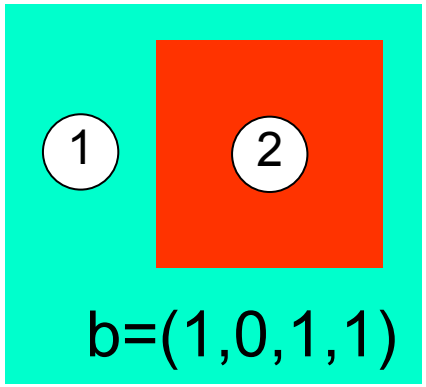


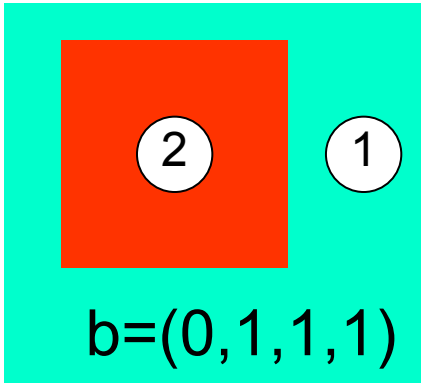


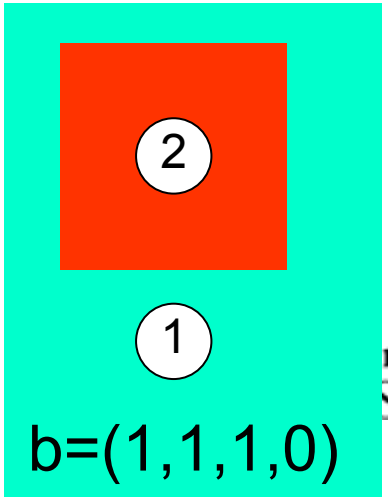
MILP Sense Constraints

- New binary decision variables
  - $m_{CW}(i,k)$=1 if move is clockwise from quadrant i at time k
  - $m_{ACW}(i,k)$=1 if move is anticlockwise from quadrant i at time k
  - $m_{NR}(i,k)$=1 if no move from quadrant i at time k
- Choice of m fixes b







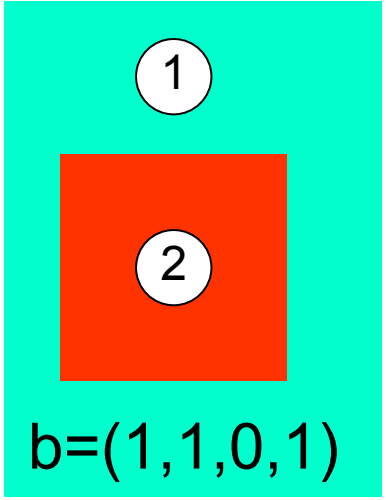


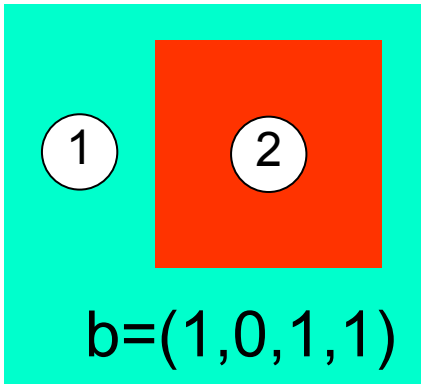
MILP Sense Constraints

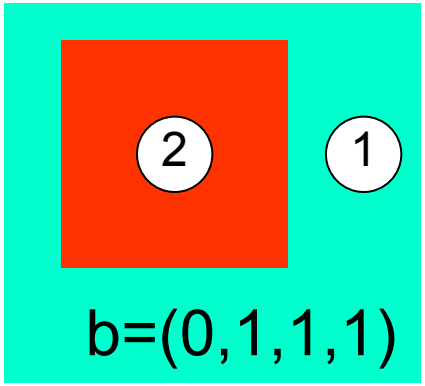
- For clockwise resolution, number of clockwise moves > number of anticlockwise moves

