ANTAREX

European Commission | Horizon 2020 European Union funding for Research & Innovation

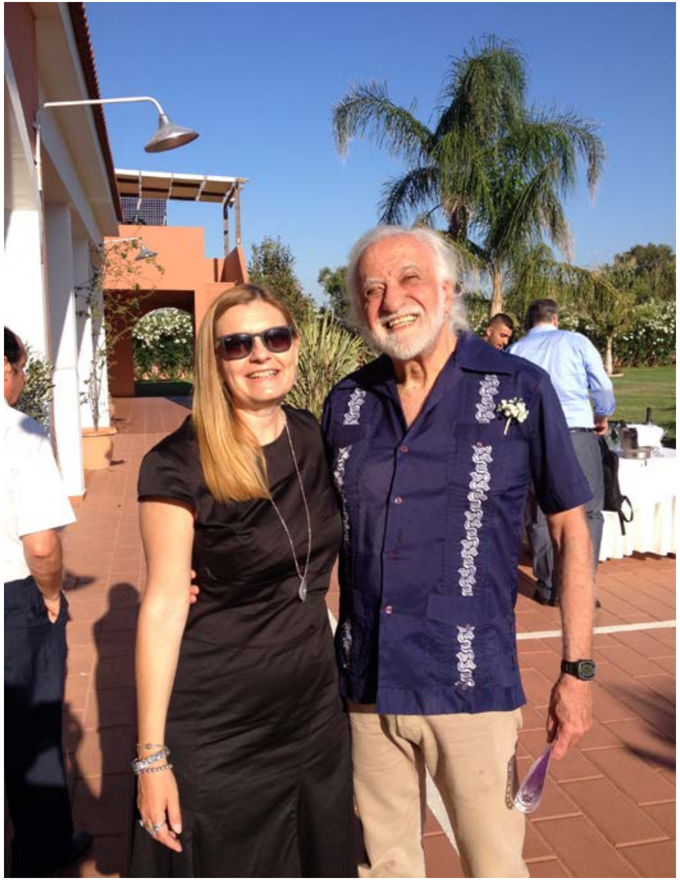
POLITECNICO MILANO 1863

Dynamic Application Autotuning for Approximate Computing

Cristina Silvano

Multi-core and Many-core Microprocessors
What must we do differently
if we are to harness them effectively?
Yale Patt
The University of Texas at Austin
Politecnico di Milano
Milano, Italia
November 13, 2008
DIPARTIMENTO DI
ELETTRONICA E
INFORMAZIONE

Yale talk at Politecnico di Milano, November 2008

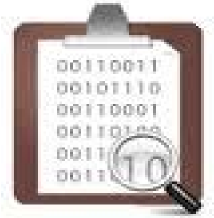


Chania, Carlo and Niki Wedding, July 2016

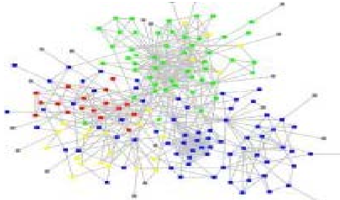
Approximate Computing Applications

Image Processing

Machine Learning

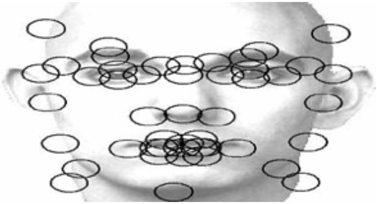


Big Data Analytics

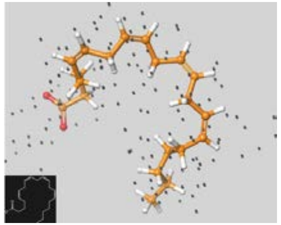


Graph Analytics

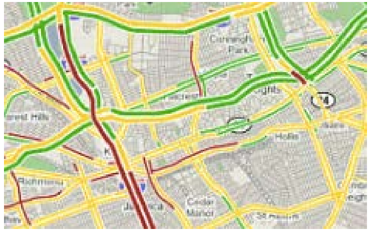
Multimedia Applications



Computer Vision



Drug Discovery

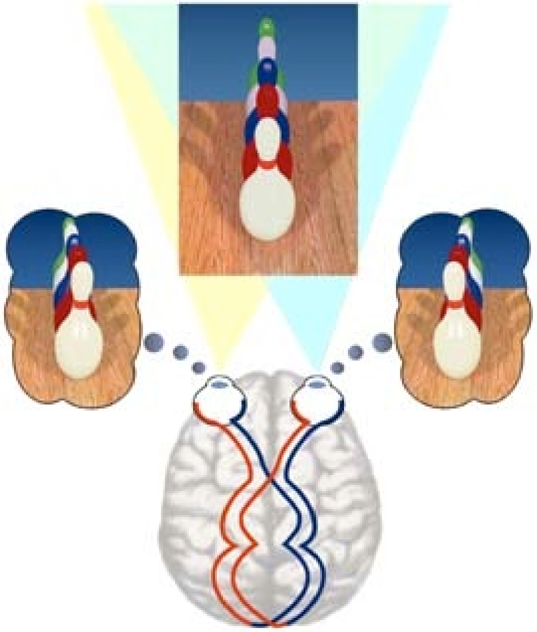


Traffic Prediction

100% computation accuracy is not always required…

Approximation offers opportunities for trading off Accuracy vs. Performance vs. Energy

