3rd Global Trajectory Optimization Competition Workshop

Organised by

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History

- GTOC started in 2006 by Dario Izzo of the Advanced Concepts Team, European Space Agency
- Outer Planets Mission Analysis Group of the Jet Propulsion Laboratory, winner of GTOC1, organised GTOC2 in 2006
- Aerospace Propulsion group of Dipartimento di Energetica of Politecnico di Torino, winner of GTOC2, organised GTOC3 in 2007

Motivations

- test methods for spacecraft trajectory optimisation by applying them to difficult problems
- share information concerning trajectory optimization among groups with sometimes different background
- stimulate research in this area

Global and Local Methods

- global optimisation: find the global optimum of a given performance index in a large domain, characterised by many local optima
- possible approaches:
  - use of local optimisation methods on selected subsets of the whole domain
  - use of global optimisation methods that scan the whole domain
- methods: direct (NLP), indirect (CV), evolutionary (GA, DE), neural networks, graphs theory

Optimal Solutions to Past Problems

- GTOC1: scarce use of propulsion, large number of flybys (good for direct methods)
- GTOC2: no flybys allowed, large thrust arcs, only one short coast arc (good for indirect methods)

GTOC3 Problem

- departure from Earth, rendezvous with three NEAs, return to the Earth in 10 years
- performance index puts emphasis on opposing requirements (large final mass versus long stay times at the asteroids)

$$J = \frac{m_f}{m_i} + K \frac{\min_{j=1,3} (\tau_j)}{\tau_{\max}}$$

Criteria

- large design space, large number of local optima
- complex but not overwhelming problem
- simple mathematical formulation, no specific knowledge in astrodynamics required
- (quite) new problem to all the teams
- include a limited number of flybys, alternated coast and thrust arcs

Participants

- 26 registered teams
  - four continents
  - mainly from aerospace background
- 16 solutions at the deadline
  - 13 solutions accepted

Classification

Rank	Team	Index J	Sequence	Departure Arrival, MJD	Final mass m_f, kg	Min. stay τ_{min}, days
1	4 CNES	0.8700	E E E 49 E 37 85 E E	60968 64620	1733	60
2	14 JPL	0.8685	E E 49 E 37 85 E E	60945 64597	1730	60
3	2 Georgia	0.8638	E 49 E 37 85 E E	60996 64648	1721	60
4	17 Deimos	0.8617	E 49 E E 37 85 E E	60964 64616	1717	60
5	18 TAC	0.8372	E 88 E 96 49 E	57726 61316	1647	245
6	13 TAS	0.8353	E 96 E 88 49 E	58169 61799	1647	211
7	8 MAI	0.8321	E 88 E 96 E 49 E	58075 61654	1658	60
8	1 GMV	0.8279	E E 96 76 E 49 E	59259 62870	1649	60
9	5 MSU	0.8257	E 96 E 88 49 E	58478 61998	1633	165
10	7 Glasgow	0.8063	E 88 19 49 E	58813 62365	1606	62
11	9 Tsinghua	0.7946	E 88 76 49 E	58091 61642	1565	225
12	11 Pisa	0.7744	E 88 49 19 E	58094 61319	1528	191
13	25 IKI	0.7537	E 76 96 49 E	58129 62332	1501	60
-	21 Milano	0.8376	E 88 E 96 49 E	58169 61693	1663	110
-	6 ESA	0.8172	E 96 88 49 E	58144 61650	1614	187
-	10 Delft	-	E 96 122 85 E	59308 62416	1130	94

Results

- four teams found the same (optimal) asteroids sequence and time frame, different number/position of flybys, using different methods
- Earth flybys necessary for best solutions
- best solutions required shortest stays on asteroids (in contrast with our intent)
- longer stays required with one/zero flybys

And Now...

Enjoy the workshop and your stay in Turin