Optimization @ Siemens

Research Group ORD (Operations Research for Decision Support)

Siemens Technology

Dr. Petra Bauer, Senior Key Expert Discrete Optimization

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A Glance at Siemens

Our Work

Project Domains

Project Examples:
Next Generation Ticketing

Project Examples:
Photovoltaic Power Plant Layout

My Background

University

Diploma in Mathematics / Computer Science, University of Augsburg, Germany (Prof. Grötschel)
PhD in Computer Science, focus: Integer Linear Programming, University of Cologne, Germany (Prof. Jünger)
PostDoc at the Georgia Institute of Technology, Atlanta, USA, studies in Integer Linear Programming (Prof. Nemhauser)

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Member of the Discrete Optimization / Operations Research Group since 1995

Main Projects:

- 1995 - 2009 Optimization for Printed Circuit Board Assembly (Siplace Machines / Lines / Production Sites)
- 2009 - 2012 SUNNY – Tool for Optimized Layout of Large Photovoltaic Power Plants
- 2012 - 2020 SiMobility JustGo: Next Generation Ticketing
- 2021 - Production Planning and Scheduling

A Glance at Siemens

Businesses and Services of Siemens AG

320,000

people worldwide work for Siemens[1]

Industrial Business

Digital Industries

Smart Infrastructure

Mobility

Siemens Healthineers[1]

Portfolio Companies

Siemens Advanta

Services

Siemens Financial Services

Siemens Real Estate

Global Business Services

1 Publicly listed subsidiary of Siemens; Siemens' share in Siemens Healthineers is 75%

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Research and Development at Siemens

€ 6.2 bn
Expenditures for R&D[1]

50,000
R&D employees

Inventions and patents – Securing our future

5,400
Inventions[1]

2,900
Patent applications[1]

Global research collaborations

16
Siemens Research and Innovation Ecosystems

1 FY23

Technology (T)

2,150
Employees worldwide

1,755
Researchers

Data Analytics & Artificial Intelligence (T DAI)
> 235
Researchers

Operations Research & Decision Support (T DAI ORD-DE)
15
Researchers

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Our Work

Mission and Competences

Mission

Design and development of **tailored** optimization **algorithms** and software **solutions**.

Direct value creation for our company-internal customers and their end-customers.

Technologies

Mathematics

- (Non-)Linear & Mixed Integer Programming
- Graph Theory
- Discrete, Combinatorial & Stochastic Optimization

Software development competence

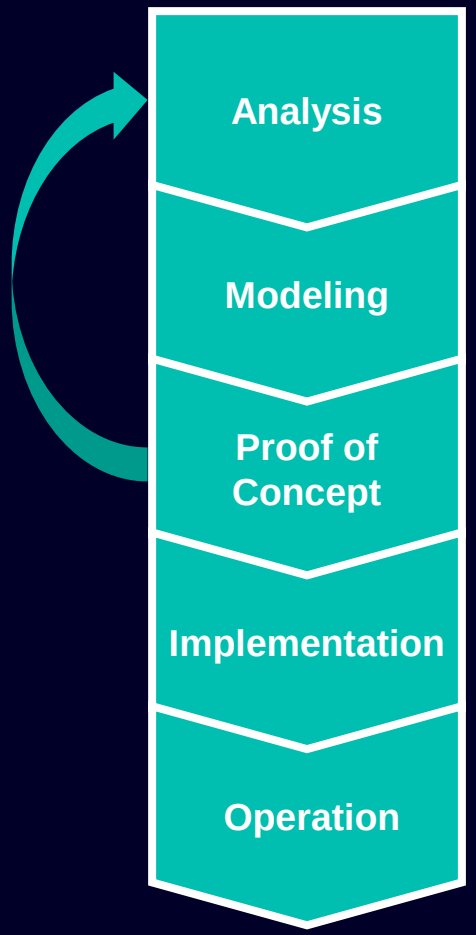
- Object Oriented Programming (C#, Java, Python, ..)
- Software Engineering (continuous Integration and deployment, testing, containerization, container orchestration …)
- Software Architecture
- UI Development (TypeScript, Vue.js, Vuetify, …)
- Cloud Services
- …

Tooling (Assets)

- tools that support rapid prototyping and development / deployment of productive solvers (model driven development)