The human eye stereo-matching



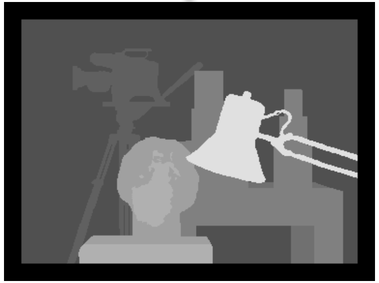
2 eyes → third dimension

Stereo-matching: Pixel Disparity Error vs Throughput

Left camera

Right camera

Stereo-matching

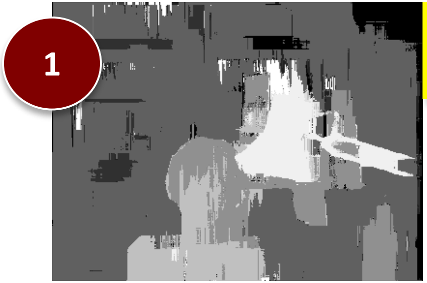


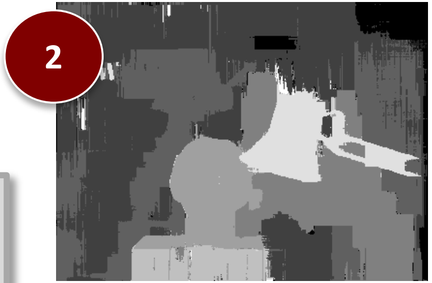
Reference Image

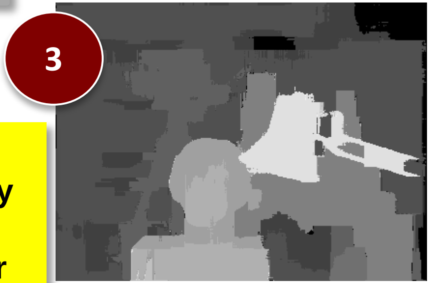
Application Tuning

Lower Disparity Error & Better Quality

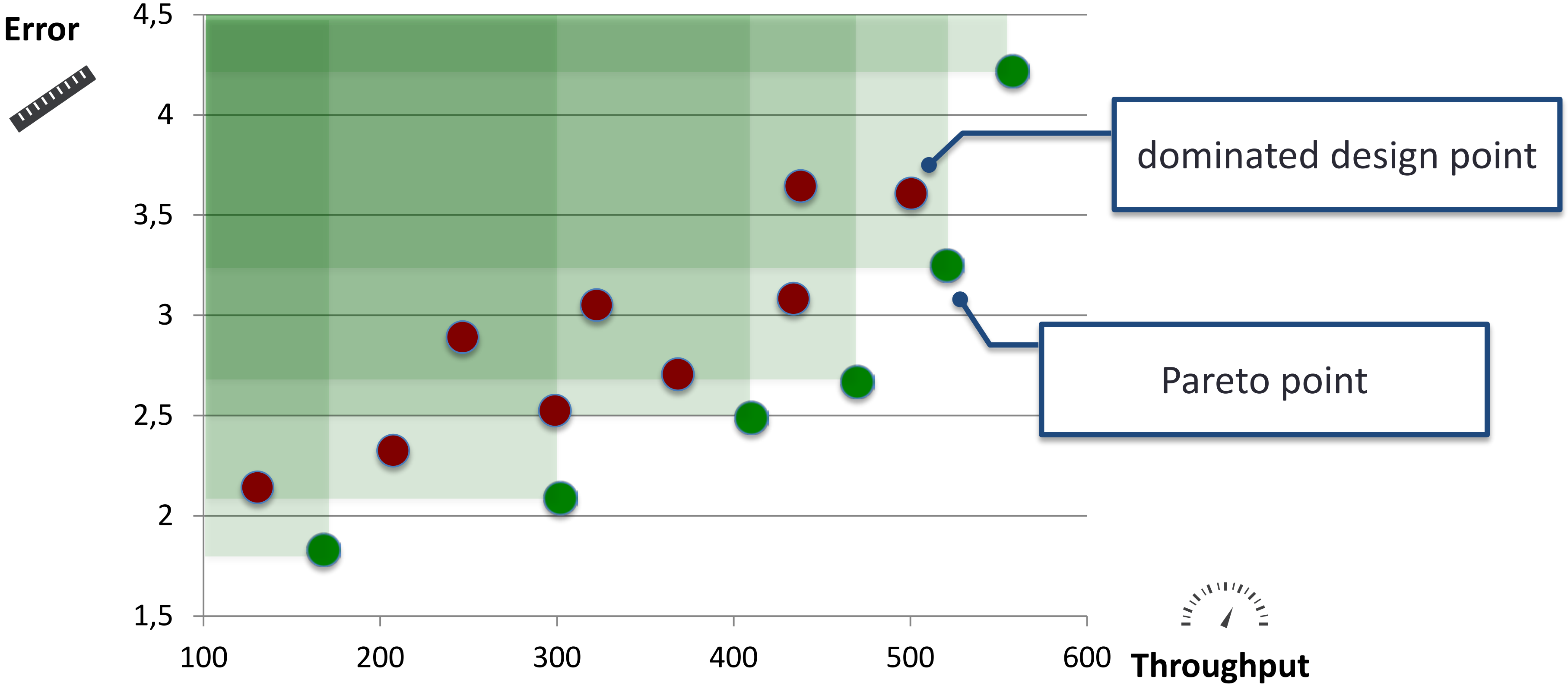
Higher Throughput







Approximate Computing: Pareto Points



dominated design point

Pareto point

Dynamic Autotuning of Applications

Dynamic Autotuning

At **runtime** according to the computation evolution

Automatic

Tuning:

1: to adjust in musical pitch or cause to be in tune: *tune a guitar*

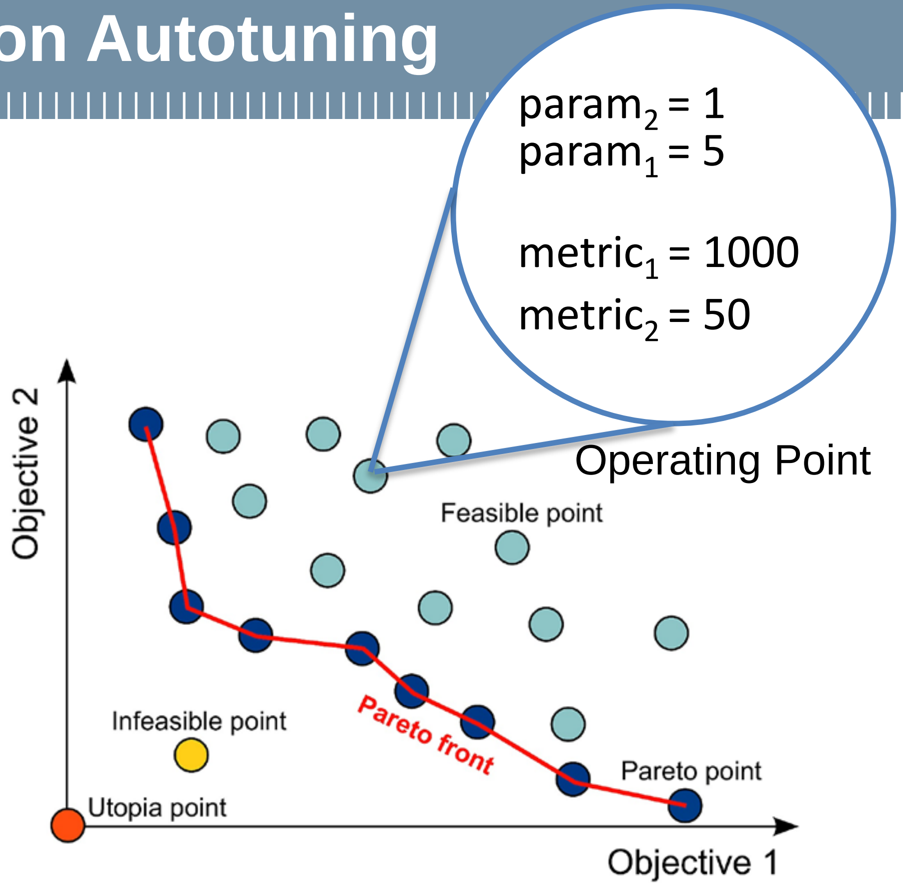
2 : to adjust for precise functioning: *tune up an engine*

In our context:

3: To adjust the values of application parameters to optimize the application metrics

Design-time Phase: Application Autotuning

- Best practice is to write parametric code with **software parameters:**
  - Number of iterations
  - Application-specific parameters
- At **design-time** we extract the **application knowledge:**
  - **Instrument** the application
  - **Design Space Exploration**
  - **Machine-learning Models**
  - **Store** the Pareto front to get the best tradeoffs

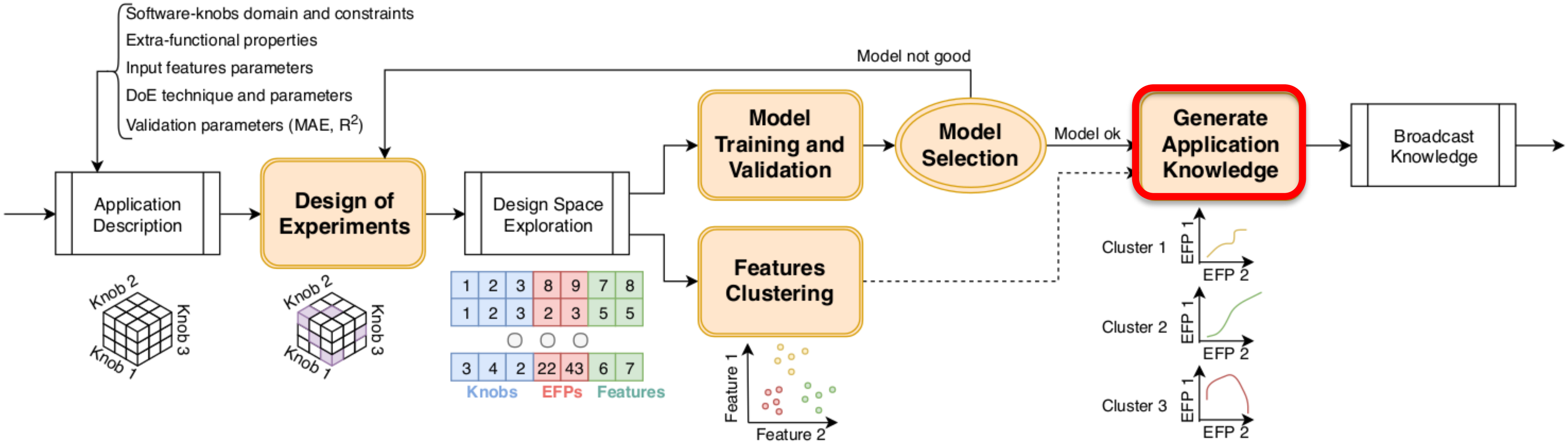


$\text{param}_2 = 1$
$\text{param}_1 = 5$

$\text{metric}_1 = 1000$
$\text{metric}_2 = 50$

Operating Point

Design-time: Learning the Application Knowledge



Software-knobs domain and constraints
Extra-functional properties
Input features parameters
DoE technique and parameters
Validation parameters (MAE, R^2)

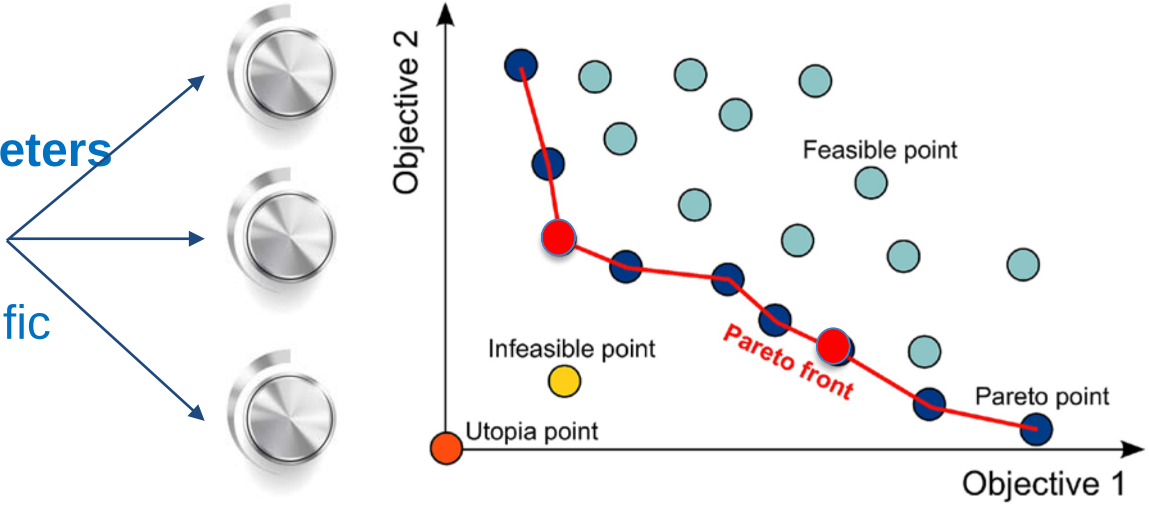
1	2	3	8	9	7	8
1	2	3	2	3	5	5
○		○		○		
3	4	2	22	43	6	7
Knobs			EFPs		Features	