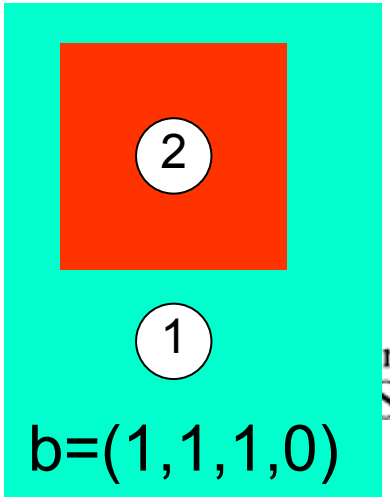
  $\Sigma m_{CW} > \Sigma m_{ACW}$

  – Vice versa for anticlockwise

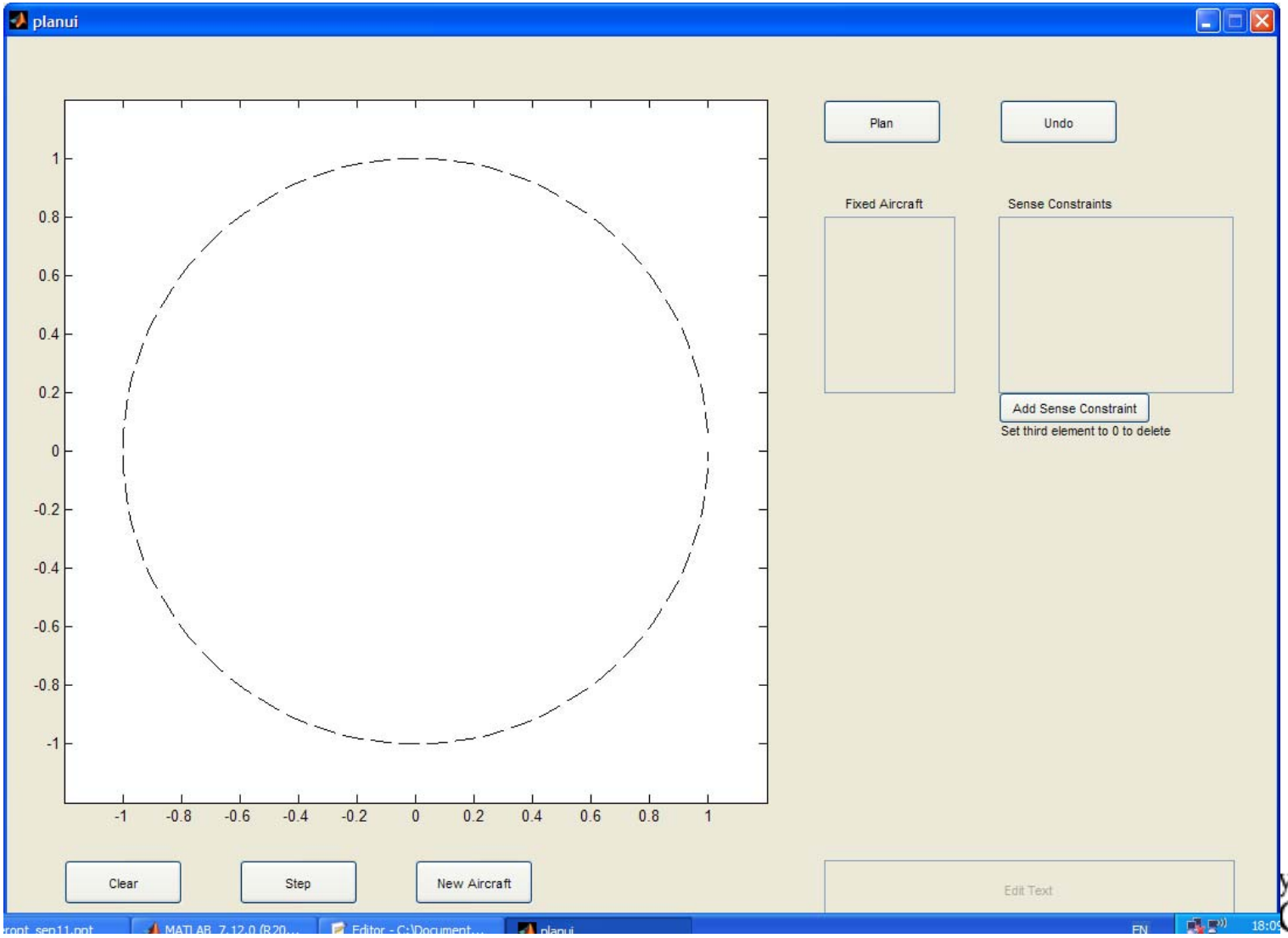








Demonstration



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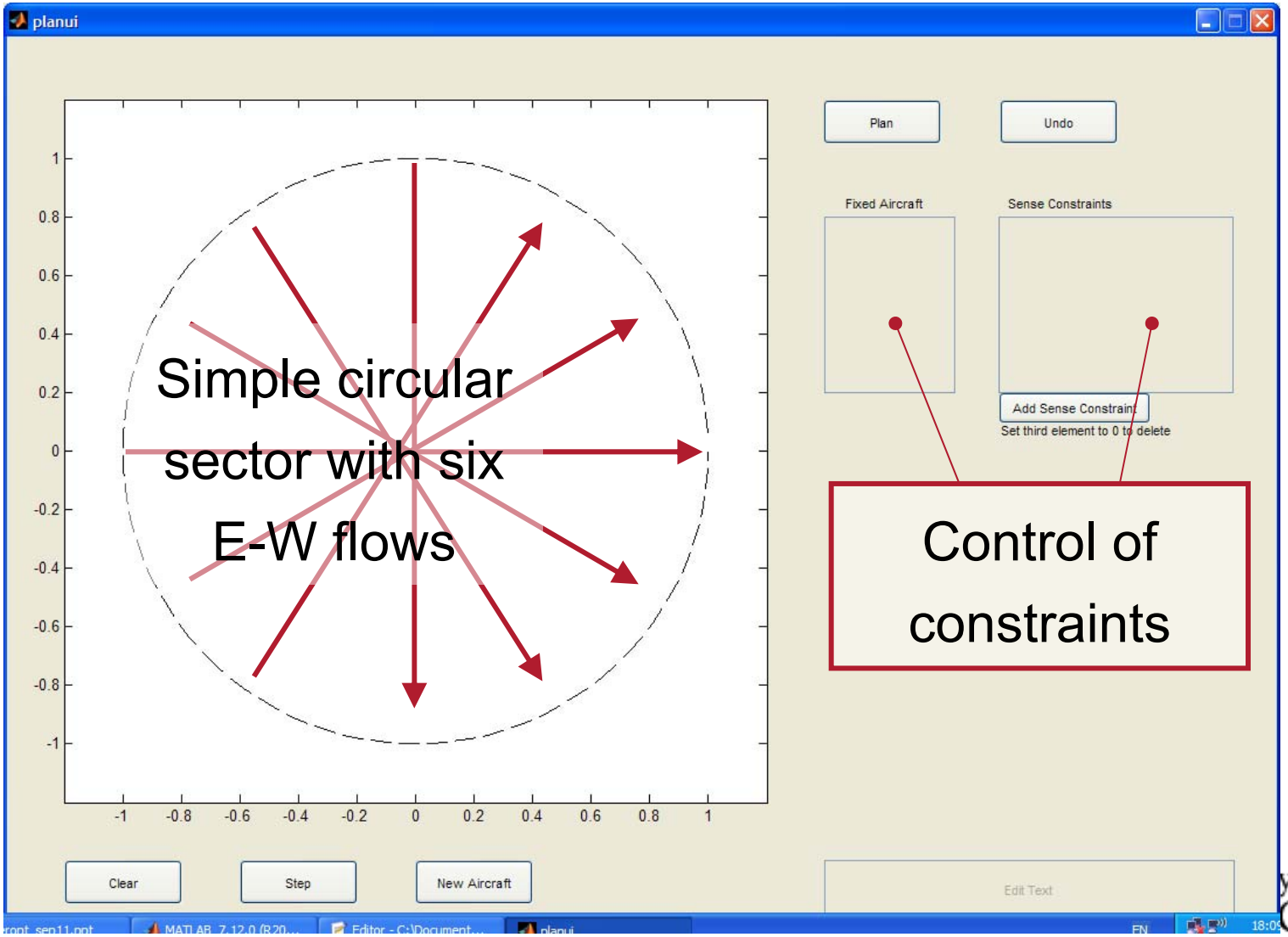

