INFORMATION TECHNOLOGIES IN THE SERVICE OF CLINICAL BIOCHEMIST

Informacijske tehnologije u službi medicinskog biokemičara

Mario Štefanović

Klinički bolnički centar “Sestre milosrdnice”
Klinički zavod za kemiju

Hrvatsko društvo za medicinsku biokemiju i laboratorijsku medicinu

11th Congress of the Croatian Society of Medical Biochemistry and Laboratory Medicine, Vodice, October 9 - 12, 2024

OVERVIEW

1. Introduction to IT and AI in Clinical Chemistry Labs
2. Key Advantages and Applications of AI
3. Historical Development and Future Trends
4. Challenges and Ethical Considerations
5. Practical Use Cases and Impact on Productivity

IT IN CLINICAL CHEMISTRY

WHAT?	**Information technology (IT)** ▸ lab data management using computer technology
WHY?	**Why follow IT technology if we aren't IT professionals?** ▸ rapid IT development impacting clinical chemistry ▸ keeping pace with time ▸ understanding and implementing new technologies ▸ boosting productivity
FOCUS?	▸ improving lab operations ▸ practical IT applications and optimization ▸ scientific development

HISTORICAL PERSPECTIVE: EVOLUTION OF IT & AUTOMATION

Manual processes	• Error-prone, laborious, inefficient
Basic IT systems	• Early databases (e.g., DBASE), DOS environment • Early tools (Excel, Word) for basic data management
Automation	• IT systems standardizing lab processes • Reduces human intervention, improving accuracy • Real-time data exchange via LIMS/LIS

LABORATORY AUTOMATION: OVERVIEW

Advantages & Challenges

Advantages
- Faster processing,
- consistent results,
- reduced error risk
- Frees up human resources

Challenges
- High costs,
- need for validation
- staff training

Automation Levels

Non-automated
- Manual work, low productivity (small labs)

Partially Automated
- Integration, reduced staff (medium/big labs)

Fully Automated (TLA)
- Integrated analyzers & pre/post-analytical modules (big modern labs)

Laboratory Automation

Benefits
- Increased efficiency,
- reduced human error

Challenges
- Implementation costs
- specialized training

Phases of Automation

Pre-analytical
- Sample registration,
- barcode usage,
- transport (e.g., pneumatic tubes)

Analytical
- Automated analyzers,
- LIMS integration,
- reflex testing

Post-analytical
- Result validation,
- autovalidation, QC, data reporting

Implementation Strategy

Start Parameters
- Samples, staff, speed, budget, space

Optimization
- Use LIMS, automate sample handling,
- QC monitoring

TECH AND IT INNOVATIONS IN CLINICAL LABORATORY

1. Automation & Workflow Optimization

Pneumatic Tube System
- sample delivery using tube systems: hospital departments -> lab

Automated Sample Handling
- robotic systems: sorting, labeling, tracking reduce human error
- real-time monitoring of sample quality and storage conditions

LIS/LIMS (Laboratory Information Systems):
- Manages lab data, tracks samples, automates workflows
- quality standards and regulatory compliance
- QMS (Quality Management Systems): quality and improvement

2. Advanced Diagnostic Tools

Wearable Health Technology Integration
- data from glucose monitors, fitness trackers: into lab analyses
- data aids in personalized medical treatments

Point-of-Care Testing (POCT)
- Immediate results, faster diagnosis

Advanced Sensors
- precise measurement (temperature, chemical concentrations)

3. Data Processing & Analysis

Cloud Storage, Bioinformatics and Analysis
- cloud systems: storing and analyzing large data, results and analysis

AI & Machine Learning
- large datasets, pattern analysis, predictive modeling
- analyzing unstructured data (photos, PDFs…)

Statistical Software (R, Python):
- complex data analysis and research interpretation

Visualization Tools (Tableau, Power BI):
- data visualization

4. Other: Training Technologies, Analytical Tools

Augmented Reality (AR)
- interactive virtual training: new equipment, protocols, new skills

High-Resolution Microscopy, Spectroscopy
- detailed molecular and atomic level analysis