Dynamic Autotuning

It is a way to constantly improve performance/energy tradeoffs with low developer effort over a wide range of run-time situations

Dynamic SW parameters

- ➔ num sw-thread
- ➔ loop perforation
- ➔ application-specific

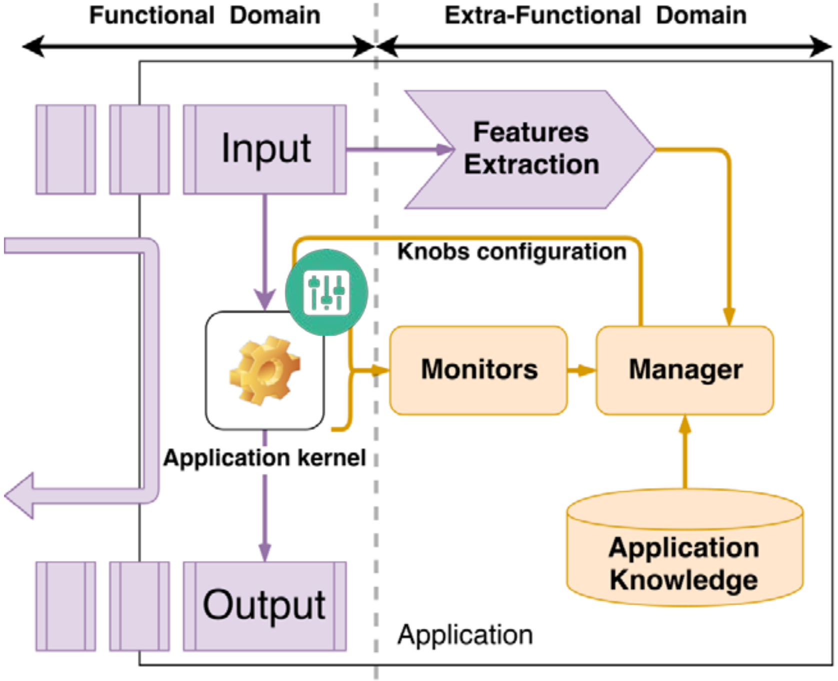


mARGOT Dynamic Autotuning Framework

It enhances a target application with an **adaptation layer**

- It is a C++ library to be linked to the target application

- Separation of concerns between functional and extra-functional domains.



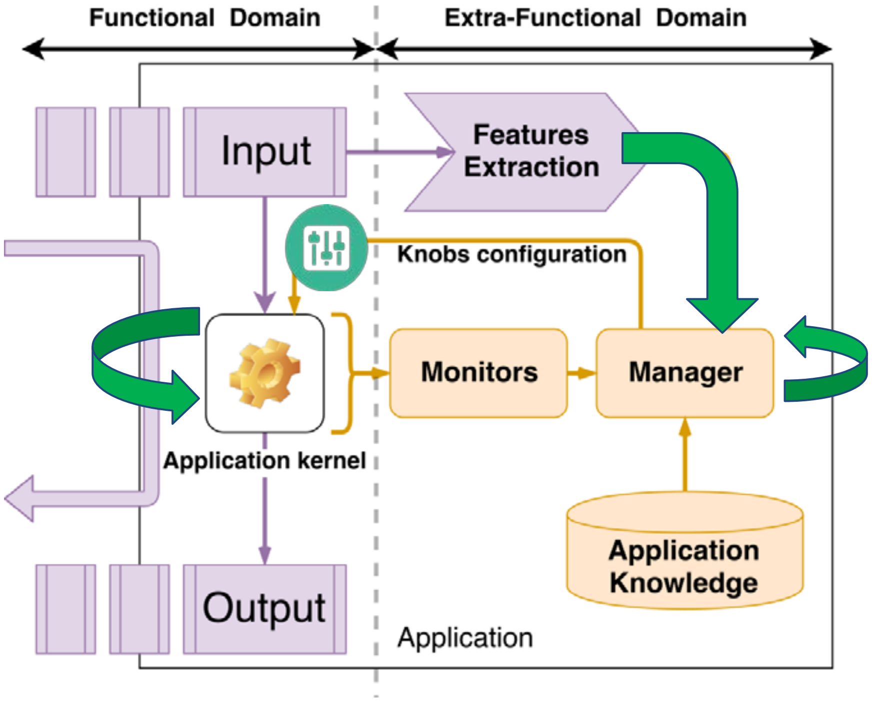
Public repository: https://gitlab.com/margot_project/core

D. Gadioli, E. Vitali, G. Palermo, C. Silvano, "mARGOt: a Dynamic Autotuning Framework for Self-aware Approximate Computing", **IEEE Trans. on Computers,** Nov. 2018.

mARGOT Dynamic Autotuning Framework

mARGOT provides an adaptation mechanism to react to changes in:

- Application requirements
- Application-knowledge due to online learning
- System monitoring values
- Data-features extracted from input data (such as image resolution)



Public repository: https://gitlab.com/margot_project/core

What sort of society challenges could be addressed by exploiting the ANTAREX technologies?