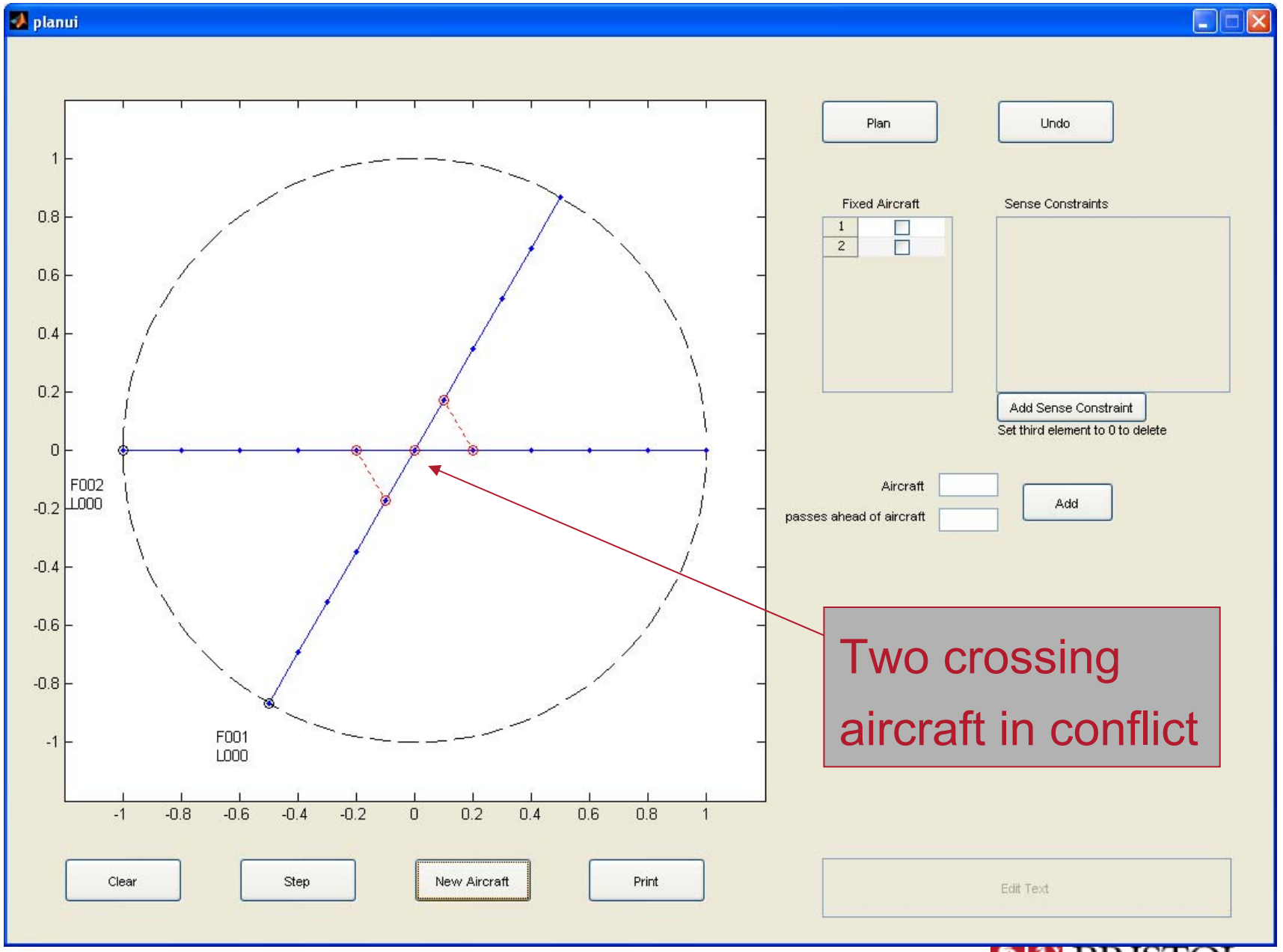
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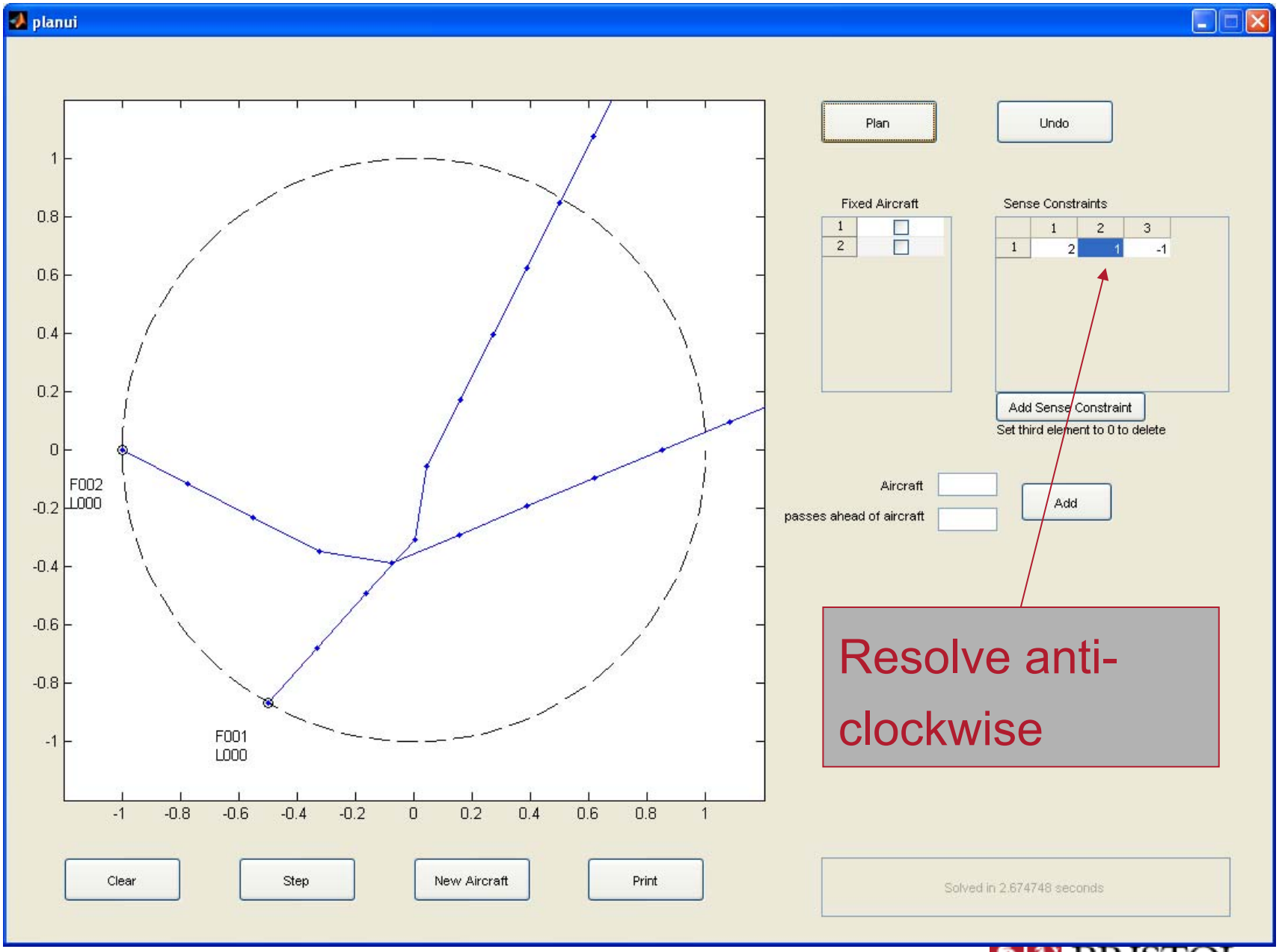
Plan
Undo
Fixed Aircraft
1
2
Sense Constraints
Add Sense Constraint
Set third element to 0 to delete
Aircraft
passes ahead of aircraft
Add
F002
L000
F001
L000
Clear
Step
New Aircraft
Print
Edit Text