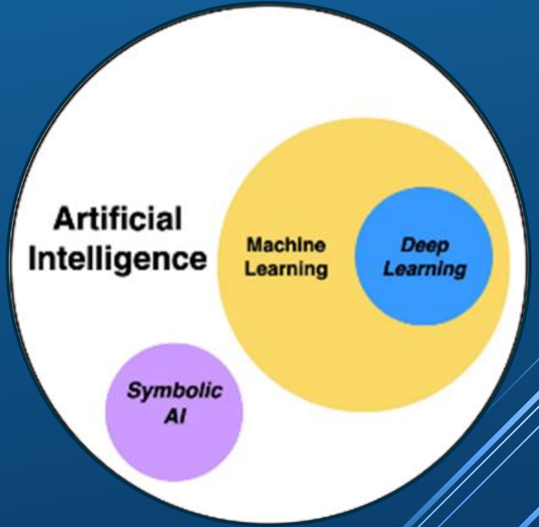
EVOLUTION OF AI IN LABORATORIES: FROM AUTOMATION TO GENERATIVE AI

ARTIFICIAL INTELLIGENCE - AI

- Machine simulation of human intelligence, automates analysis, pattern recognition

Evolution of AI

1950s	1980s	2010s	2020s
Artificial Intelligence (AI) Human-like Intelligence Initial Concepts	**Machine Learning** Learning from Data Historical Data	**Deep Learning** Brain-like Functions Complex Problem-Solving	**Generative AI (Gen AI)** Foundation Models Original Content Creation
	predictions/classifications pattern recognition large datasets	complex predictions neural networks: image, speech recognition more data complexity	creates new original content content generation creative tasks (art, music, text)



https://community.aws/content/2drbbXokwrIXivltJ8ZeCk3gT5F/introduction-to-artificial-intelligence-and-machine-learning

