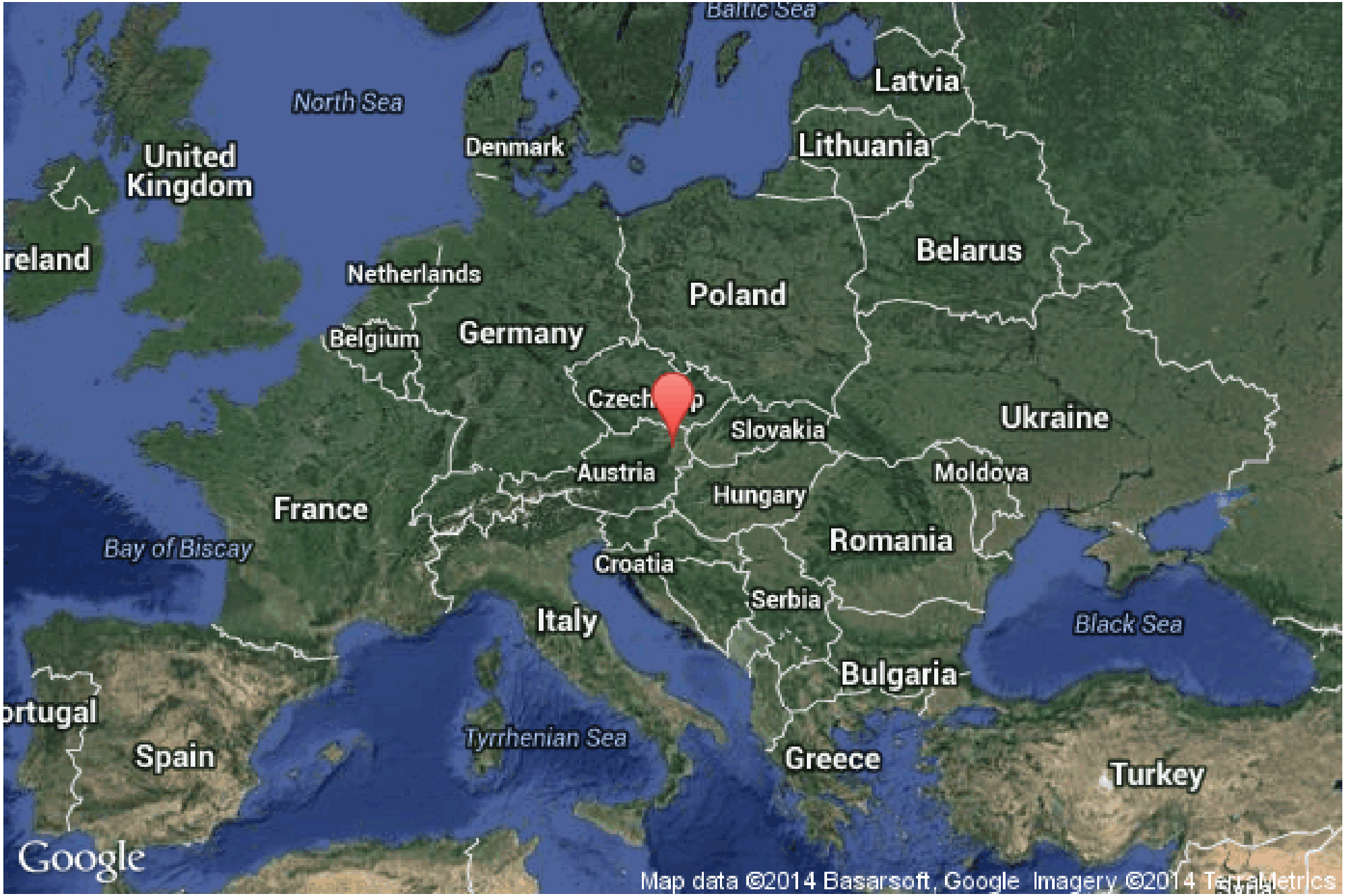
Why study Computational Logic in Vienna?

Gernot Salzer

Technische Universität Wien
Faculty of Informatics
Theory and Logic Group

November 2015

TU Wien – center of Vienna – heart of Europe



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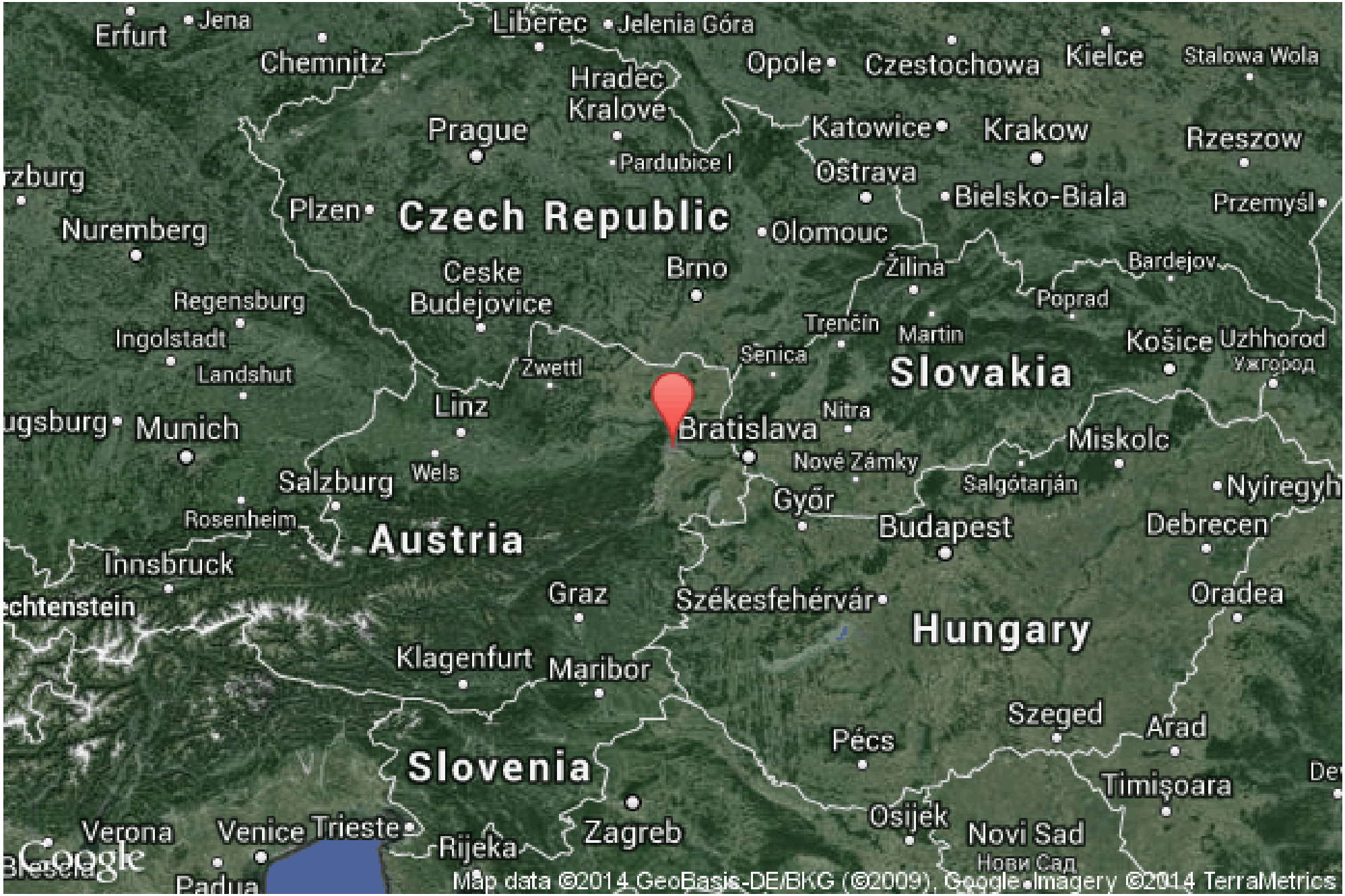