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Universidade do Porto
Faculdade de Engenharia
FEUP

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

inria
informatics mathematics

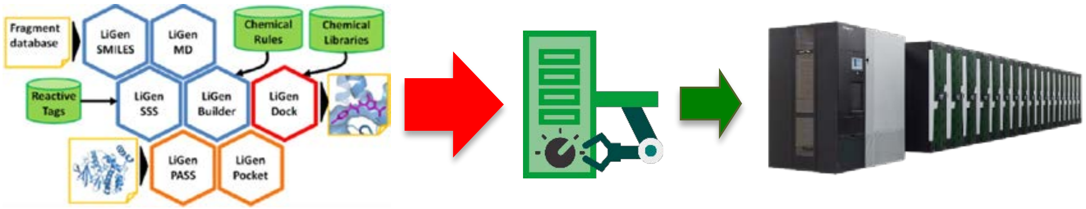
CINECA

IT4Innovations
national supercomputing center

VŠB 1849 TECHNICKÁ UNIVERZITA OSTRAVA

Dompé

Sygic



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Horizon 2020
European Union funding
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Dompé

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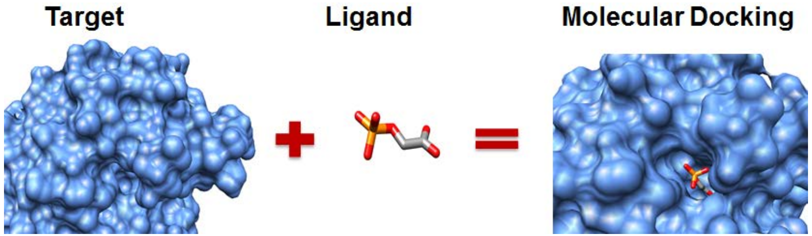
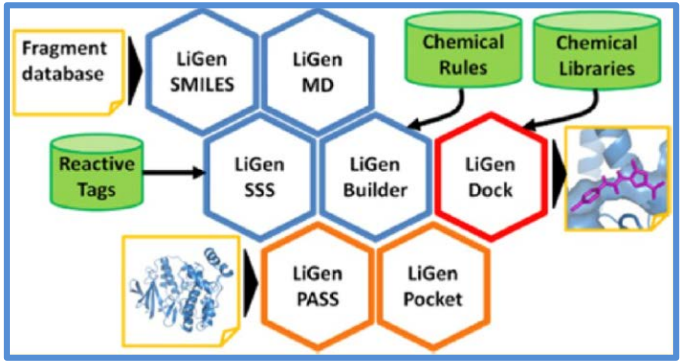
CINECA

Autotuning Geometric Docking for HPC Accelerated Drug Discovery

HPC Accelerated Drug Discovery

Need of HPC in Drug Discovery: HPC Molecular Simulations





LiGen HPC application for drug discovery

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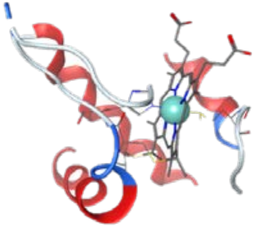
Developing **energy and resource efficient** algorithms

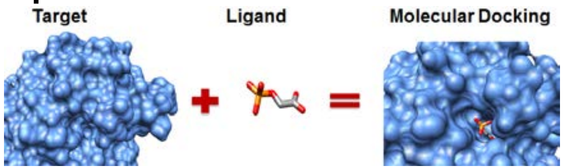
Using **self-functionalities to adapt and scale-out** the application

Exascale-ready HPC Virtual Screening

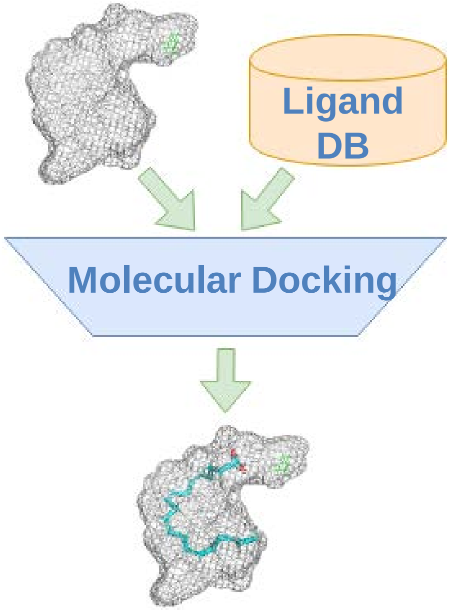


Geometric Docking

Molecular docking is a method to estimate the preferred 3D position and shape of a candidate drug (ligand) in the target protein pocket when bound to each other

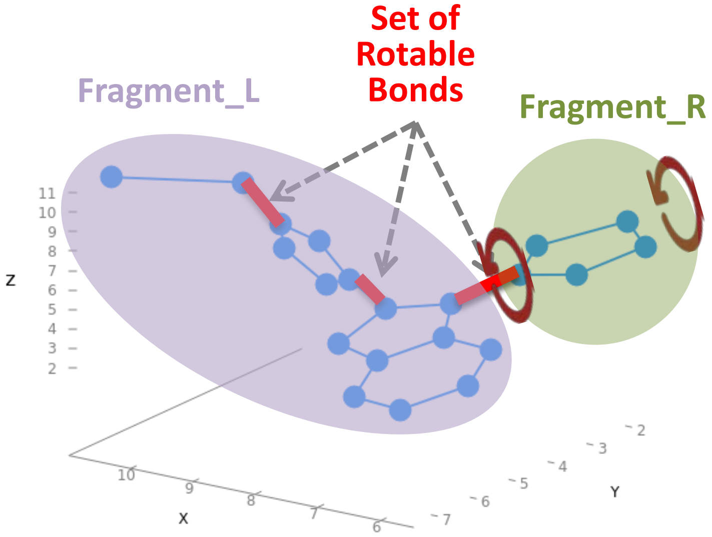


- **Geometric Docking**
  - **Shape Complementarity: 3D geometric matching search to find out compatible pairs and most suitable poses**
- Pharmacophoric Docking
  - Molecular Simulation: exploration of a large energy landscape given by chemical & physical interactions