LEADING AI MODELS: CHATGPT AND THE RISE OF AI TOOLS

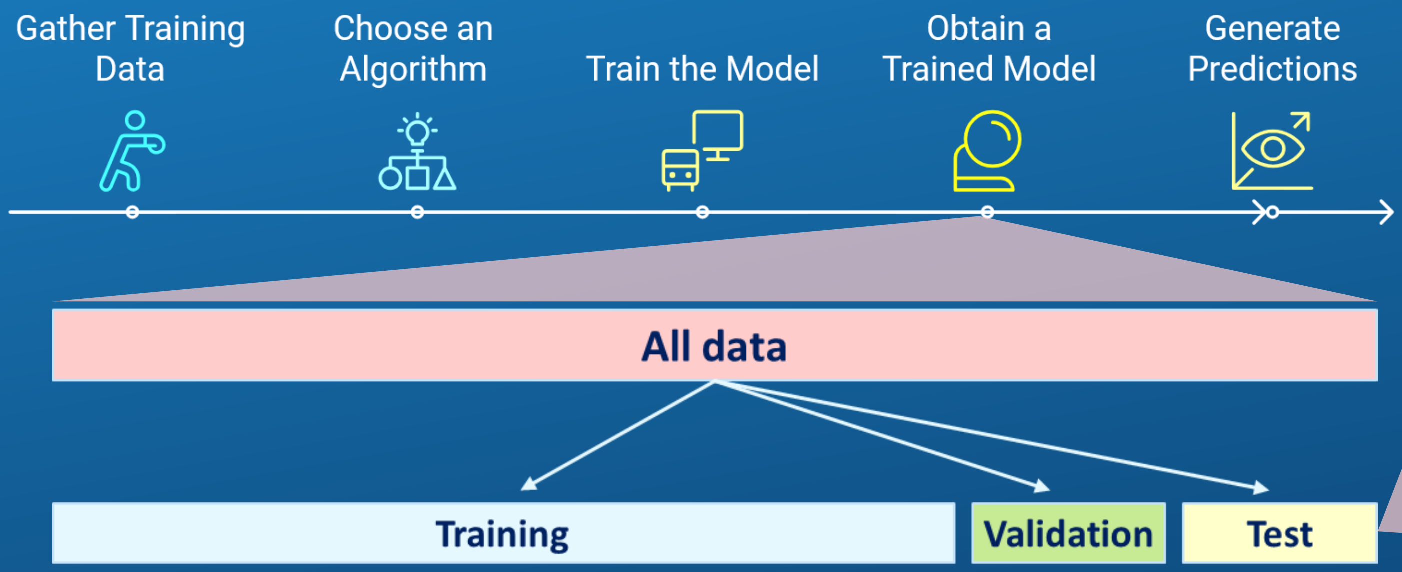
ChatGPT – OpenAI

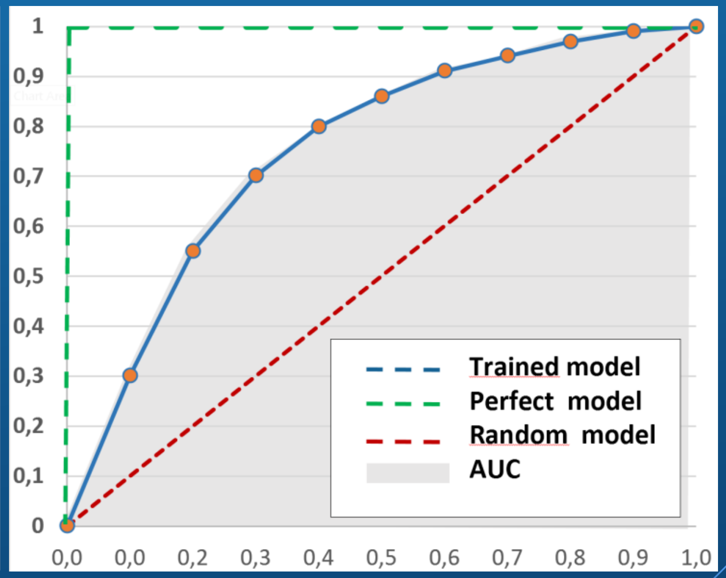
- General Pre-Trained Transformer
- public since 30.11.2022
- running LLM in background
- fastest adoption in history (100M/first month)

LEADING AI MODELS AND THEIR PRACTICAL APPLICATIONS

Category	Model	Description
Transformers and LLMs	GPT-3 & GPT-4 (OpenAI)	Language generation, chatbots
	BERT (Google)	Text understanding in Google Search
Generative AI Models	DALL-E (OpenAI)	Image generation from text
	Midjourney	Creative artwork generation
Specialized AI Models	AlphaFold (DeepMind)	Protein structure prediction
	Stable Diffusion	Image generation
Implementation Examples	Voice Assistants	Voice control
	ChatGPT, Copilot, Gemini, Llama, Claude, Grok	Generative AI