Customized Decision Support Tools with Mathematical Optimization

Typical phases of the development process



- Detailed analysis of the real-world problem
  - Which decision should be automated?
  - Which solutions are feasible, which preferable?
- Transformation of the problem into mathematics
- Fast development of prototypes
  - Come up with calculated results quickly
  - Discuss “first decisions” with the customer and gain better understanding
- Efficient development based on sophisticated tools and experienced developers
- Helping to bring the tool into operation and to keep it alive:
  deployment, integration, optimization services, training of users, support

Project Domains

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Project Domains of our Research Group

Industry

Infrastructure

Mobility

Healthcare

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Energy

ASM (Assembly Systems)

Semiconductor Manufacturing

…

former Siemens businesses / others

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Project Examples:
Next Generation Ticketing

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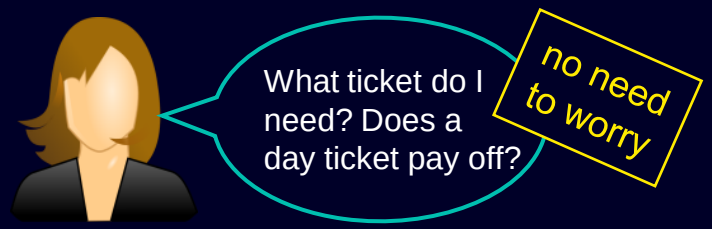
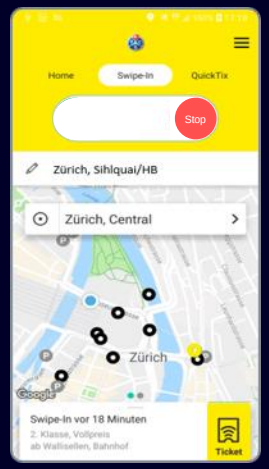
XIXO - Next Generation Ticketing - Idea

“First Travel – then Pay” – Easy and Flexible Use of Public Transport





Idea:

- “swipe in” (Check-In) and enter vehicle
- - > app grants travel permission and records journey
- travel (vehicle may be changed)
- leave (Check-Out / Be-Out)
- - > trip reconstruction from data collected on the way (coordinates, beacon signals, …)
- do more trips ….
- -> best price ticket the next day (Post Price Ticketing)

Benefit:

- no need to know the tariff system
- no need to buy a ticket in advance
- no need to know all trips in advance to get the best ticket→ easy and flexible use of public transport

XIXO Next Generation Ticketing

April 2018, **XIXO** (BIBO, CICO, CIBO*) launched for the public in Switzerland.**

- **Commercial Swipe-In** (CheckIn-CheckOut) solution for public transport throughout Switzerland
- **First commercial Walk-In** (BeIn-BeOut) solution **worldwide** on trains and busses of SOB (Südostbahn Schweiz)

Partners: Siemens Mobility / Siemens HaCon, Siemens Technology, eos-Uptrade

*C = “Check”, B = “Be”, I = “In”, O = “Out”) **commercial pilot till 2020, launch in Osnabrück 2020 “YANiQ”

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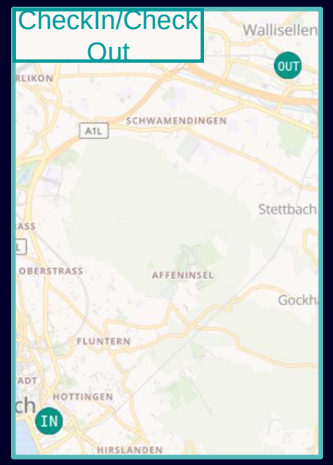
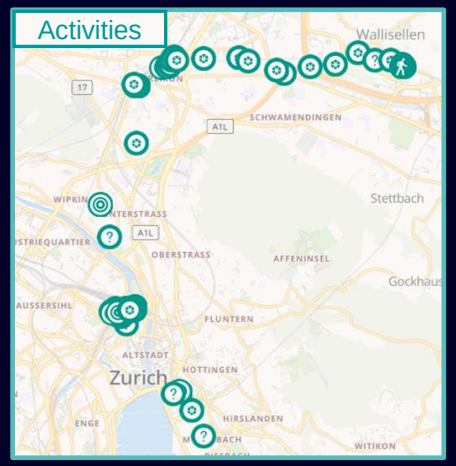
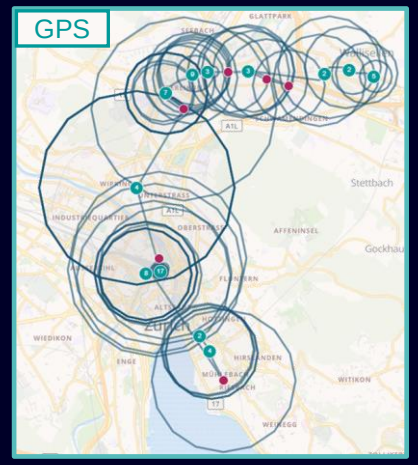
XIXO - Next Generation Ticketing - Check-In / Check-Out, GPS-based, basic setup