Two crossing aircraft in conflict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F002
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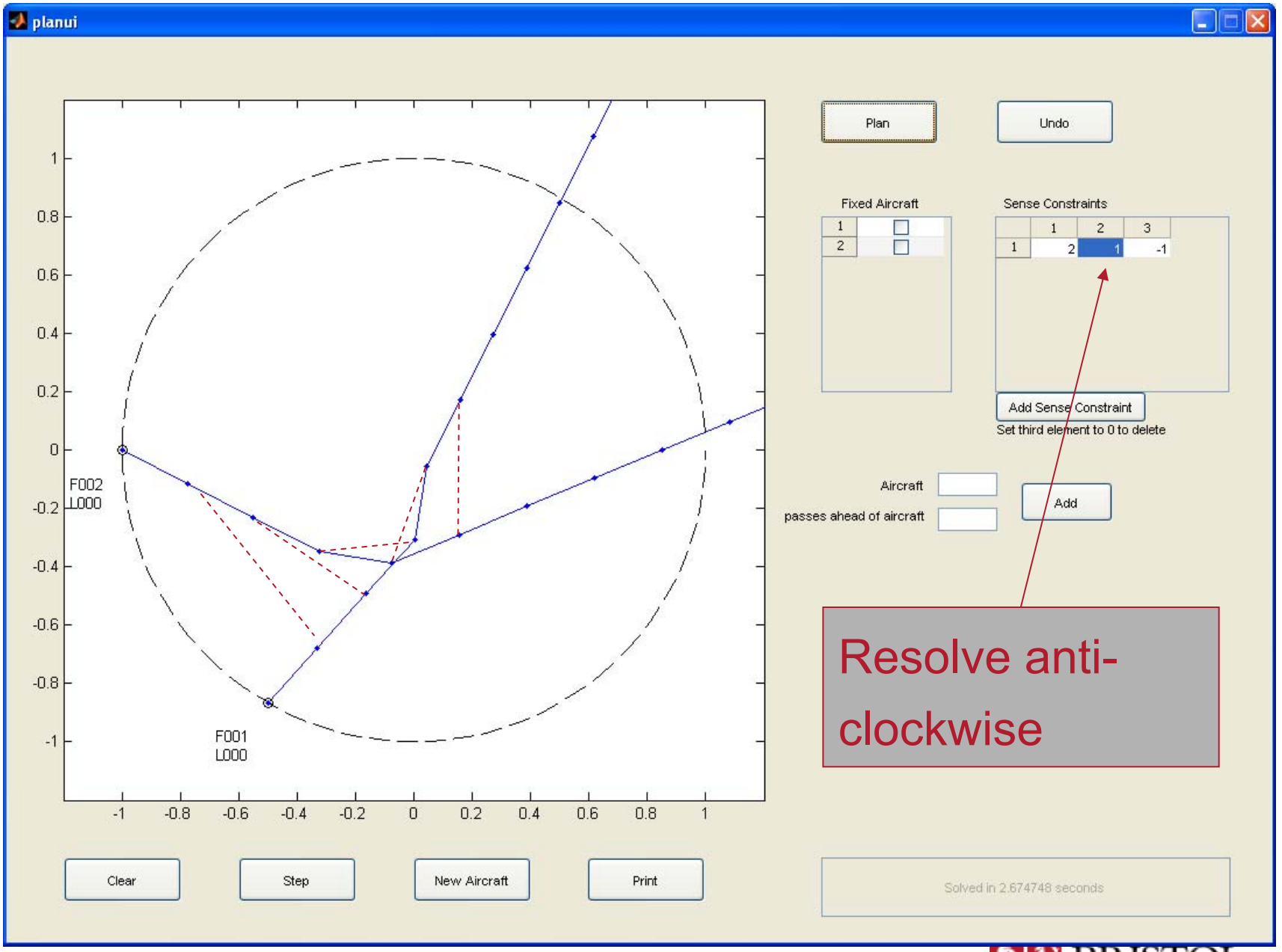
L000
Clear
Step
New Aircraft
Print
Solved in 2.674748 seconds
Resolve anti-clockwise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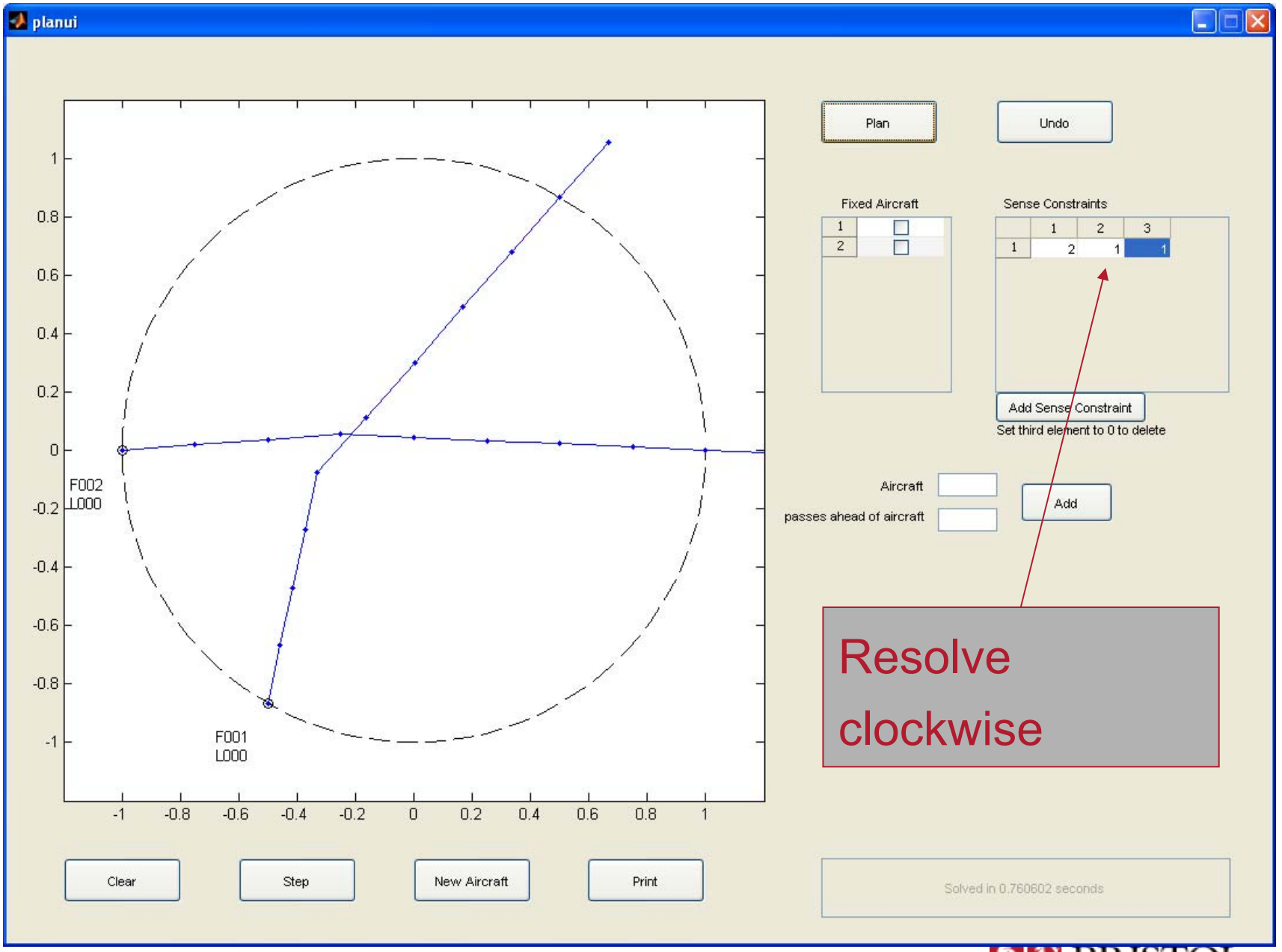
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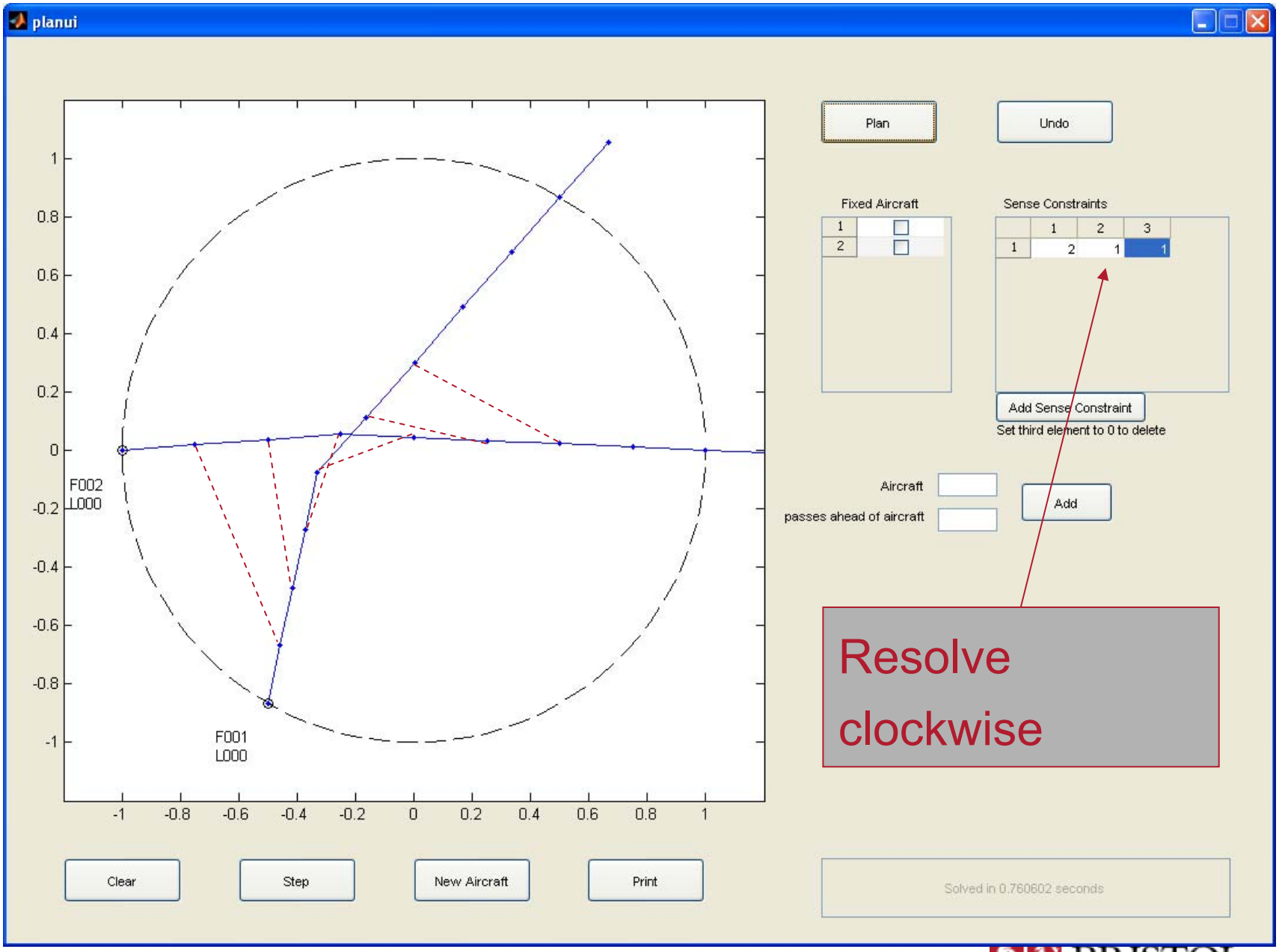
