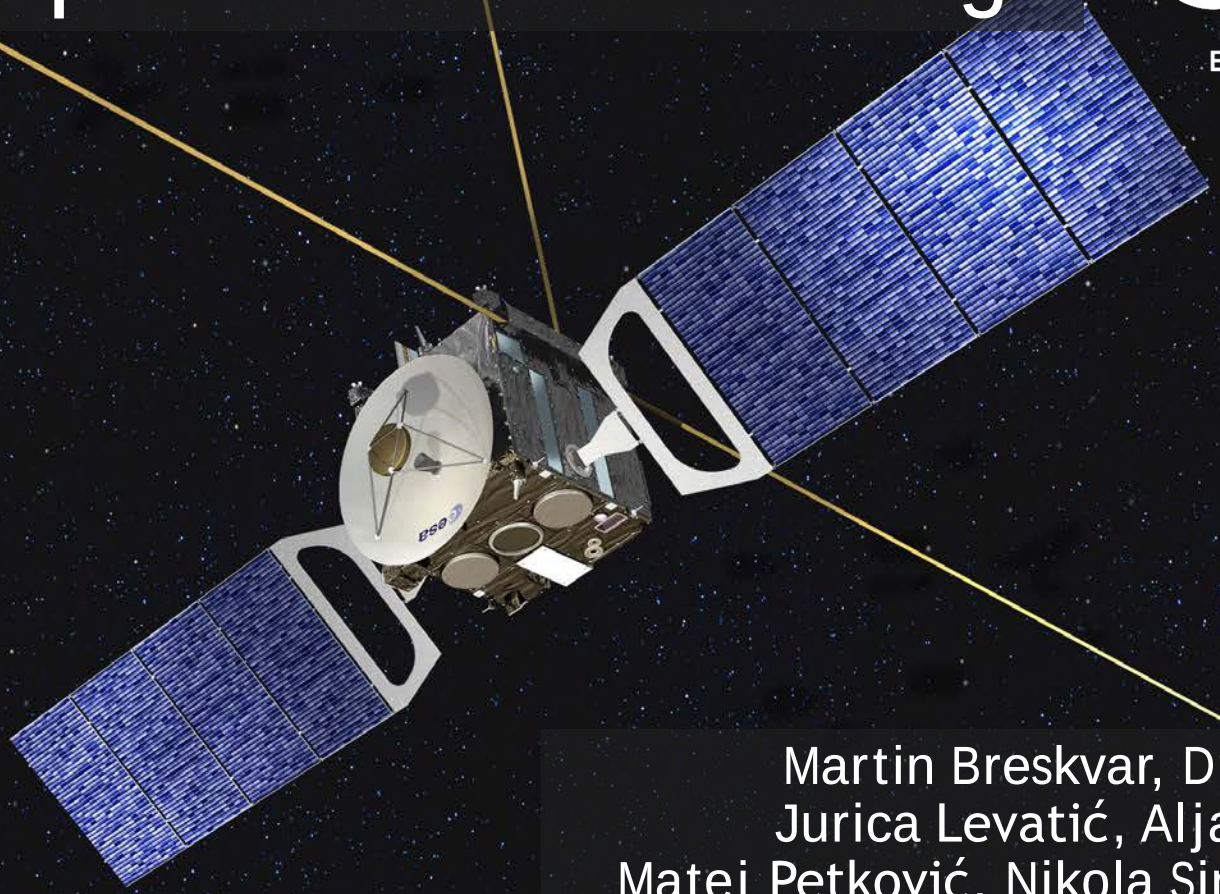
Mars Express Power Challenge



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The equipment needs to be at certain temperature:

- Electronics – room temp.
- Imaging sensors – low temp.