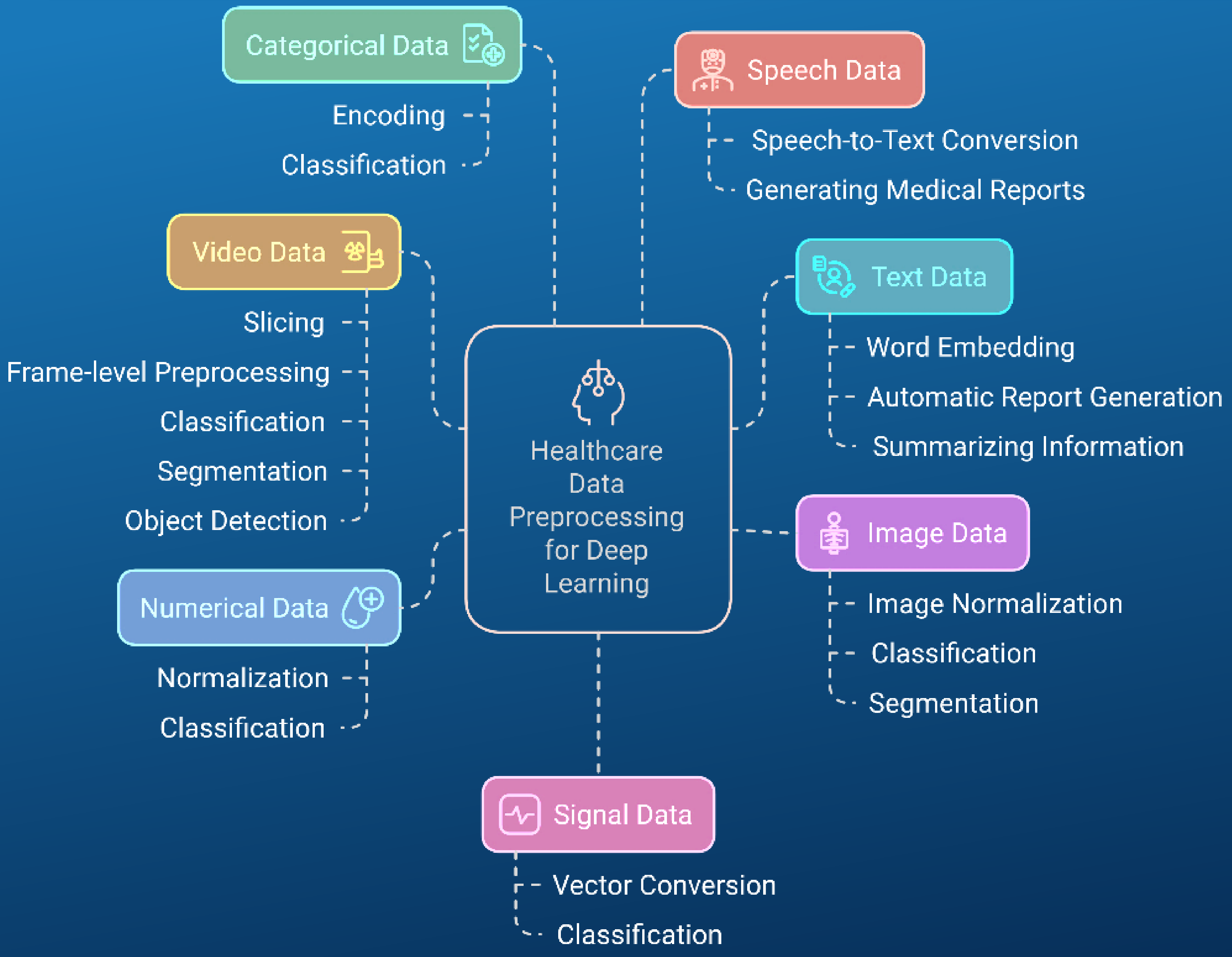
MACHINE LEARNING WORKFLOW AND MODEL EVALUATION





1. Collect data to build the model
2. Select the appropriate algorithm
3. Use training to adjust model's parameters
4. The model is trained after processing the data
5. The trained model makes predictions
6. AUC comparison of model performance