Solved in 0.760602 seconds
Resolve clockwise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L000
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Step
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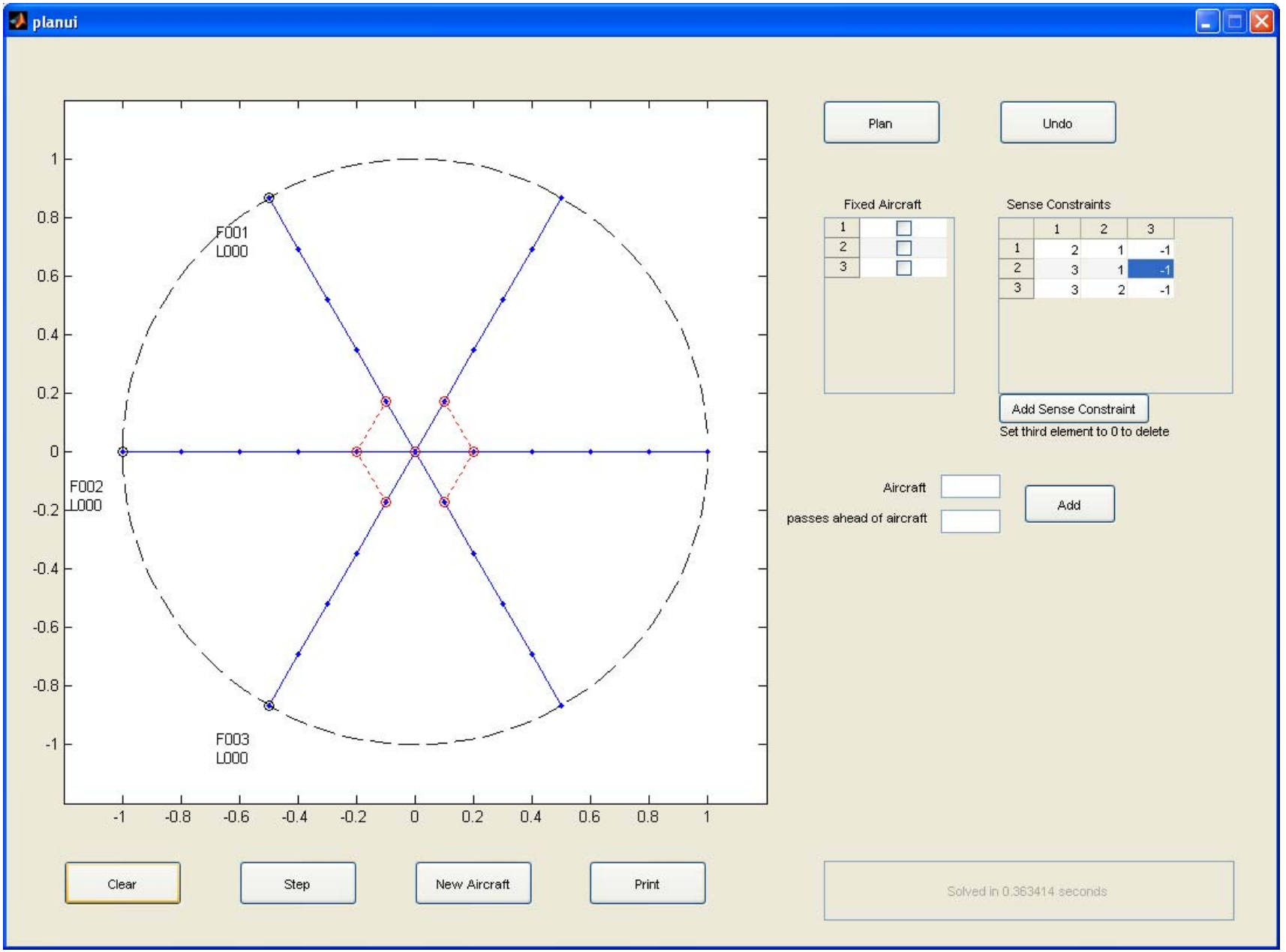
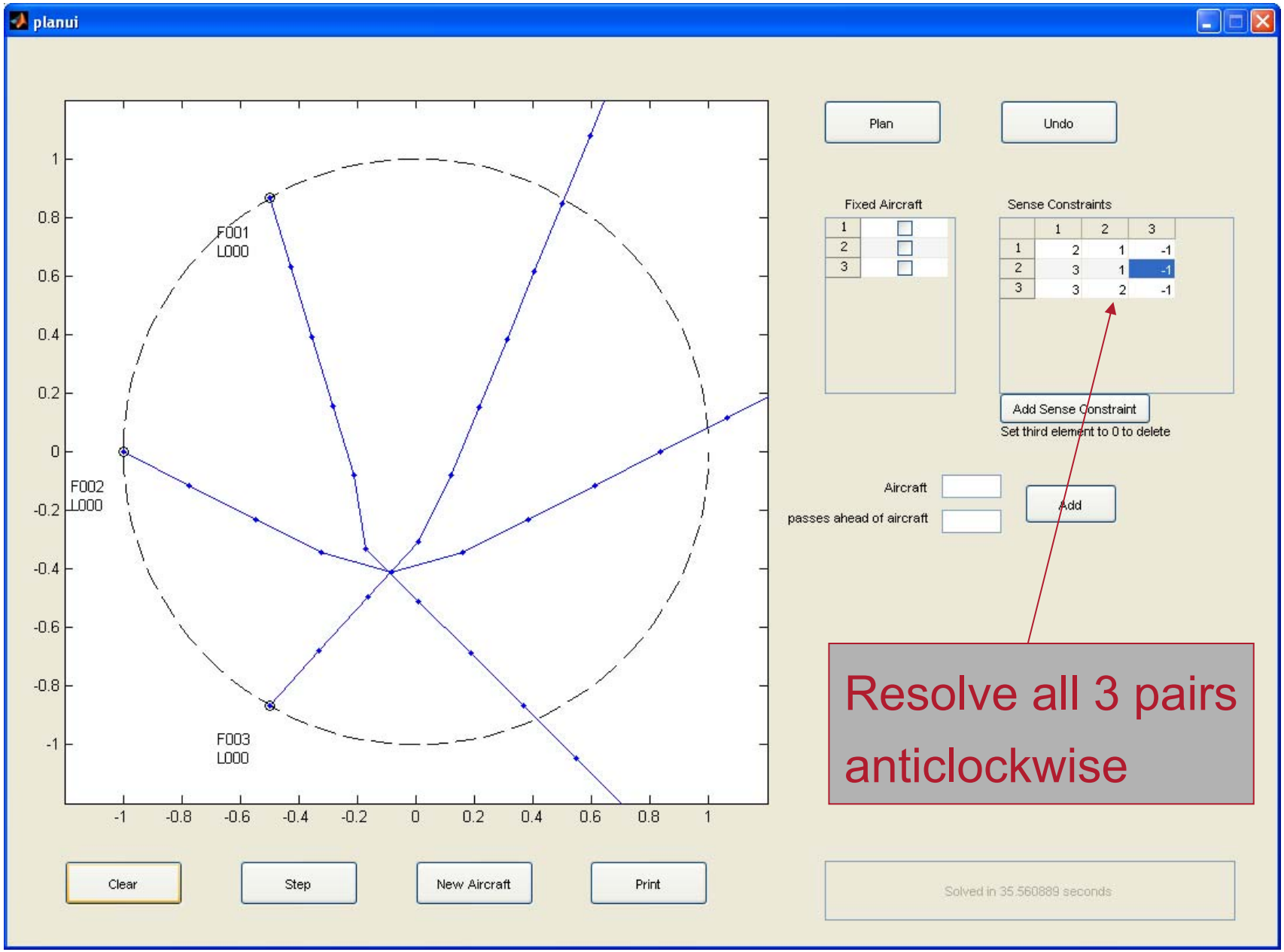
Solved in 0.760602 seconds
Resolve clockwise