GeoDock Tuning Parameters

Expose software-parameters from the geometric docking application



Low Precision Rotation Step

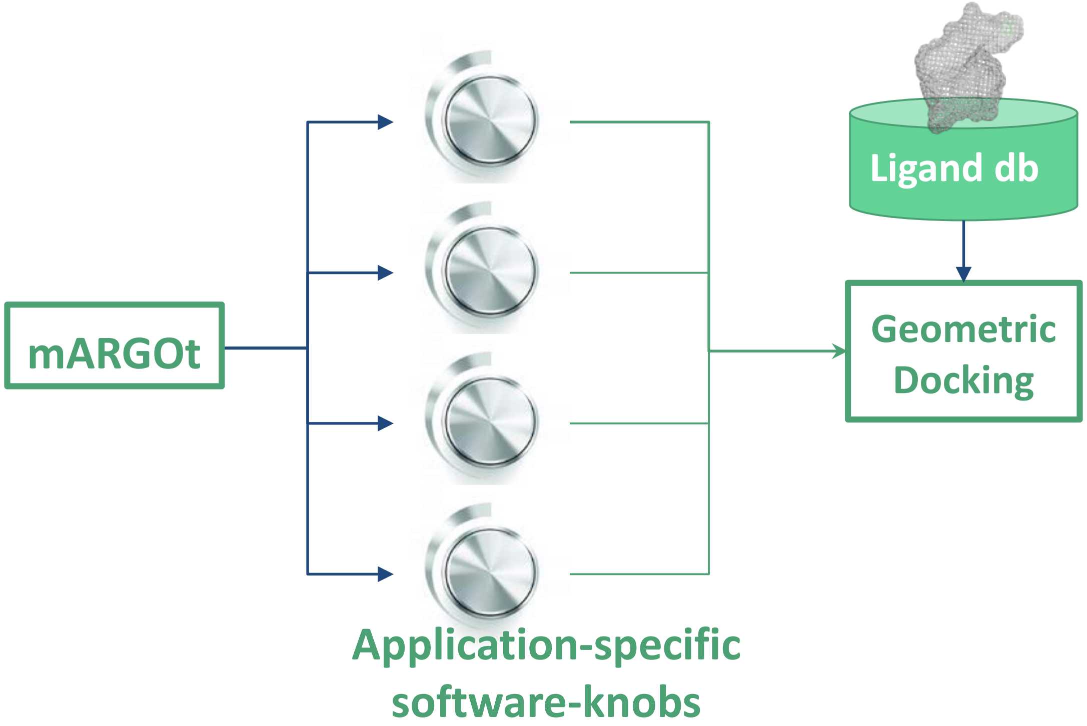
High Precision Rotation Step

#Iterations

Size Threshold

Dynamic Autotuning of GeoDock

Expose software-knobs to get trade-offs between accuracy and throughput

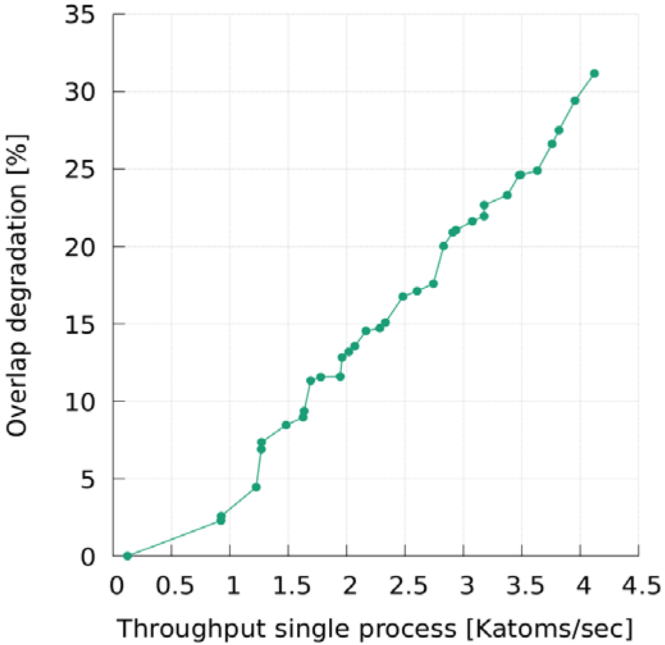


mARGOt

Ligand db

Geometric Docking

Application-specific software-knobs



D. Gadioli, E. Vitali, G. Palermo, C. Silvano, "mARGOt: a Dynamic Autotuning Framework for Self-aware Approximate Computing", **IEEE Trans. on Computers,** Nov. 2018.

Marconi: the most powerful public supercomputer in Italy

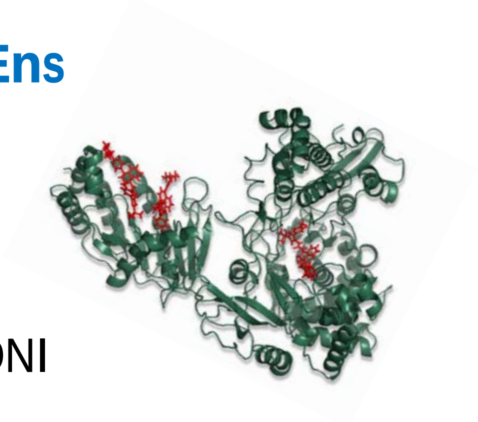
- **No. 19 in Top500 and No.4 in Europe:** Marconi Intel Xeon Phi: 10.38 PetaFlops (Linpack performance) 18.8 PetaFlops (peak performance) with 348,000 cores. Site: Casalecchio di Reno, Bologna (Italy)

- **Marconi** is the Cineca's Tier-0 system, co-designed by Cineca and Lenovo based on the Lenovo NeXtScale platform and Intel® Xeon Phi™ product family alongside with Intel® Xeon® processor and Intel Omni-Path