HEALTHCARE DATA PREPROCESSING FOR DEEP LEARNING



Preprocessing medical data for DL

Numerical:
- Blood reports

Categorical:
- Medical test results

Text:
- Medical reports

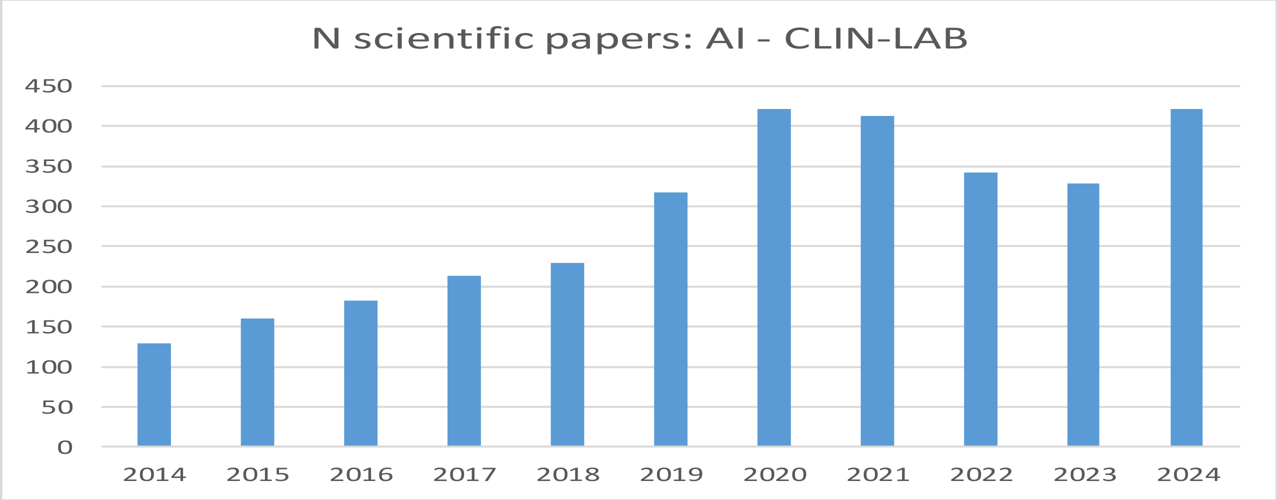
Image:
- X-ray

Video:
- CT, MRI, Ultrasound output

Speech:
- Voice typing

Signals:
- ECG, EMG signals

ARTIFICIAL INTELLIGENCE IN CLINICAL CHEMISTRY LABORATORY



Pubmed search

"Artificial Intelligence" OR
"Machine Learning" AND
"Medical Biochemistry" OR
"Clinical Chemistry" OR
"Laboratory Medicine" AND
publication date from 2019 to 2024

Category	Negative Aspects	Positive Aspects	Key Conclusions	No. of Articles	References
AI Applications	Data accuracy issues	Improved diagnosis and efficiency	AI enhances accuracy, but needs further validation	13	Hou H et al. 2024, Spies N et al. 2024
	Lack of transparency in algorithms	Optimized lab processes	Human-AI collaboration is essential		Dabla P et al. 2024, Pighi L et al. 2024
Ethical and Regulatory	Data privacy and security concerns	AI enhances transparency when regulated	Ethical guidelines and regulations are needed	4	Plebani M et al. 2024, Meyer J et al. 2024
	Responsibility for AI errors	Reduces medical errors when used properly	Privacy and bias must be addressed before broad use		Plebani M et al. 2024, Meyer J et al. 2024
Personalized Medicine	Ethical challenges in individualized treatment	Precision in diagnostics and tailored therapies	AI and digital tools boost personalized care	3	Padoan A et al. 2024, Flores E et al. 2024
	Data quality and integration issues	Improved outcomes through AI-based predictions	Validation and regulation needed for wider adoption		Lou X et al. 2024
Quality Control	High implementation costs	Reduced errors in lab results	AI improves quality control but requires monitoring	2	Lorde N et al. 2024, Lang T et al. 2024
	Limited interoperability between systems	Faster identification of preanalytical and analytical errors	Ongoing monitoring needed for sustained effectiveness		Lorde N et al. 2024, Lang T et al. 2024
Educational Use of AI	Risk of AI overuse for learning	AI supports medical education	AI complements but does not replace human experts	2	Ibrahim R et al. 2023, Ahmed S et al. 2024

ARTIFICIAL INTELLIGENCE IN CLINICAL CHEMISTRY LABORATORY

Clin Chem Lab Med 2023; 61(7): 1158–1166 DE GRUYTER

EFLM Paper

Janne Cadamuro, Federico Cabitza, Zeljko Debeljak, Sander De Bruyne, Glynis Frans, Salomon Martin Perez, Habib Ozdemir, Alexander Tolios, Anna Carobene and Andrea Padoan*

Potentials and pitfalls of ChatGPT and natural-language artificial intelligence models for the understanding of laboratory medicine test results. An assessment by the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) Working Group on Artificial Intelligence (WG-AI)

Cadamuro et al. 2023

- ChatGPT
- can recognize abnormal laboratory test values
- provides superficial interpretations
- not suitable for comprehensive medical diagnostics

Advances in Medical Education and Practice Dovepress
open access to scientific and medical research
Open Access Full Text Article

ORIGINAL RESEARCH

Human versus Artificial Intelligence: ChatGPT-4 Outperforming Bing, Bard, ChatGPT-3.5 and Humans in Clinical Chemistry Multiple-Choice Questions

Malik Sallam[1–3], Khaled Al-Salahat[1,3], Huda Eid[3], Jan Egger[4], Behrus Puladi[5]

Sallam et al. 2024

- ChatGPT-4
- outperformed human students and other AI models
- multiple-choice questions in clinical chemistry
- poor higher cognitive functions (analysis and application)