Three Aircraft

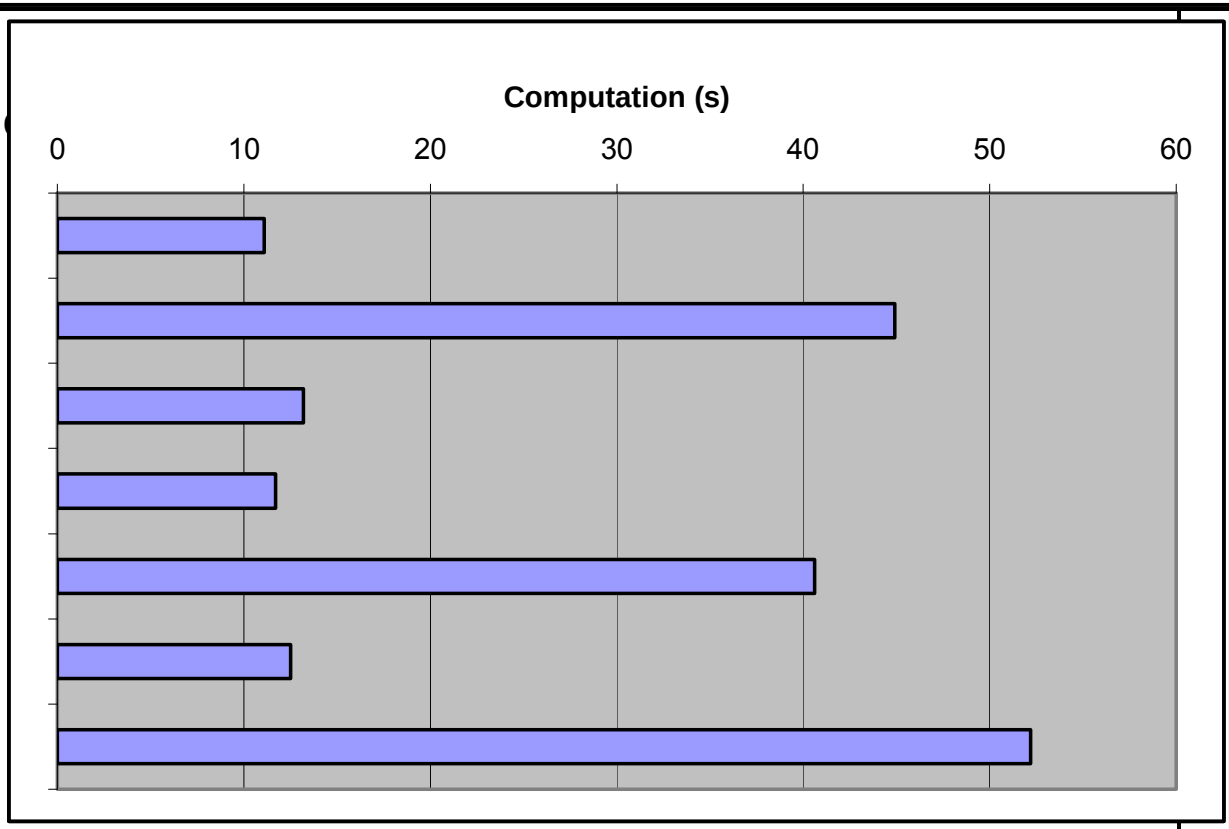


Three Aircraft



Computation

Sense constraint		
3 v 2	2 v 1	3 v 1
ACW		
CW		
CW	CW	
CW	ACW	
CW	ACW	ACW
CW	ACW	CW