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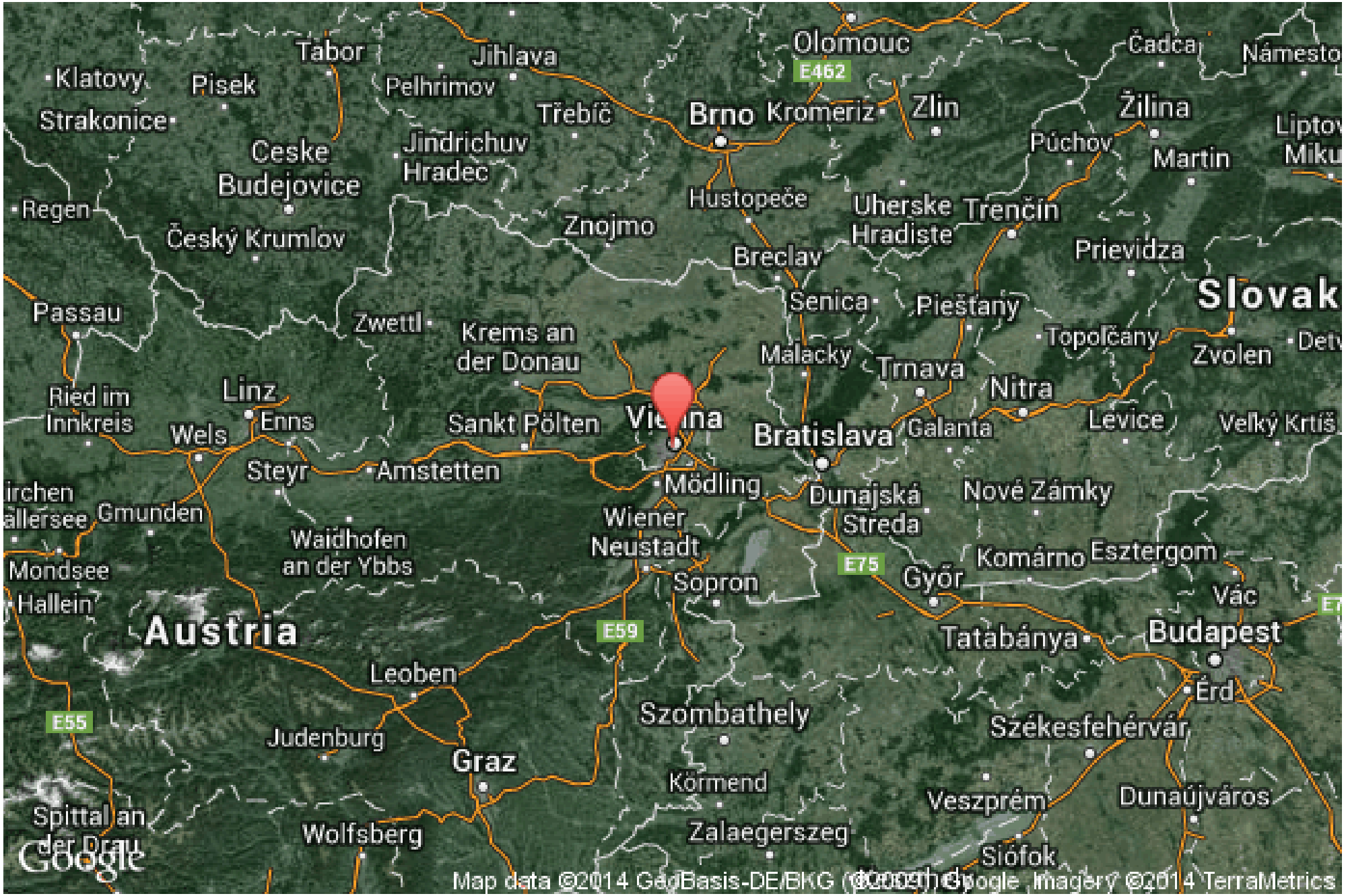

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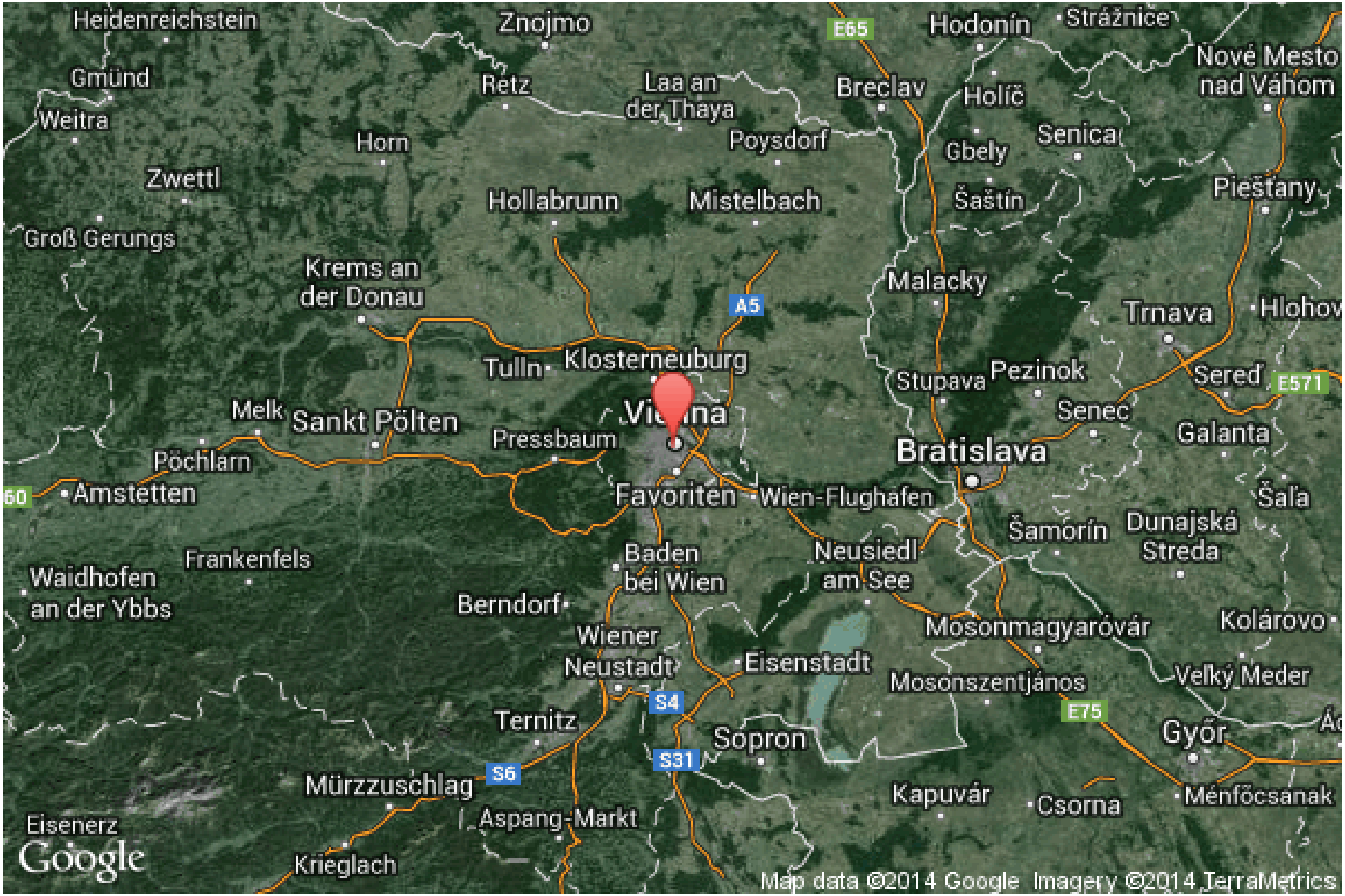

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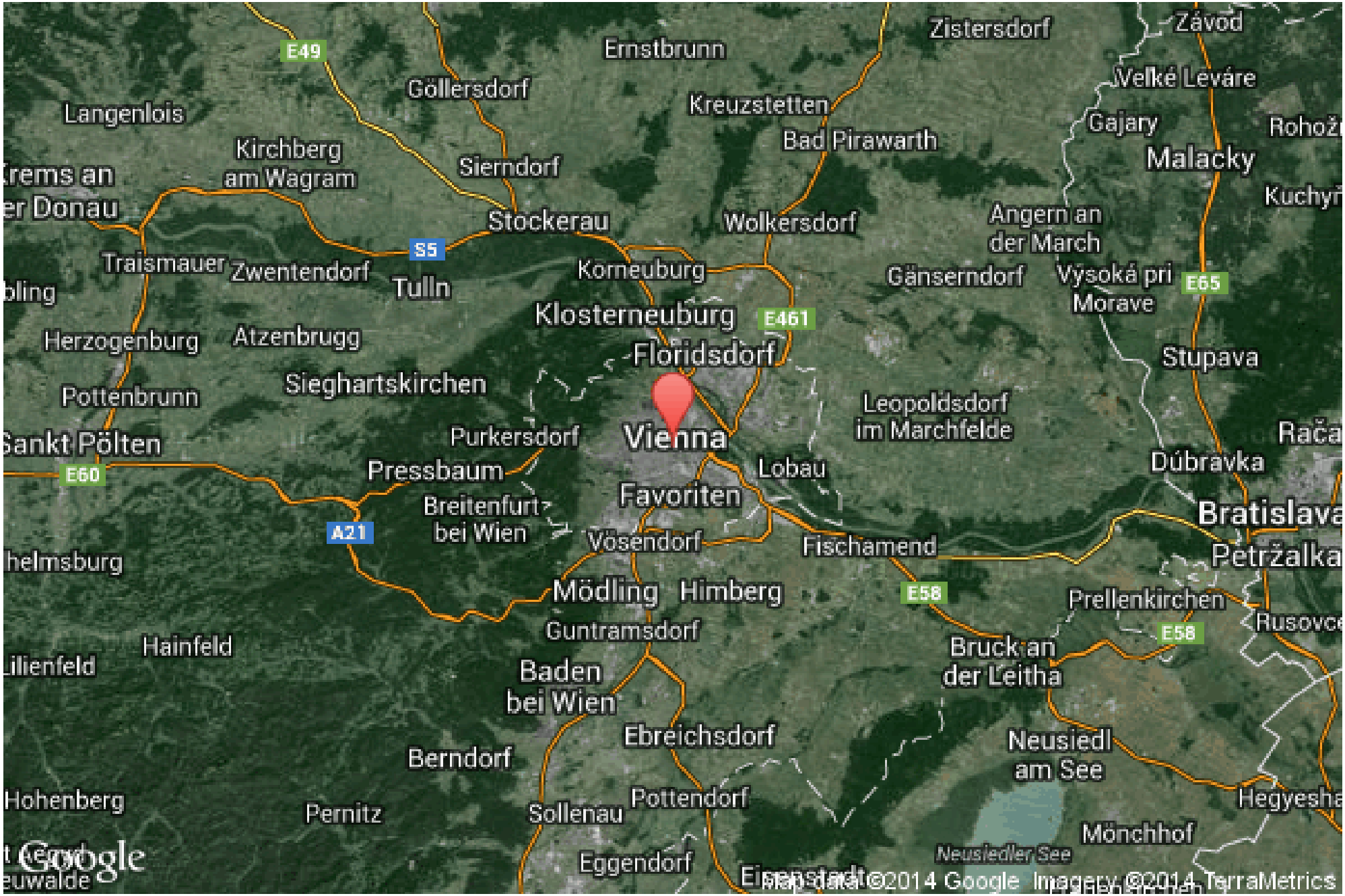