Science Power = Produced Power - Thermal Power

The Problem

Given: data for 3 Martian years:

- Year 1: 2008-08-22 to 2010-07-10
- Year 2: 2010-07-10 to 2012-05-27
- Year 3: 2012-05-27 to 2014-04-14

Multi-target regression

Predict: power consumption of 33 thermal lines for

- Year 4: 2014-04-14 to 2016-03-01 (per hour)

The Data

- Solar Aspect Angles (SAAF)
- Detailed Mission Operations Plan (DMOP)
  - subsystem on/off
- Flight Dynamics TimeLine with pointing events (FTL)
- Long term data
  - solar constant, mars-sun distance etc.
- Other events
  - Umbras, pen-umbras…

33 target attributes:

- Measured electric current every 30-60 seconds

Solar Aspect angles

- ut_ms: unix timestamp in milliseconds
- sa: angle of Mars Express solar panels' normal
- sx: solar angle of the X axis of satellite
- sy: solar angle of the Y axis of satellite
- sz: solar angle of the Z axis of satellite

Detailed Mission Operations Plan

- ut_ms: unix timestamp in milliseconds
- subsystem: name of the operated subsystem command

Unix timestamp, Subsystem
1219370500000, AXXX305A
1219370632000, AXXX3AFF
1219370819000, MAPO.0000008333
...

Other events:

Unix timestamp, Description
1219370500000, "1200_KM_DESCEND„
1219370632000, "MRB_AOS_10„
1219370819000, "800_KM_DESCEND„
1219370902000, "MAR_PENUMBRA_START„
1219370986000, "MAR_UMBRA_START„
1219371075000, "MAR_UMBRA_END„
...

Feature Construction

- Data time frame (resolution)
- Current solar radiation
- Solar radiation in the past
- DMOP and FTL (orbiter commands and pointing events)

Data time frame

- Power data (targets) typically measured in 30-60s intervals with a lot of gaps
- 1min time resolution (=time step)

- ➢ Fixed 60s time step for entire data set
- ➢ Remove larger gaps (5 or 10 time steps)
- ➢ Linear interpolation and integration for continuous data (electric, solar power)

➢2.6 million examples!

Current Solar Radiation

- For each of the 6 six sides of the orbiter + solar panels:

$$A_E = A \max\{\cos\alpha, 0\}$$

$$\texttt{feat}(t_i) = \int_{t_i}^{t_{i+1}} A_E(t) c(t) U(t) \mathrm{d}t$$

- Using orbiter orientation angles α, solar constant c and (pen)umbra coefficient U

Orbiter History

- Current orbiter state depends on its state in the past
- Lagged features
- Summed features

$$\texttt{feat-sumN}(t_i) = \sum_{t=t_{i-1}}^{t_{i-N}} \texttt{feat}(t)$$

- N = 4, 16, 32, 64, 128

DMOP and FTL Features

- DMOP: when different subsystems' commands have been triggered

➢Time since (max 1 day) activation for:

  - all command/subsystem pairs
  - any command for a given subsystem

- FTL: when different spacecraft pointing events took place + communication with Earth

➢Event Active/Inactive

Final Data Set

- 1 min time resolution
- 465 features
- 2.6M examples
- 7.4 GB

- Newer versions:
  - 1 and 2 min time resolution
  - Lagged and summed DMOP and FTL
  - 600 and 1200 features
  - 2.6M and 1.3 M examples
  - 17 GB

Machine Learning

What we tried:

- Predictive Clustering Trees (PCTs)
- Random Forests of PCTs
- Single target and multi target prediction
- Clustering of targets to combine ST and MT
- Tuning of RF parameters
- All data (years 1+2+3) and only recent data (3rd year)
- A few different data sets
- Feature ranking
- Ensemble of ensembles
- Extreme Gradient Boosting
- ...

What worked best?

- Random Forests of PCTs:
  - 200 trees in ensemble
  - minimum of 500 examples in tree leafs
  - consider ¼ of all features (instead of sqrt)
- Smaller data set (465 features, 2.6M examples, 7.4 GB)
- Single target prediction (6th place -> 1st place)

- Training time: ~15h per target
- ~100 Gb of RAM

What the Others Did?