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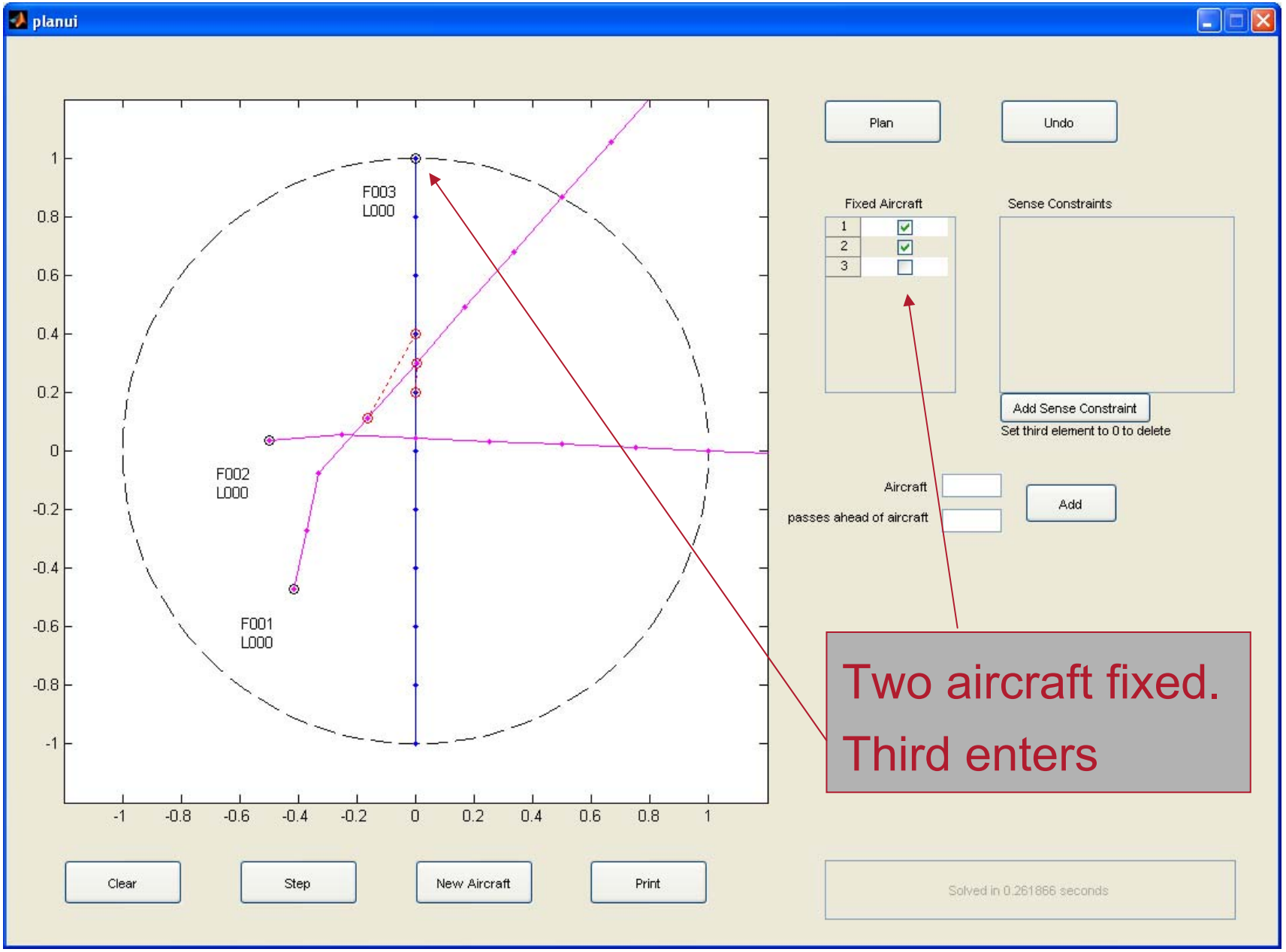
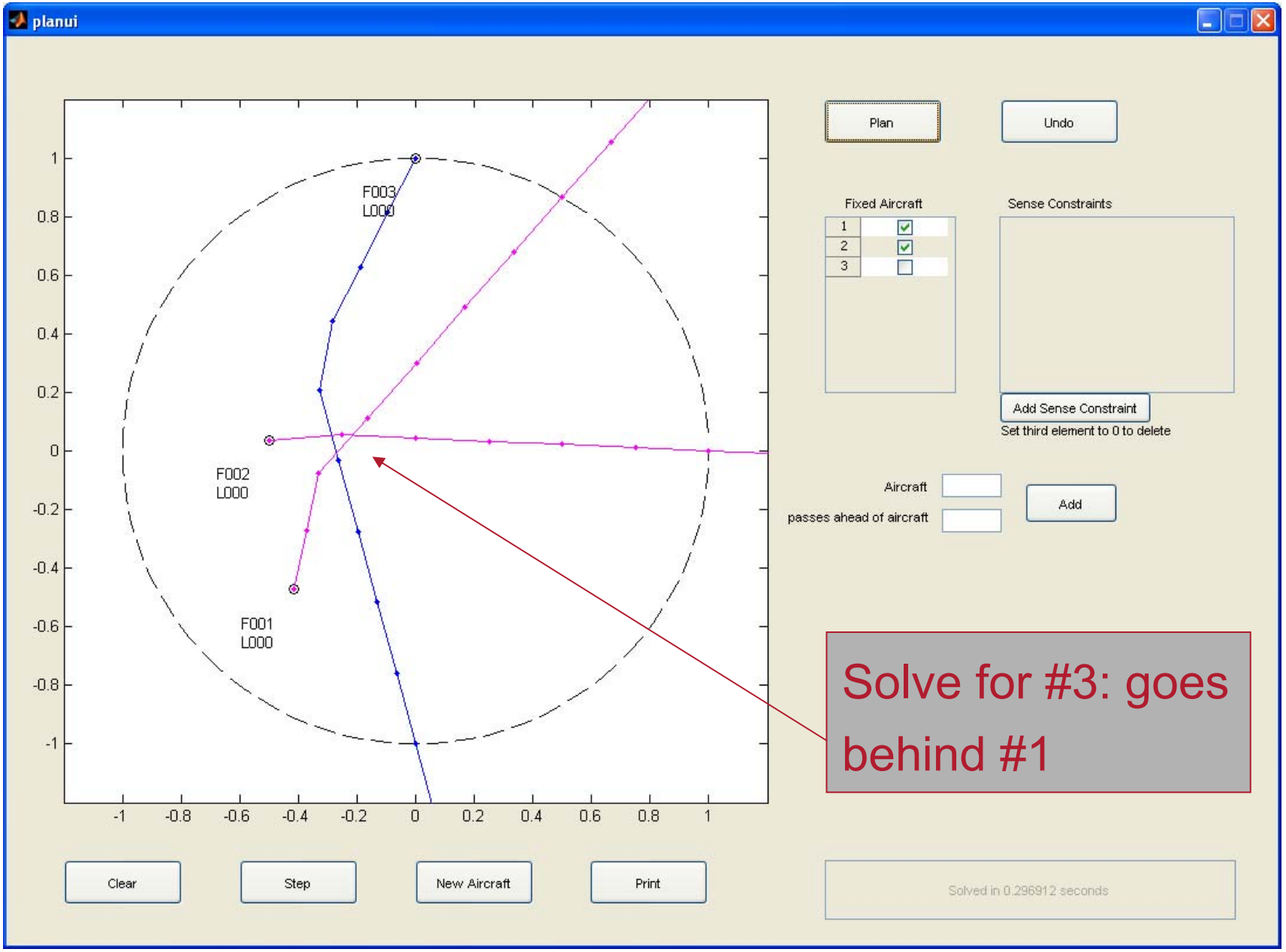
Ahead or Behind