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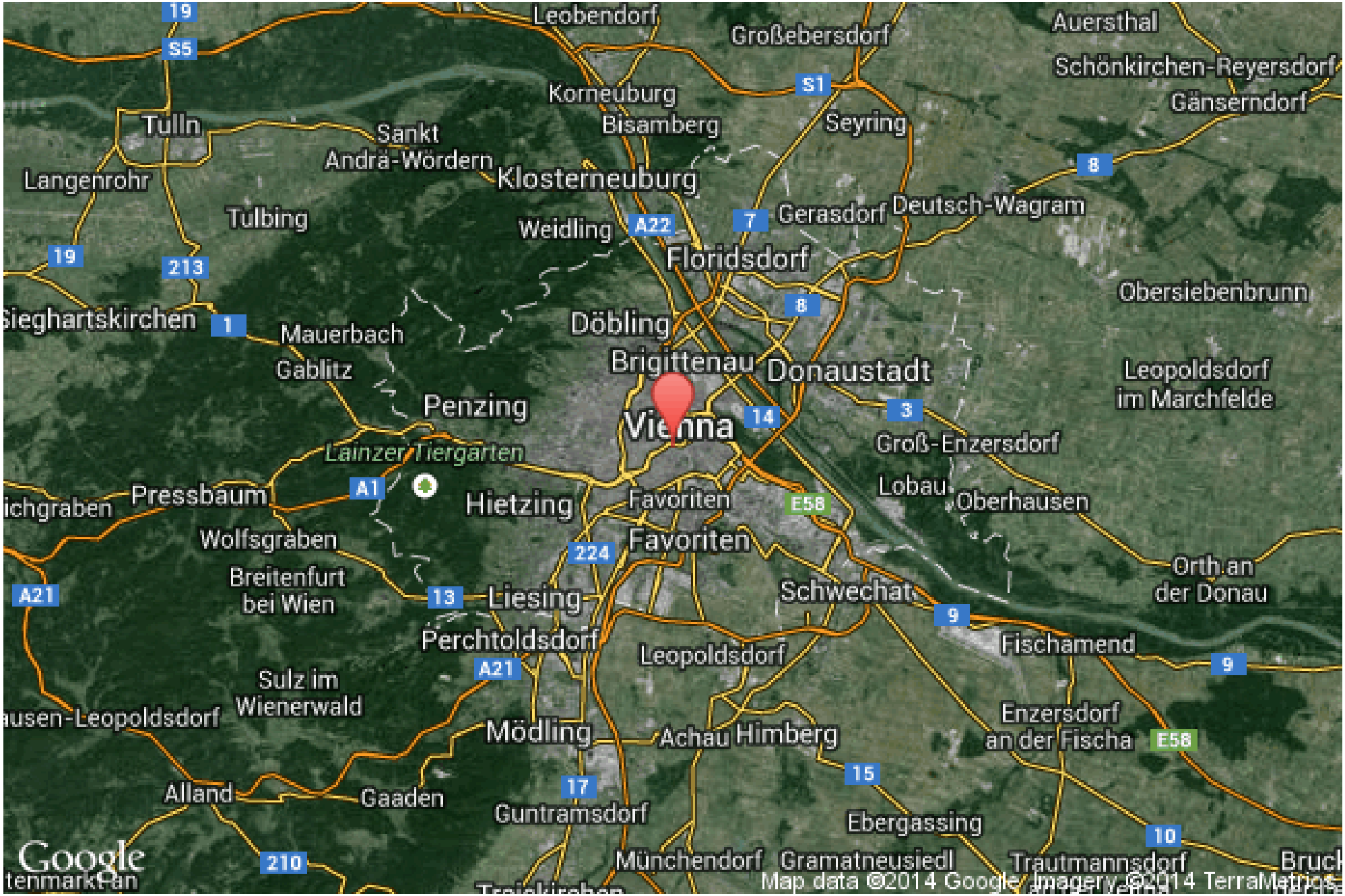

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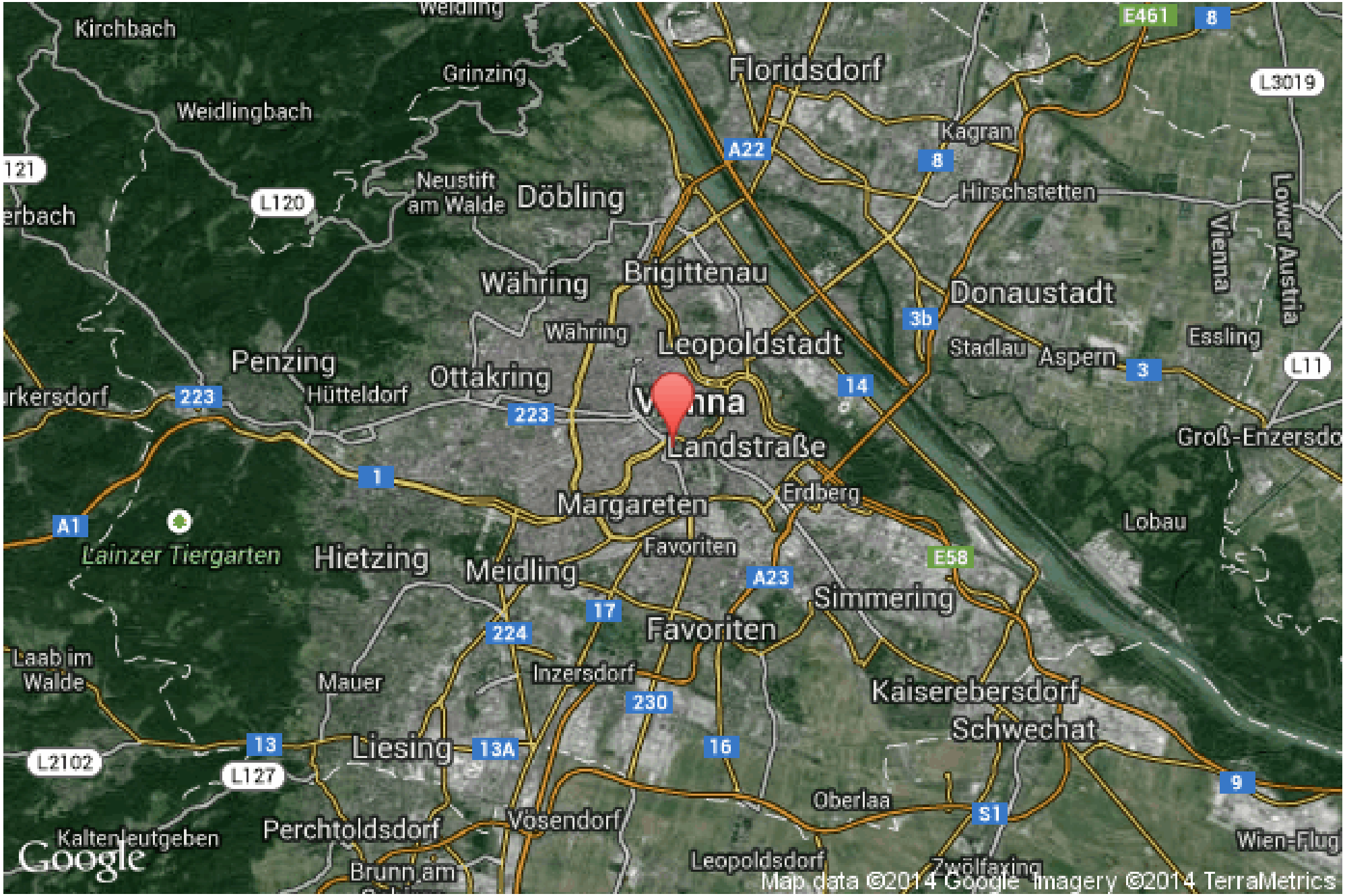