Trip Reconstruction by Mathematical Optimization

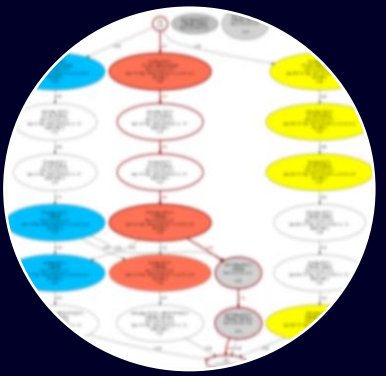


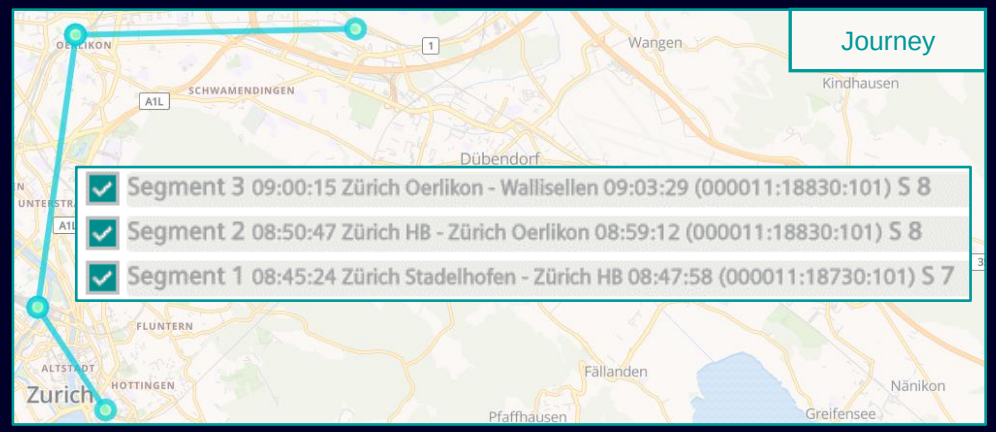




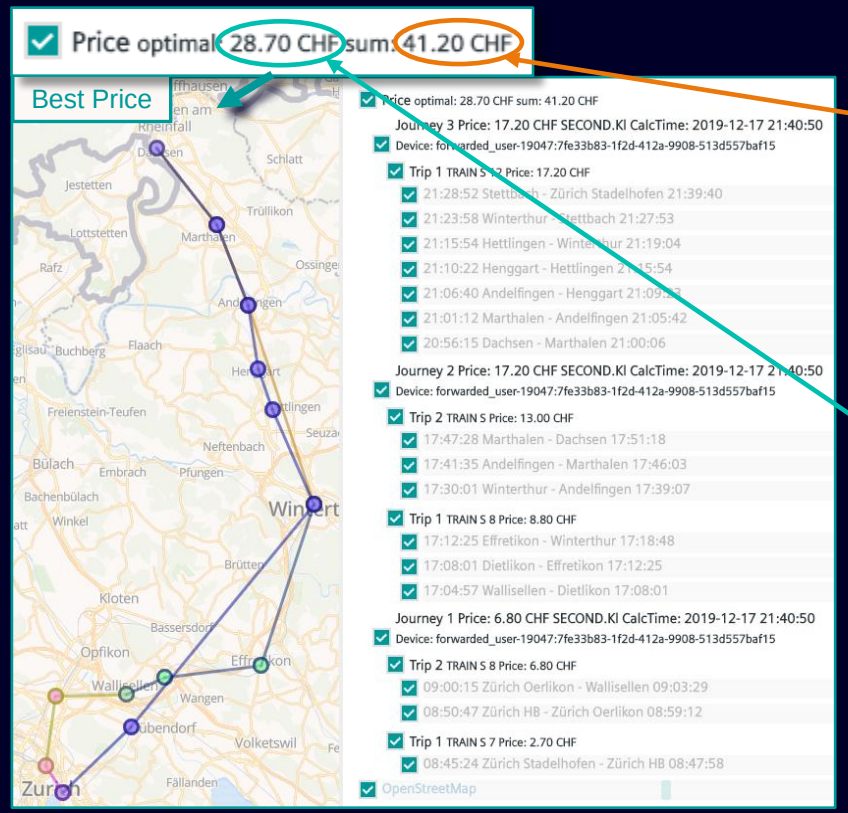
Discrete Optimization / graph algorithms for