LiGen GeoDock: The Zika virus experiment

EXSCALATE: ExaSCale smArt pLatform Against pathogEns

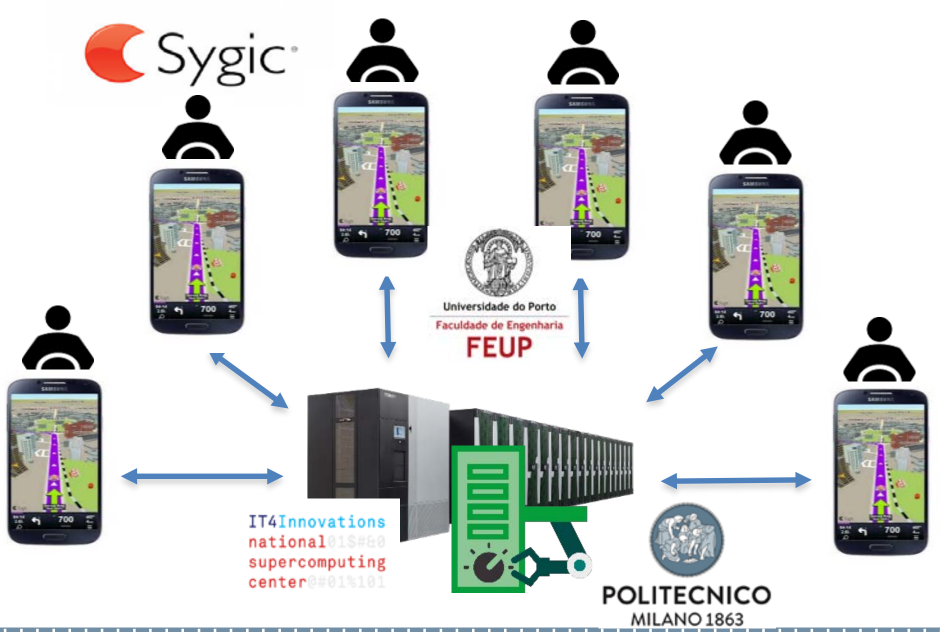
- 1.2 Billion ligands dataset (candidate drugs)
- 26 Zika binding sites (pharamacological targets)
- 8 Trillion poses scored (by GeoDock)
- 260 TeraByte of stored data
- About 900K Threads on 300k cores on 10 petaFLOPs MARCONI
- 1 MW measured power consumption
- Run Time to Solution: 3.2 h for 1 out of 26 sites (run in Jan 2019)
- Total Time to Solution: 3.5 days (84 h) for 26 sites
- Energy to Solution: 84 MWh



Estimated Exascale Run in 2021: from 84 h to less than 1 h

Experiment website:

https://www.antarex4zika.eu



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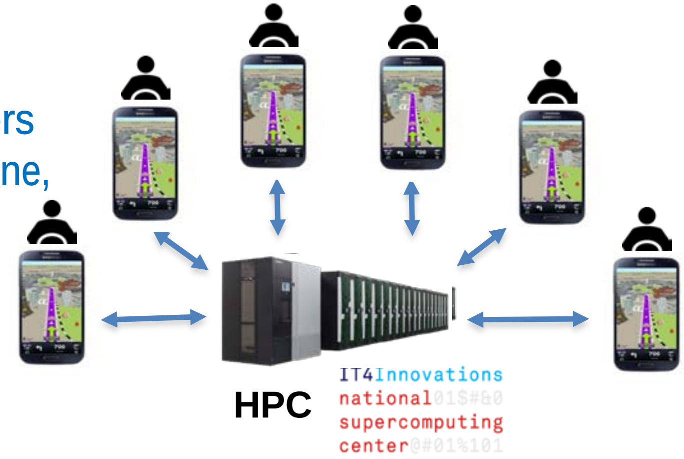
Autotuning an HPC-based Navigation System for Smart Cities

Self-adaptive Navigation System

Sygic Company develops world`s most popular navigation application & provides professional navigation software for business solutions

- ✓ Sygic Top #2 App in navigation category worldwide with 200 M users
- ✓ Sygic world's 1st for iPhone, 2nd for Android

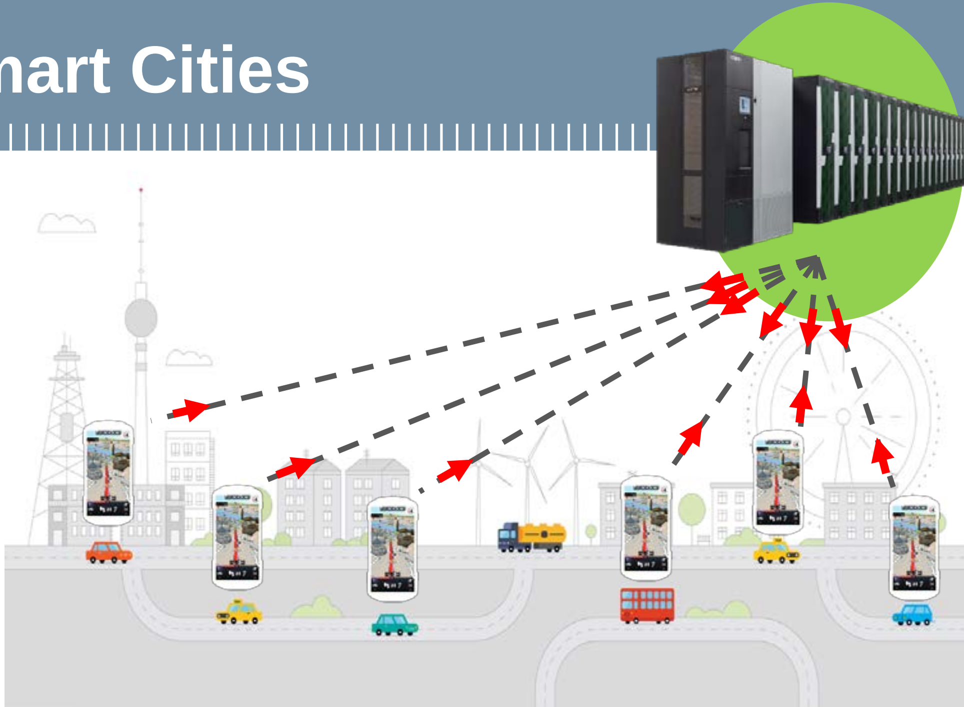


Exploit synergies between client-side and server-side:

- Many drivers – many routing requests to HPC system
- Traffic status data sources
- Continuous update of traffic flow calculation
- ***Smart City Challenge***