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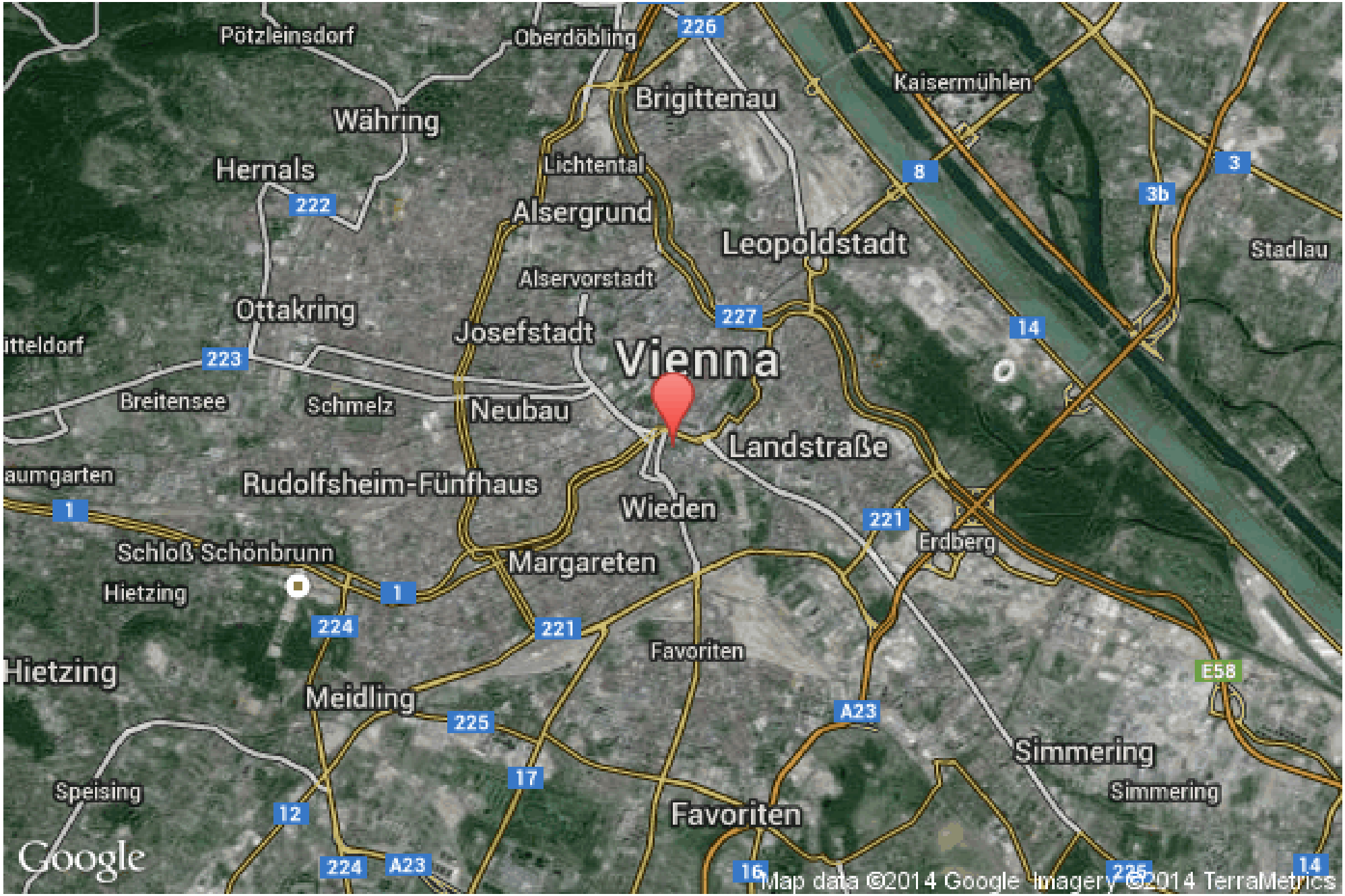

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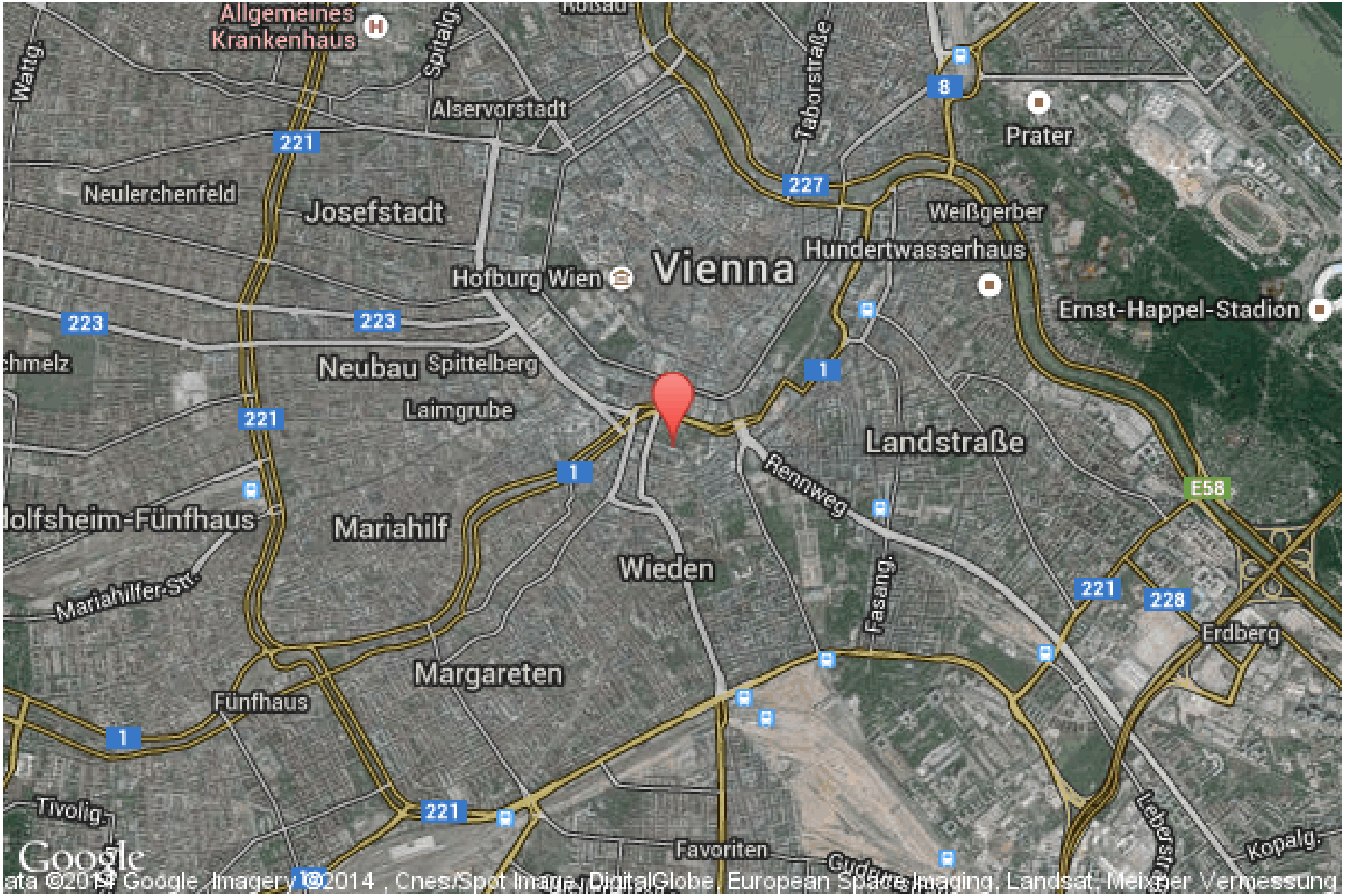

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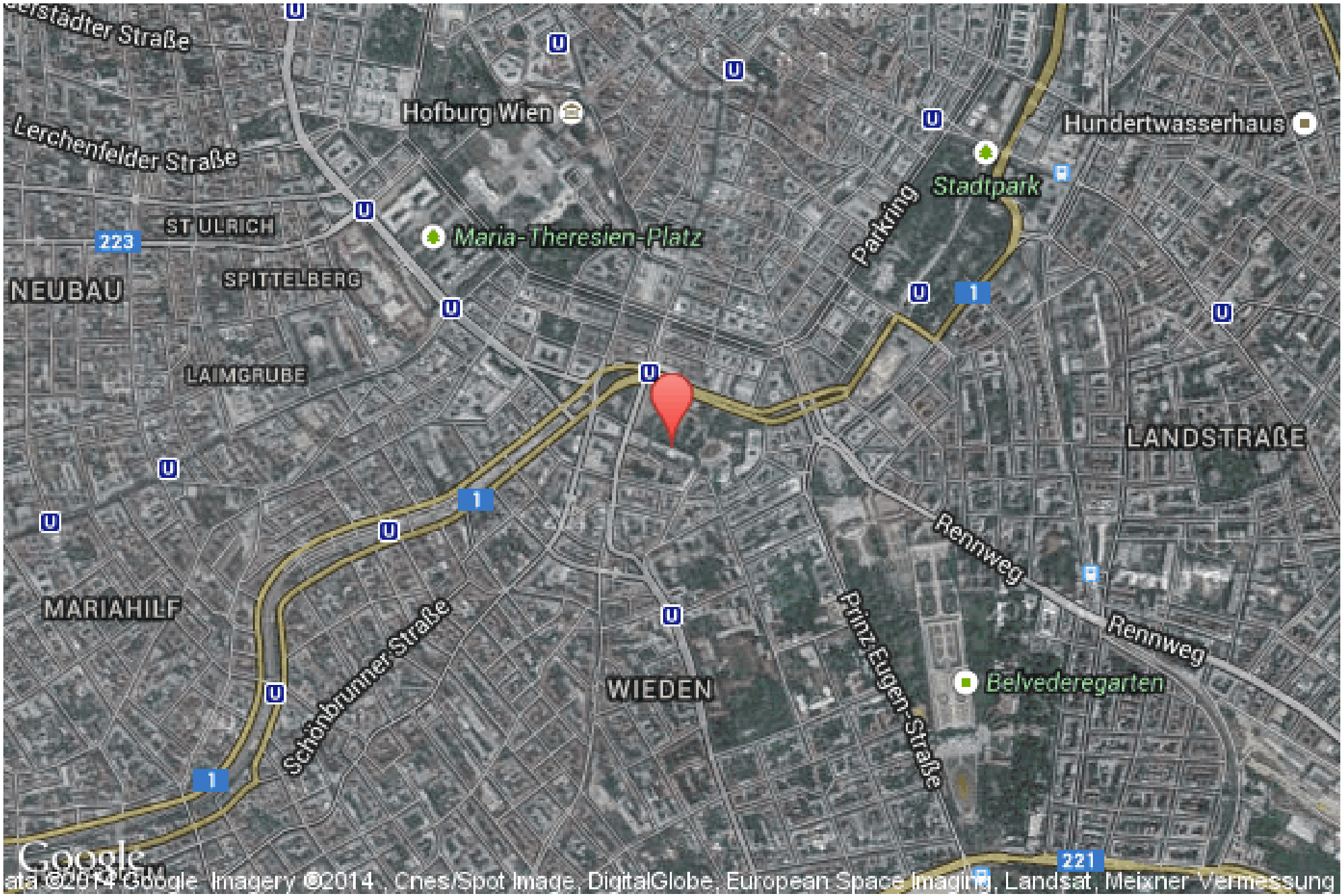