- journey reconstruction
- best price calculation
- …





station geographies, planned timetables



sum of single ticket prices

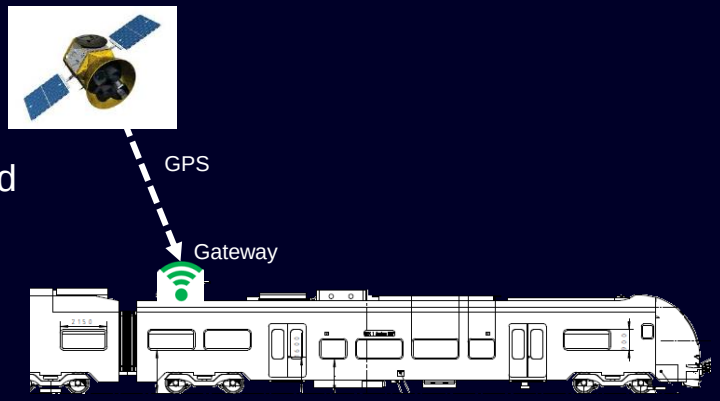
best price: day ticket

user trip reconstruction using field data, timetables, station geography

XIXO: Next Generation Ticketing: Variants

Be-In / Be-Out:

- vehicles are equipped with gateways that send positions
- vehicles are equipped with Bluetooth beacons whose signals are received by the user phones
- vehicle route reconstruction by mathematical algorithms using positions sent by the gateways and information about routes that are served
- user trip reconstruction from beacon signals and reconstructed vehicle routes



Check-In / Be-Out:

- user does not have to check-out
- check-out is automatically detected from information collected by the phone (activities, gps position, …)
- (we cannot automatically detect check-in because we would have to track the user without her/his explicit consent whenever the app is running, user gives consent by checking-in)

Check-In / Be-Out or Check-In / Check-Out using subway lines:

- beacons are installed at entrances / exits of subway stations
- user trip reconstruction is done by mathematical algorithms considering received beacon signals and gps coordinates.

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Project Examples:
Photovoltaic Power Plant Layout

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SUNNY: Photovoltaic Powerplant Layout and Design

Goal: automatically find a layout such that e.g.

- **peak power is maximized**
- **investment costs are minimized** for given target power
- **efficiency** of the plant is maximized …

where **design rules** and **technical requirements** are fulfilled.

Subproblems to solve:

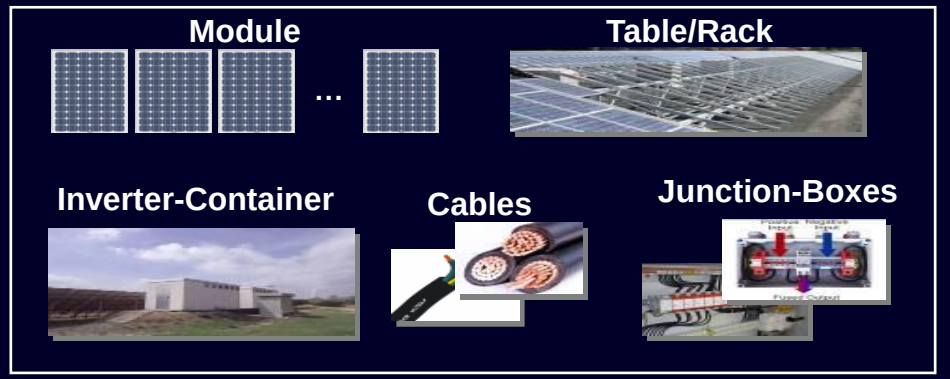
- location of pathways
- location of tables
- selection of inverters, assignment of tables to inverters, inverter positions
- positioning of junction boxes
- electrical wiring (cable cross sections, cable routing)