Ahead or Behind



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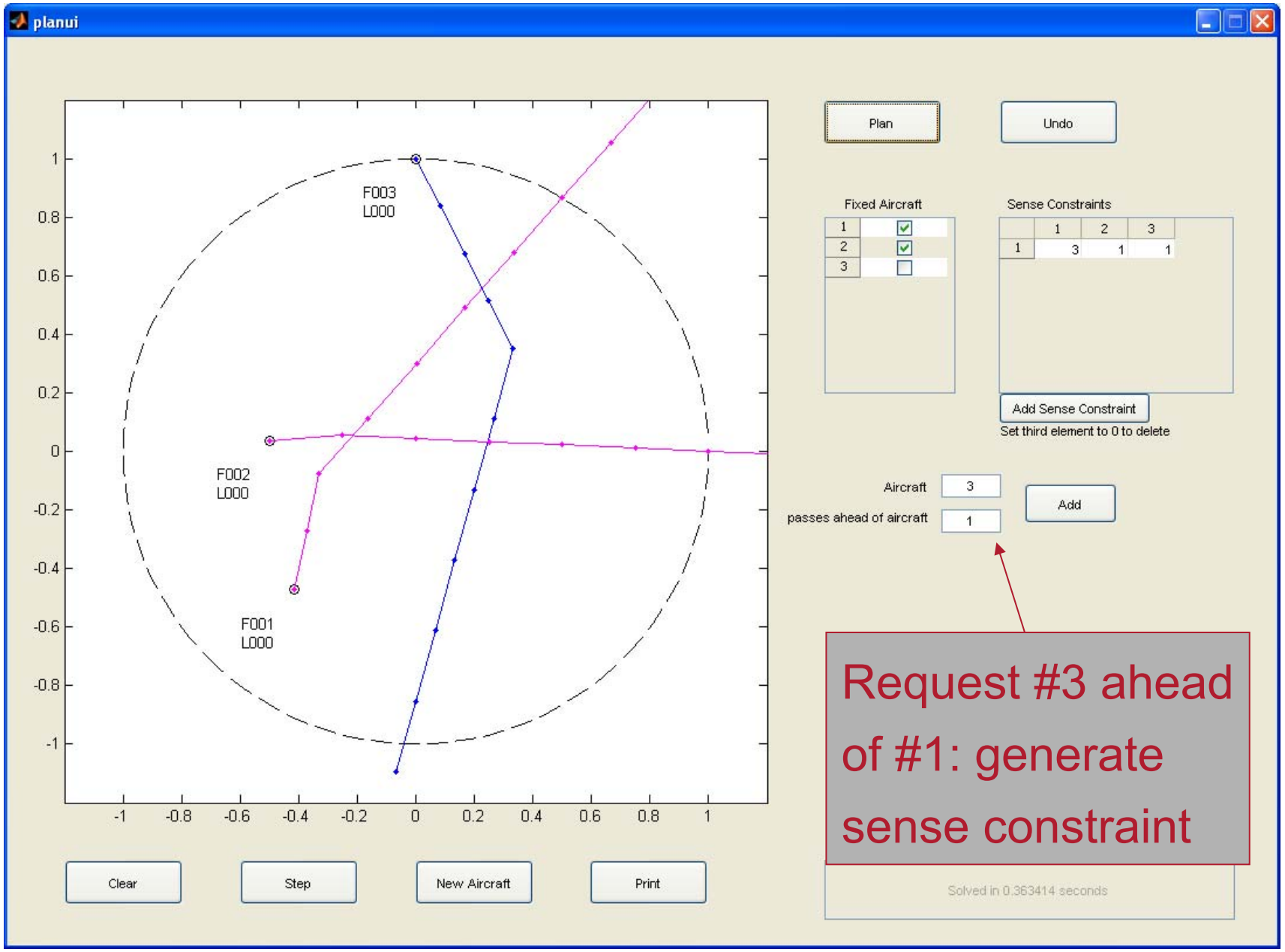
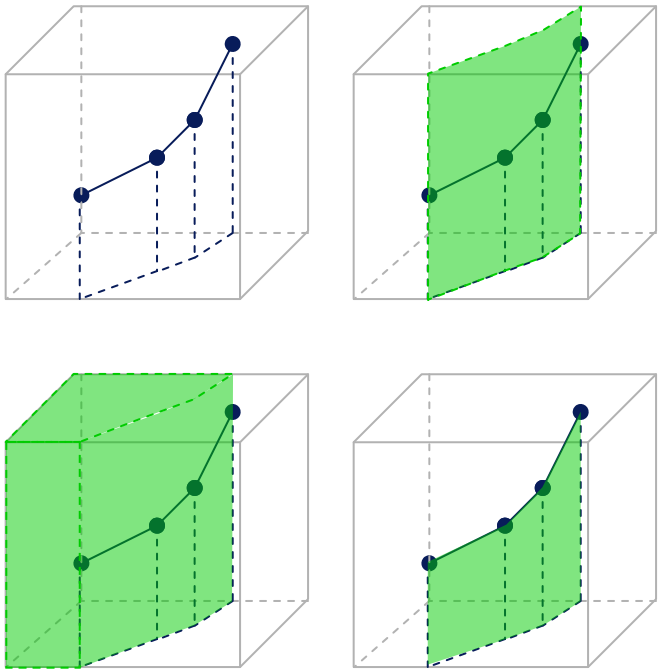


Summary

- Expressed sense constraints in terms of total angle change between aircraft
- Captured and constrained sense within MILP optimization
- Offers an intuitive control of conflict resolution optimization

Next Steps (1 of 2)

- More constraint trials
  - Corridor relative to nominal
  - Deviation from nominal
- Jump to 3-D
  - Easily done in the code
  - Expand possibilities for constraints
    - Resolve above/below
    - Deviate above/below



Next Steps (2 of 2)

- Switch to alternative nonlinear optimizer
  - Core methods available and understood
  - Incorporate new constraint forms
    - Compare with MILP
- Move on to prioritization
  - New idea for cost weight generation
  - Easily done in MILP
  - B&B idea for generic inclusion in any opt.