- 1h time resolution
- Extreme Gradient Boosting, Neural Nets, Ensembles of ensembles
- Multi target to single target conversion (new attribute specifying the target):

  Original dataset (F=Feature, L=Power Line):

F1	F2	L1	L2
1.3	0.2	0.4	0.6
1.9	1.2	0.2	0.7

  Flattened dataset (LID = Line ID):

F1	F2	LID	L
1.3	0.2	1	0.4
1.3	0.2	2	0.6
1.9	1.2	1	0.2
1.9	1.2	2	0.7

Leaderboard :-)

Leaderboard

Name	Submissions	Last Submission	Best Submission	Best Score
MMMe8	21	July 30, 2016, 9:17 a.m.	July 30, 2016, 9:17 a.m.	0.0803769211622248
redrock	58	July 29, 2016, 11:39 p.m.	July 29, 2016, 11:39 p.m.	0.0804496833344005
fornaxintospace	58	July 29, 2016, 7:38 p.m.	July 29, 2016, 7:38 p.m.	0.0819239101733324
Alex	42	July 22, 2016, 8:24 p.m.	July 22, 2016, 8:22 p.m.	0.0846394180545192
trnka	38	July 29, 2016, 9:12 p.m.	May 22, 2016, 8:23 a.m.	0.0906015604695004
w	49	July 29, 2016, 8:12 p.m.	July 29, 2016, 8:12 p.m.	0.0906458520844299
otto	10	July 29, 2016, 7:35 p.m.	July 29, 2016, 7:35 p.m.	0.0966951084083446
Gagan@Gowda	39	July 30, 2016, 2:59 a.m.	July 30, 2016, 2:59 a.m.	0.0976163772137674
dinesh	26	July 30, 2016, 6:14 a.m.	July 28, 2016, 5:15 p.m.	0.0987883463469848
qianzhaozhi	3	May 26, 2016, 3:56 p.m.	May 25, 2016, 5:52 p.m.	0.0997231086092421
Mars_km.dfki	21	July 29, 2016, 7:13 p.m.	July 29, 2016, 7:13 p.m.	0.0997384213146519

Leaderboard :-(

Leaderboard

Name	Submissions	Last Submission	Best Submission	Best Score
redrock	64	July 31, 2016, 11:57 p.m.	July 31, 2016, 11:48 p.m.	0.0802580418739296
MMMe8	24	July 31, 2016, 11:53 p.m.	July 30, 2016, 9:17 a.m.	0.0803769211622248
fornaxintospace	63	July 31, 2016, 11:56 p.m.	July 29, 2016, 7:38 p.m.	0.0819239101733324
Alex	42	July 22, 2016, 8:24 p.m.	July 22, 2016, 8:22 p.m.	0.0846394180545192
luis	6	July 31, 2016, 11:56 p.m.	July 31, 2016, 11:56 p.m.	0.089078627464354
w	53	July 31, 2016, 5:06 p.m.	July 31, 2016, 5:06 p.m.	0.0895714760419749
trnka	42	July 31, 2016, 11:57 p.m.	May 22, 2016, 8:23 a.m.	0.0906015604695004
Gagan@Gowda	41	July 31, 2016, 10:39 p.m.	July 31, 2016, 10:39 p.m.	0.0963982366953394
yaseen	11	July 31, 2016, 11:13 p.m.	July 30, 2016, 5:42 p.m.	0.0964198045933572

Final Results :-)

Results

Rank	Name	Submission Date (UTC)	Score
1	MMMe8	July 30, 2016, 7:17 a.m.	0.079163638689759466
2	redrock	July 31, 2016, 9:48 p.m.	0.080301894079712499
3	fornaxintospace	July 29, 2016, 5:38 p.m.	0.081925542258189737
4	Alex	July 22, 2016, 6:22 p.m.	0.083848704280679837
5	luis	July 31, 2016, 9:56 p.m.	0.088395630359812905
6	w	July 31, 2016, 3:06 p.m.	0.088993096282001347
7	trnka	May 22, 2016, 6:23 a.m.	0.089866726592717425
8	Gagan@Gowda	July 31, 2016, 8:39 p.m.	0.096160889582667899
9	vaseen	July 30, 2016, 3:42 p.m.	0.096190288456035195

Special Thanks

CNI JSI & ARNES

Team