Deliverable:

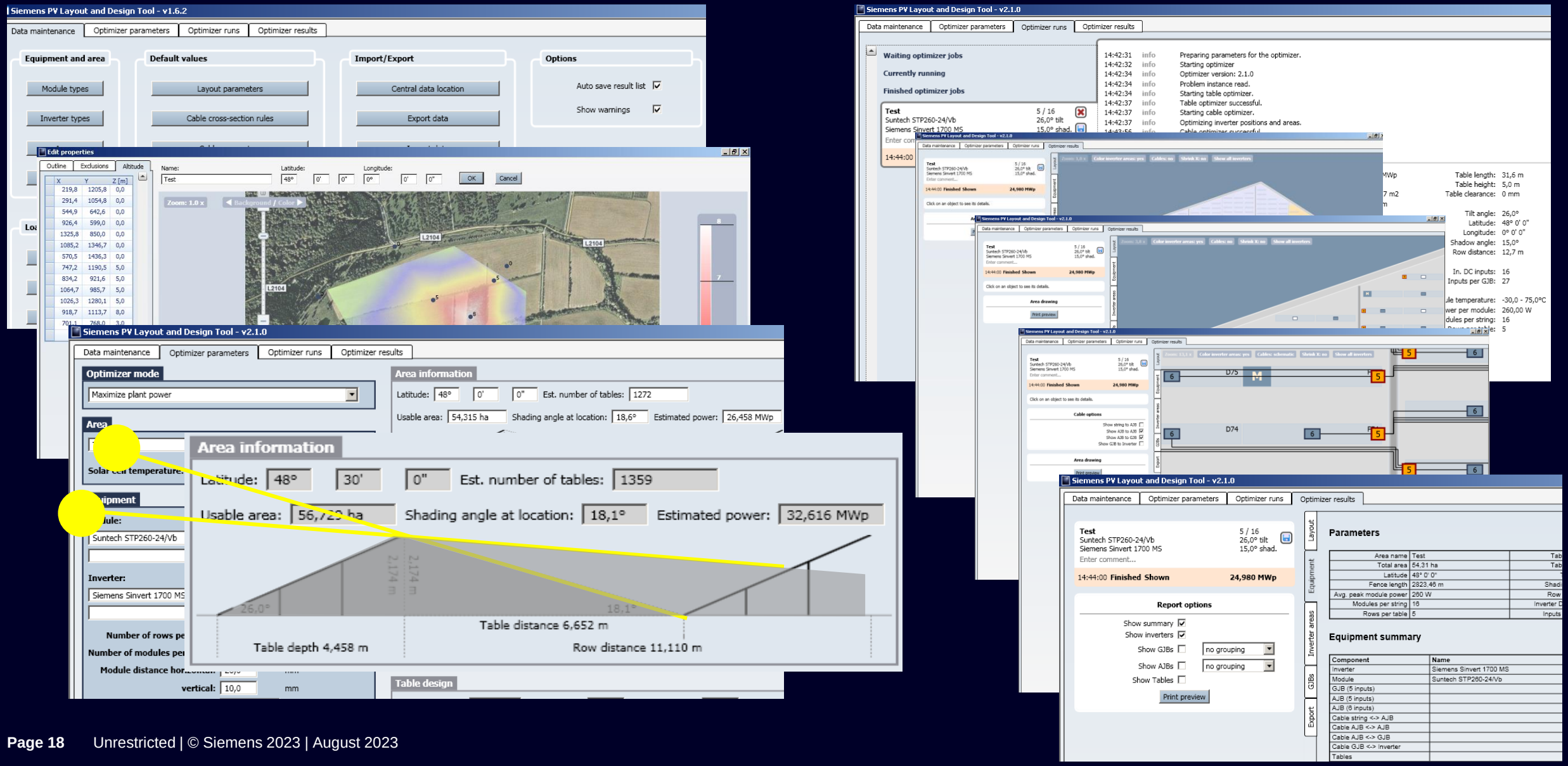
Planning tool for automized plant layout optimization supporting manual modification and reoptimization

Discrete Optimization algorithms applied:

- Mixed Integer Linear Programming
- Dynamic Programming
- combinatorial heuristics



SUNNY: Photovoltaic Powerplant Layout and Design



Thank you for your attention!

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