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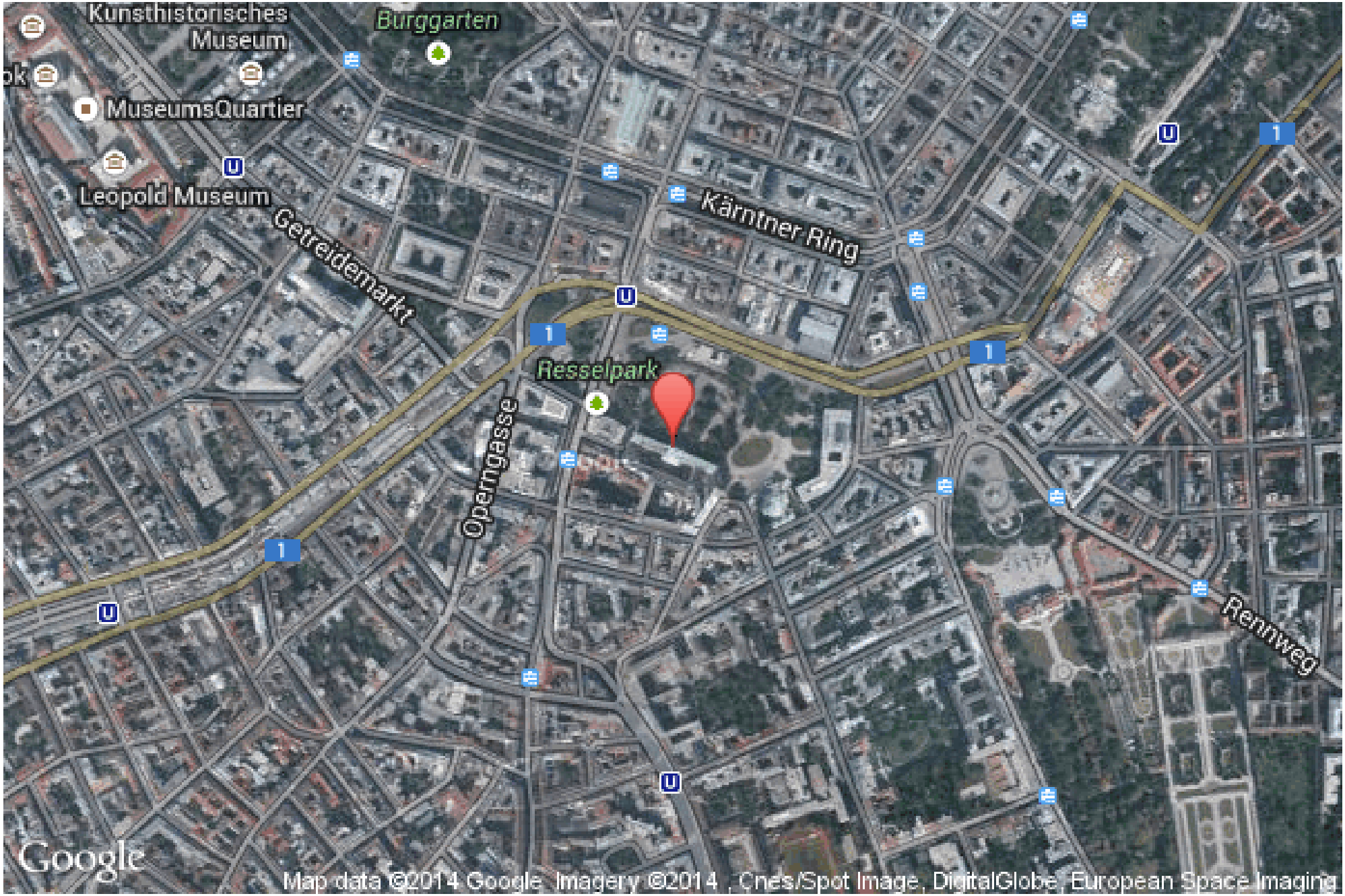

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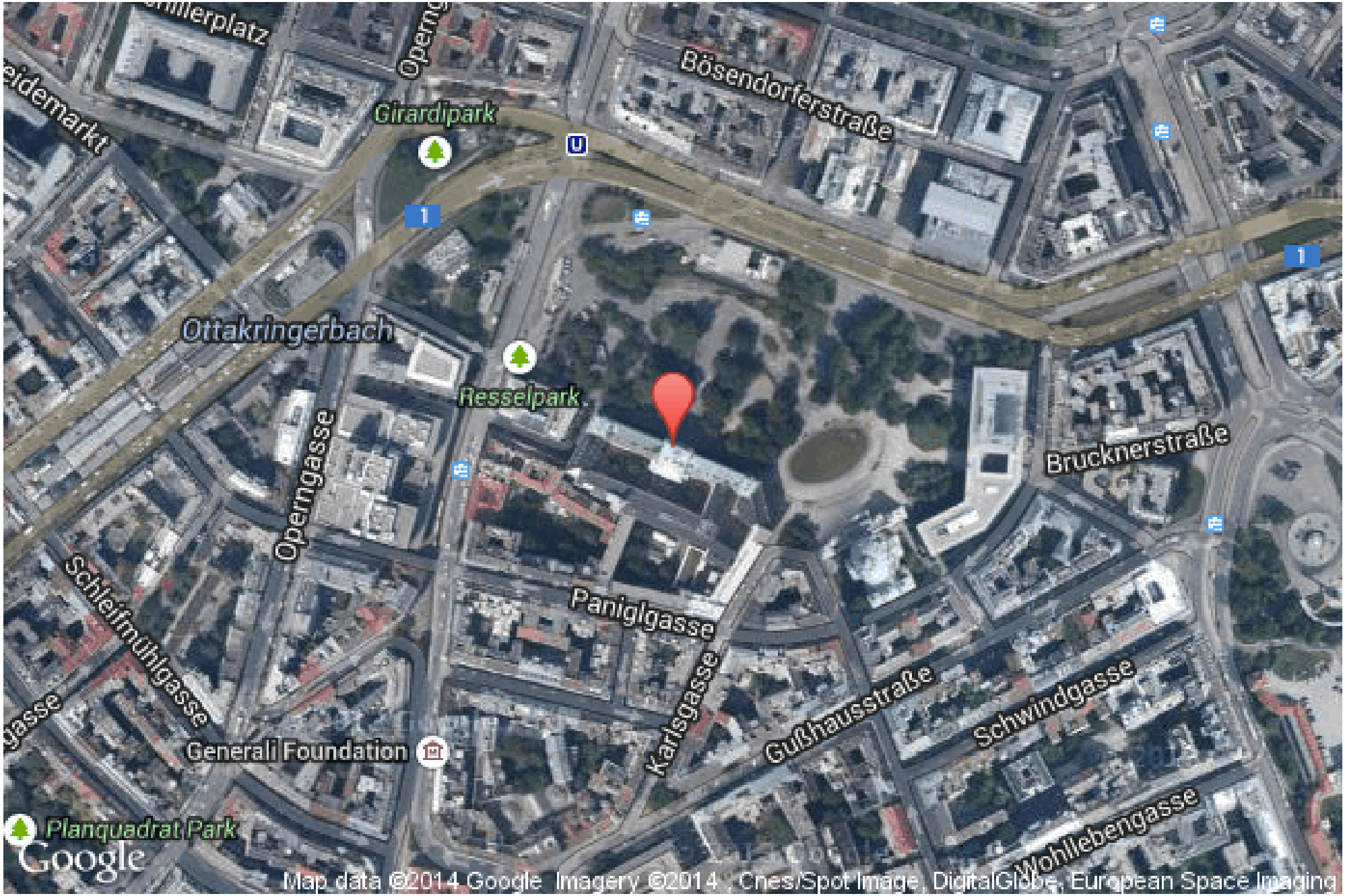