+15min
+10min
+5min

Intelligent Navigation for Smart Cities



Motivations:

- Provide optimal routes to hundred thousands of drivers/cars operating in the city area
- Serve all drivers’ requests with global best to reduce total driving time
- Avoid traffic jams

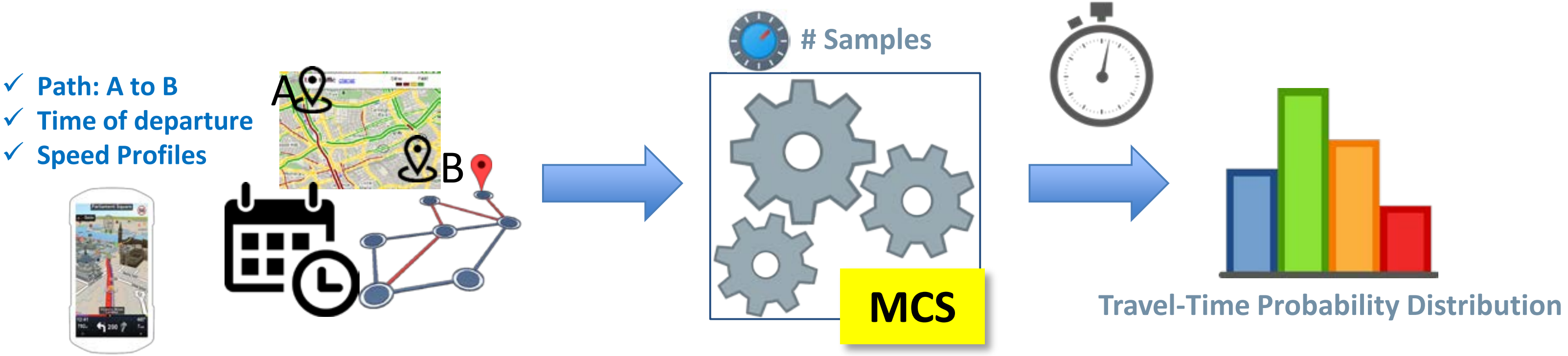
Requires:

- Intelligent routing based on accurate calculation of traffic view state
- Balance routes for a city global optimum
- Minimize data transfer

Probabilistic Time-dependent Routing

What is the Probabilistic Time-dependent Routing for a navigation system?

- ✓ Module to evaluate the ***expected travel time***
- ✓ In a client-server navigation infrastructure, the ***server-side*** must evaluate accurate expected travel time with updated traffic information
- ✓ Implemented by a ***MonteCarlo Simulation (MCS)*** to evaluate **the *probabilistic speed profile*** for each hop
- ✓ ***Dynamic autotuning*** of the number of samples for the MCS



- ✓ Path: A to B
- ✓ Time of departure
- ✓ Speed Profiles

Travel-Time Probability Distribution

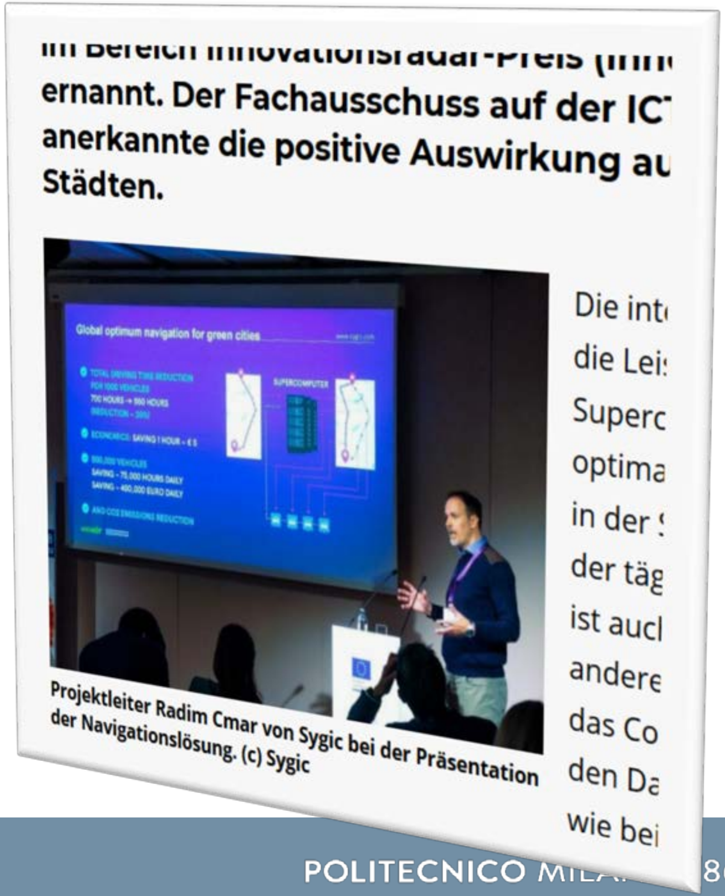
E. Vitali, D. Gadioli, G. Palermo, M. Golasowski, J. Bispo, P. Pinto, J. Martinovic, K. Slaninova, J. Cardoso, C.Silvano, "An Efficient Monte Carlo-based Probabilistic Time-Dependent Routing Calculation Targeting a Server-Side Car Navigation System", Minor revision in IEEE Trans. on Emerging Topics in Computing; Open Access: http://arxiv.org/abs/1901.06210

European Innovation Radar Prize 2018

Best Early Stage Innovation

- ✓ ***ICT 2018 Vienna Award***
  - ✓ *Top 20 Innovations in 2018*

“Saves money to drivers and cities.
Contributes to reduction of CO2 emissions.
Improves quality of life in urban areas.
Reduces time spent in daily travel traffic by more than 20 percent”


im Bereich Innovationsradar-Preis (Inn
ernannt. Der Fachausschuss auf der IC
anerkannte die positive Auswirkung au
Städten.

Projektleiter Radim Cmar von Sygic bei der Präsentation der Navigationslösung. (c) Sygic

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Global optimum navigation for green cities
SUPERCOMPUTER

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