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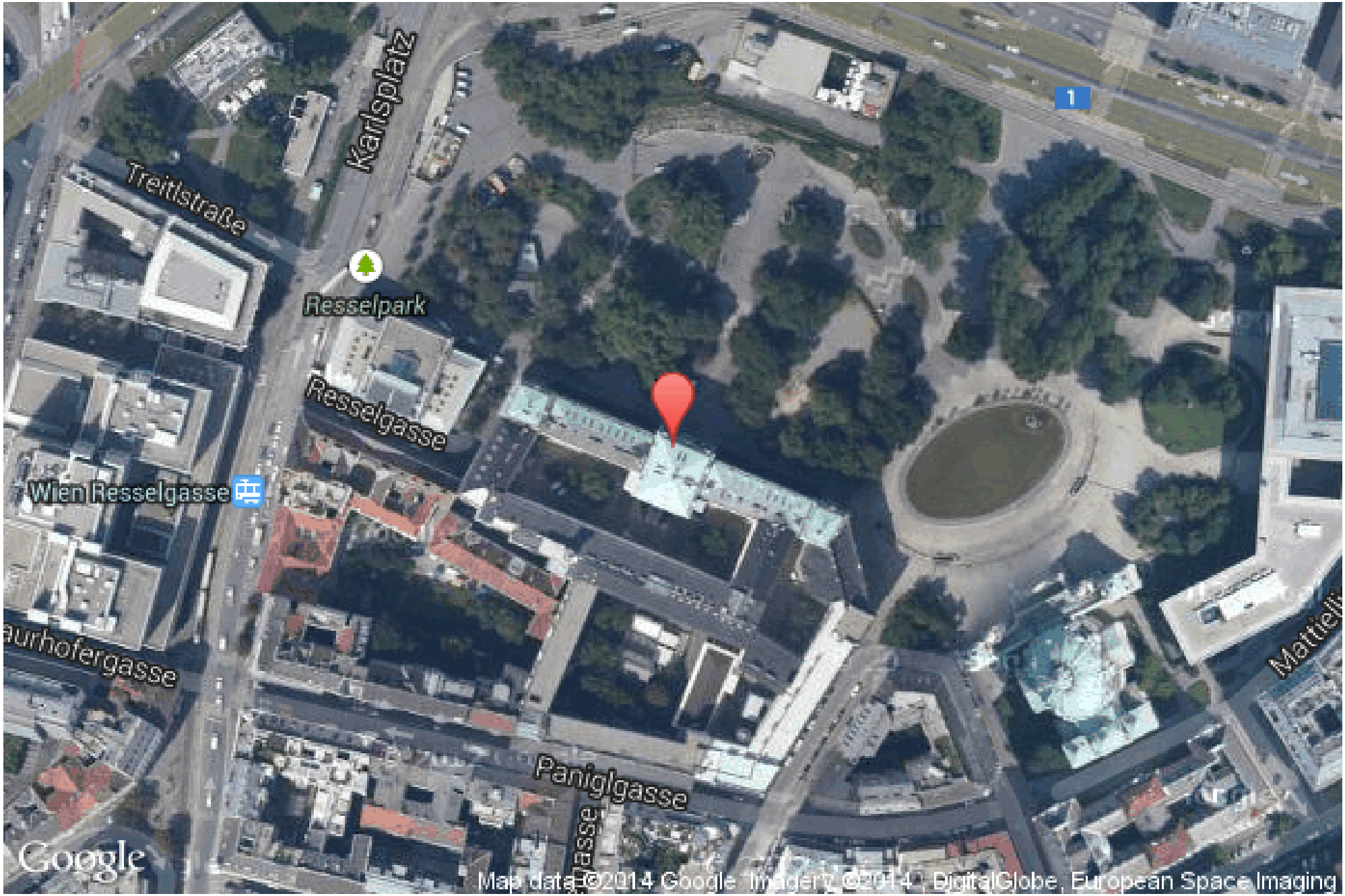

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TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Established 1815

400 professors
2 900 scientific staff
29 000 students
(7 000 CS students)

Vienna once was a center of logic

1920's: Wiener Kreis (Vienna Circle)

M. Schlick, H. Hahn, H. Menger, O. Neurath, R. Carnap, ...

Kurt Gödel

First Incompleteness Theorem (Gödel, 1931)

Every formalization of mathematics is either inconsistent or incomplete.

"This statement is not provable in your proof system."

Vienna is again a center of logic

You find logic at:

- Institute of Science and Technology Austria (ISTA)
- University of Vienna
- Vienna University of Technology (TU Wien)

Computational Logic @ TU Wien

- 17 professors
- One of two priority topics of the Faculty of Informatics

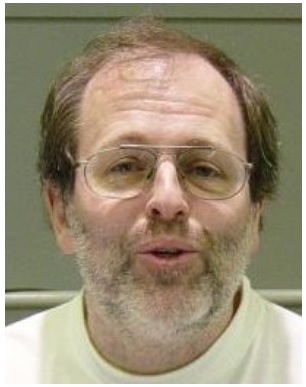
Institute of Discrete Mathematics and Geometry

Research unit "Computational Logic"

Matthias Baaz

- Proof theory
- Many-valued logics
- Temporal logics
- Mathematical logic

Research unit "Algebra"



Martin Goldstern

- Mathematical logic
- Universal algebra
- Set theory

Compilers and Languages Group

- Program analysis and optimization
- Abstract interpretation and model-checking

Jens Knoop

Laura Kovacs (Chalmers)

Theory and Logic Group

- Computational proof theory
- Resolution- and tableaux-based theorem proving
- Non-classical and many-valued logics
- Complexity of Constraint satisfaction problems

Alex Leitsch

Gernot Salzer

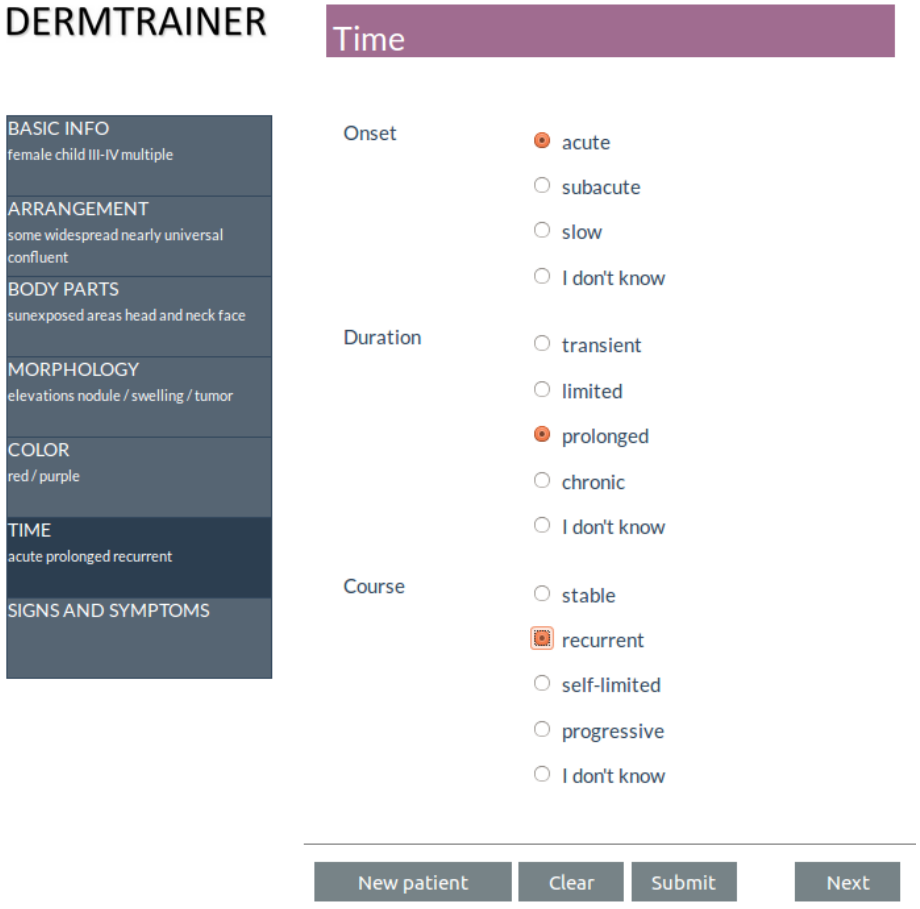
Agata Ciabattoni

Chris Fermüller

Decision Support System for Dermatology

Data problem: Where to get reliable disease data from? 50 000 values!

Diagnostic problem: How to compute the correct diagnosis?

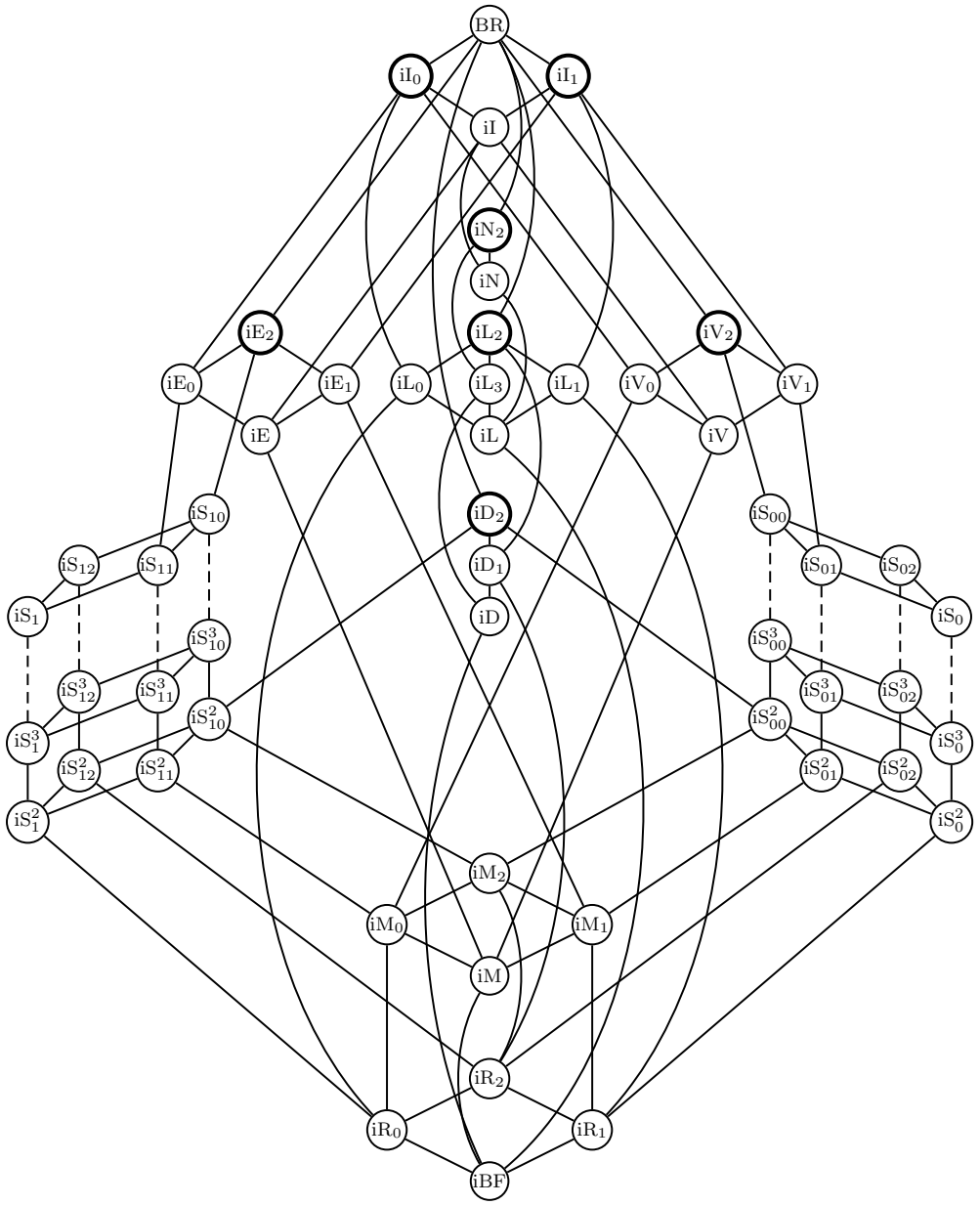


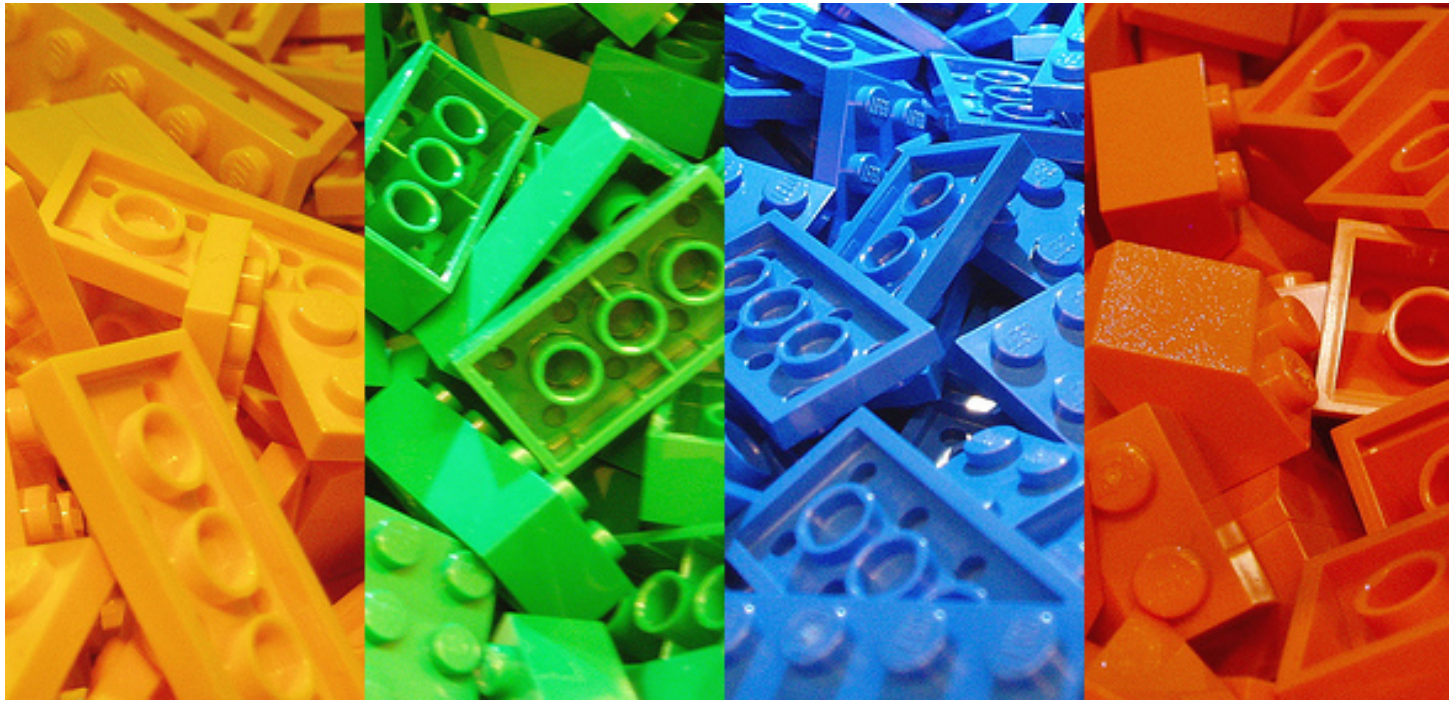
Properties of Coding Systems

Error correction: Given a message, find the nearest code word.

Nearest neighbour: Given a code word, find the next one.

Code distance: Minimal distance of any two code words?





Non Classical Proofs: Theory, Applications and Tools

Agata Ciabattoni

Vienna University of Technology
Faculty of Informatics

Logic: Toolkit for Formal Reasoning

Mathematical Statements

$9\ x.\ f(x) = x$

"the function **f** has a fixed point"

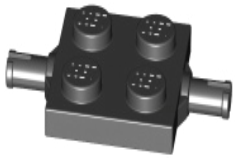
Classical Logic

Program Specifications

$\Box\ (req \rightarrow \Diamond\ ack)$

"each request is followed by an acknowledgment"

Temporal Logics



Medical Information

$oft(A \rightarrow B)$

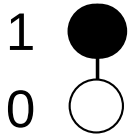
"the symptom A often implies the disease B"

Fuzzy Logics

Non-classical logics: Landscape

Non-classical logics: Differences

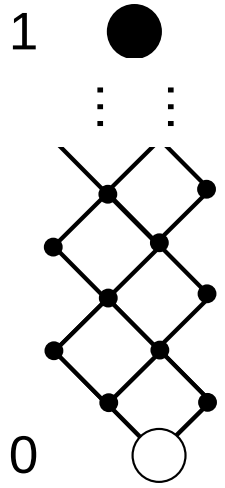
Classical Logic



Fuzzy Logics

$\mathbb{R}$ Å [0,1]

Intuitionistic Logic



(Heyting Algebra)

Fundamental Questions

How to construct proofs?

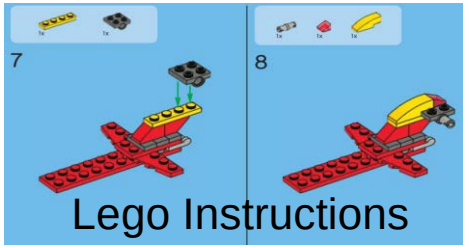
Sequent calculi, hypersequent calculi, …

Computer assisted proofs?

Decidability, complexity, Herbrand Theorems, …

Structural properties?

Algebraic completions, non-deterministic matrices, …



Fundamental Questions

How to construct proof

Sequent calculi, hype… …

11,400 entries
(google scholar)

Computer a

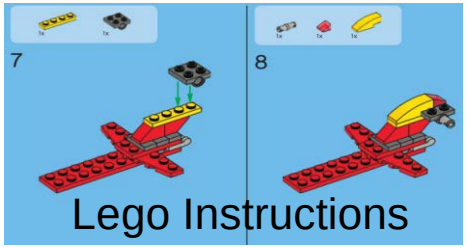
Decidability … …ns, …

State of the Art

Case-by-case

Structural p

Algebraic completions, non-deterministic matrices, …



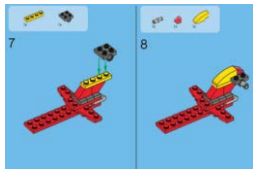
Project Aims

General and **Systematic** answers

Good calculi (sequent, hypersequent, …)

Decidability, complexity, Herbrand Theorems,…

Completions, non-deterministic matrices, …



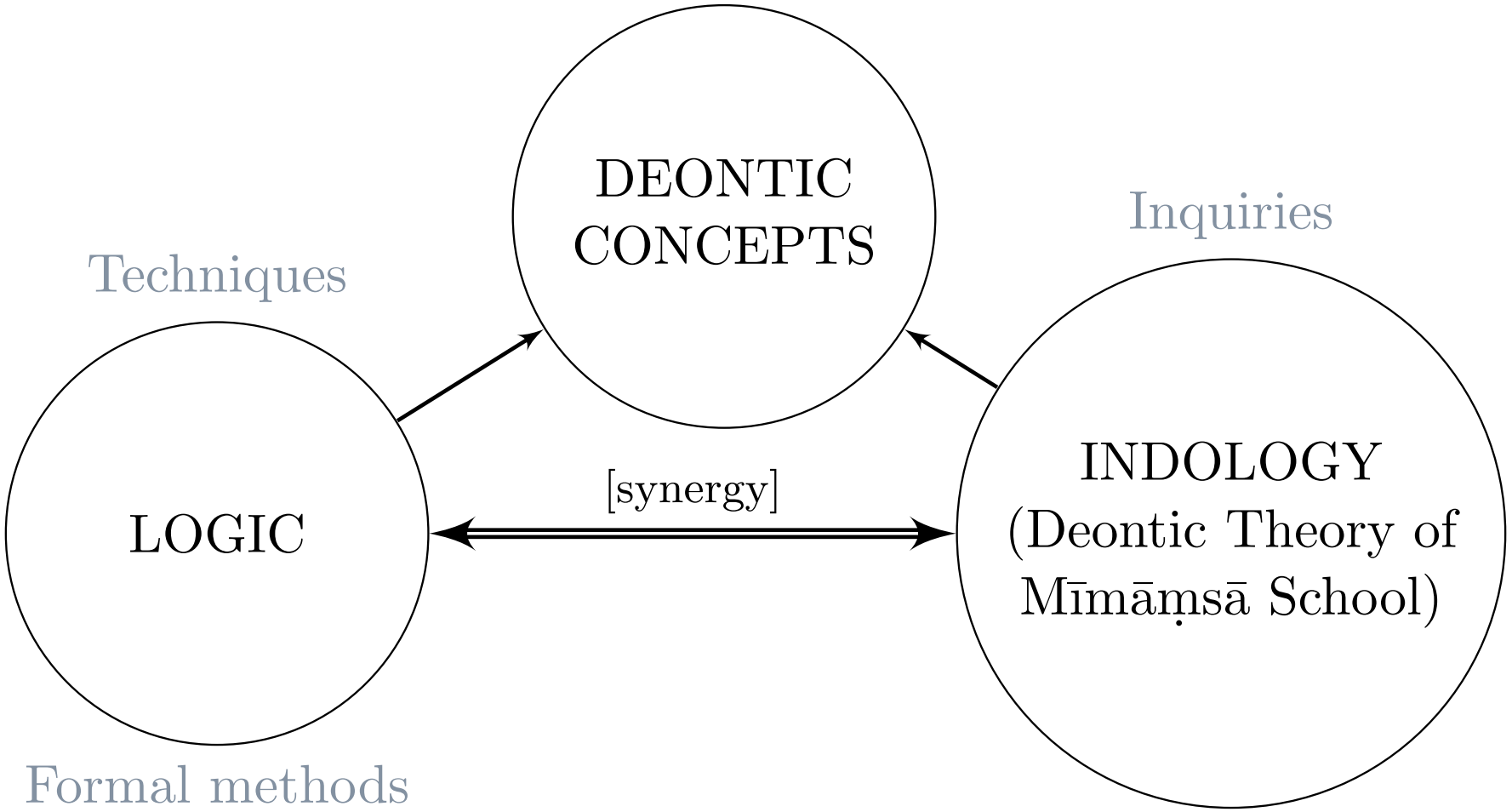
Applications

Tools

Theory

The Mīmāṃsā Project

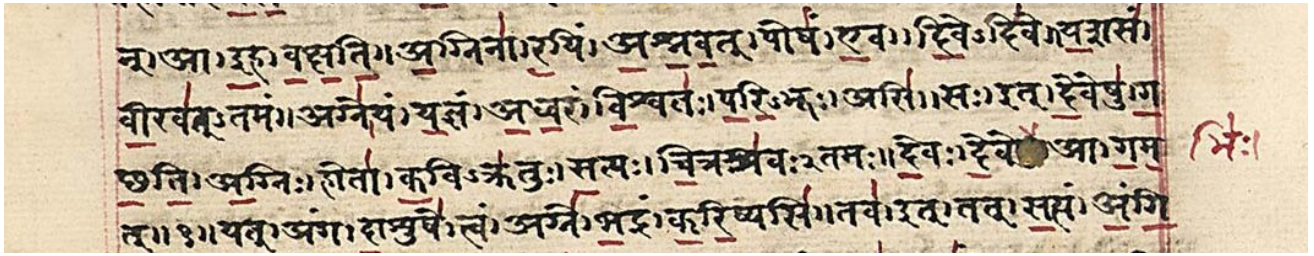
Definition and use of **formal tools** to **analyse** the work of **Mīmāṃsā school of Indian philosophy**



The Mīmāṃsā School

Mīmāṃsā (last centuries BCE - beginning of 20^{th} c.)

Indian school of philosophy focused on the **interpretation of the Vedas** (sacred texts, II - I millennium BCE)



Studying the Vedic prescriptions the school developed an **analysis of the relations between deontic concepts**

Why Logic?

Inferential reasoning

was **employed** and **discussed** by Mīmāṃsā authors

A central concern of Mīmāṃsā authors: the **absence of contradictions in the Vedas**

For example, **in the Vedas** it is prescribed:

1. ***"If one wants to harm his enemy, one must perform the Śyena sacrifice"***
2. ***"One must not perform violence on any living being"***

1 and 2 **cannot be contradictory**, because the Vedas are not (by assumption)

A Deontic Logic of Mīmāṃsā

To capture Mīmāṃsā reasoning we defined

Basic Mīmāṃsā Deontic Logic (bMDL)

that formalises the **deontic system employed** by the Mīmāṃsā school

We **extracted** a new logic **from the principles of the school (*nyāya*s)**

The Calculus & the Semantics

Use of the logic for reasoning tasks

We defined an **analytic calculus** using **general proof-theoretical methods** and we proved consistency, decidability, and complexity results

To provide **insights and explanations** about **Indological issues** we defined a **semantics for the logic**

Using calculus and semantics we analysed controversies discussed by the Mīmāṃsā school (as the mentioned consistency problem)

dbai Databases and Artificial Intelligence Group

Reinhard Pichler

Stefan Woltran

- Foundations of databases
- Semistructured data
- Advanced database systems
- Computational logic and complexity
- Knowledge Representation and Reasoning (e.g. logic-based argumentation systems)

Georg Gottlob (Oxford)

Big Data Developments

Big Data

Storage &

Computing Power

Massive Parallelization

Cloud Computing

MapReduce (Google)

Distributed File Systems

Big Data Techniques in Reasoning

- Some lessons learned from Big Data research:
  - MapReduce: new algorithmic paradigm for massive parallelization
  - Data replication because of *distributed* storage and computation
- Application to Reasoning:
  - Support reasoning (such as ASP, DLs) on top of big data
  - Apply successful big data techniques (such as parallel processing via MapReduce) to hard reasoning problems
- Complexity and performance analysis of new algorithms
  - Different performance metrics compared with “classical” algorithms (such as data replication rate, maximum server load, etc.)

Exploring the Foundations of SPARQL

- Increasing amount of data requires efficient yet powerful Query Languages
- Deep understanding of a query language is thus key for effective optimization and efficient use of a query language

SPARQL – A Query Language for RDF Data

- RDF and SPARQL: core technologies for the Semantic Web
- Distinguishing features of SPARQL to deal with the pecularities of Web Data are not well-explored

Goal:

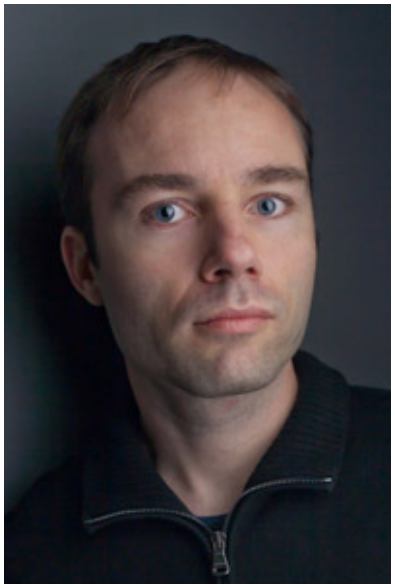
- Understand fundamental properties of SPARQL
- Transfer decades of Database Research to Semantic Web technologies
- Use these insights for Query Optimization

Results achieved so far

- Studied computational complexity of query answering
  - Problems like evaluation, enumeration, and counting
  - Identification of fragments with lower complexity
  - Usage of these fragments for approximation of answers
- Studied typical static query analysis tasks (core problems for query optimization)
  - Problems like Containment and Equivalence
- Identified rewrite rules for simplifications of queries
- Investigated the expressive power of the new SPARQL 1.1
- Proposed alternative semantics for query answering under Ontologies
  - Based on the “certain answer” semantics

Formal Methods in Systems Engineering

- Formal Methods for Embedded Systems
- Model Checking and Constraint Solving
- Automata, Logic, and Complexity



Georg Weissenbacher

Helmut Veith

Knowledge Based Systems Group

Thomas Eiter

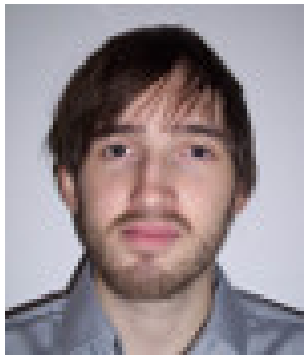
Stefan Szeider

- Knowledge representation and reasoning
- Computational logic and complexity
- Declarative problem solving
- Discrete Reasoning Methods
- Intelligent agents
- Mobile robots
- Knowledge-based systems in engineering

Hans Tompits

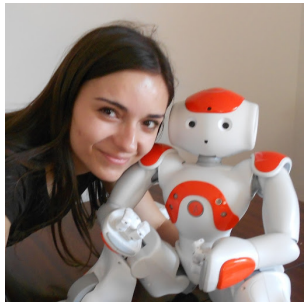
Uwe Egly

Recent thesis topics



Andreas Fellner: "Space & Congruence Compression of Proofs"
Advisors: A. Leitsch, B. Woltzenlogel Paleo

Adrian Haret: "Merging in the Horn Fragment"
Advisors: S. Woltran, S. Rümmele



Ilina Stoilkovska: "XML Data Integration"
Advisors: R. Pichler, V. Savenkov

Vienna is an attractive place for living

- 2 million inhabitants, capital of Austria
- highly international: UN headquarters, international companies, students, tourists, immigrants
- cultural center: operas, museums, concert halls, events, parties
- close to the Alps: biking, hiking, skiing
- moderate living costs
- around the corner: Bratislava, Budapest, Praha, Salzburg

Rankings:

1st according to Mercer's 2012 Quality of Living Survey
2nd according to The Economist's World's Most Livable Cities 2012
5th according to Monocle's Most Liveable Cities Index 2012
5th in QS Best Student Cities in the World 2012


HEY-U!
MEDIAGROUP

Welcome to Vienna!