DE GRUYTER Clin Chem Lab Med 2023; 61(7): 1131–1132

Editorial

Mario Plebani*

ChatGPT: Angel or Demond? Critical thinking is still needed

Plebani 2023

- ChatGPT in scientific publications
- doesn't meet authorship criteria –no responsibility
- limits in interpreting lab results without clinical context
- need for ethical standards and critical thinking

Conclusion

- **AI can help in lab diagnostics**
  - but struggles with complex contexts
- **Excels in basic education**
  - but lacks higher cognitive abilities
- **Ethical use and regulation is crucial!**
- **Much more research is needed!**

LAB PRODUCTIVITY TOOLS: DATA ANALYSIS AND REPORTING

Which tool to use for different data analysis tasks?

Use MySQL, MSSQL, or PostgreSQL
For statistics, data reports, LIS and LIMS data analysis, and research scientific work

Use Excel, Google (Looker), Gsheets, Jupyter, MS Access, Python, or R
For inventory, tests, staff, and equipment management

Use Excel, Google (Looker), Gsheets, Jupyter, MS Access, MS Power BI, Python, or R
For data mining and ML tools

Data mining and ML tools
- MySQL, MSSQL
- MS Access
- Python: Jupyter, Colab

Statistics and data tools
- Python
- R studio

Reports and dashboards
- Google (Looker), MS Power BI
- Excel, Gsheets
- Power Point, GSlides

ENHANCING LAB PRODUCTIVITY: WHICH AI/IT TOOLS?

Data Analysis & Reporting						Data Extraction
Database Management	Data Visualization	Data Analysis	Statistical Analysis	Machine Learning	Spreadsheet Tools	OCR, NLP

Use ChatGPT OpenAI

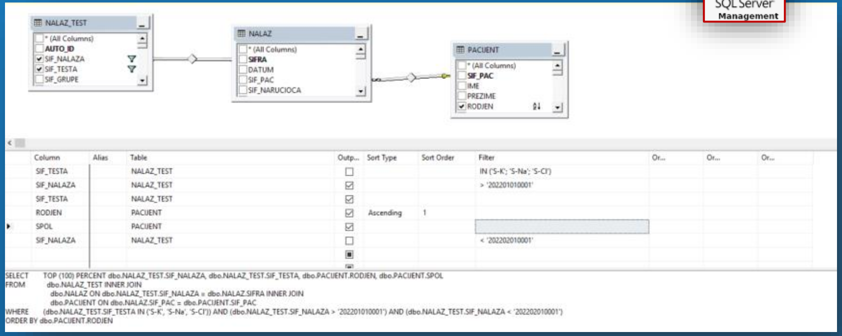
SQL database MySQL, MSSQL, PostgreSQL	**Programming Environments** Anaconda Navigator Jupyter Notebook Google Colab	**Reporting Tools** Power BI Google Looker Studio	**Statistical & Data Science Tools** Python, R studio	**Machine Learning** Google TensorFlow	**Spreadsheet programming** MS Excel (VB) Gsheets (AppScript)	**From unstructured** images, PDFs, voice Automating data entry & analysis

OTHER AI/IT TOOLS

Tool	Purpose	Ease of Use	Productivity Benefits	Examples
SQL Database	Data storage and retrieval	Pay/Free, install required	Efficient queries, research data	Storing lab data, inventory
MS Access	Database management	Install required	Relational database, simple interface	Sample tracking, data queries, programming application
Excel, Sheets (AppScript)	Data entry, analysis, automation	Excel: Paid	Programing repetitive tasks	Reagent calculation, data entry, advanced formula
Power BI	Data visualization, reports	Desktop, free version Sheets: Free, web-based	Fast analysis, better decisions	QC metrics, patient trends
Odoo	Business management	Web-based, free and paid versions	Streamline business processes	Patient management, finance
Jupyter notebook, Colab	Python-based data analysis	Jupyter/Colab: Web Anaconda: Install	Advanced analysis without coding	Clinical data analysis, trend graphs
Looker Studio	Online data dashboards	Web-based, free	Interactive insights	Lab performance dashboards
R Studio	Statistical analysis	Open-source, install	Advanced statistical analysis	QC statistical testing
TensorFlow	Machine learning models	Open-source, local or web	Predictive modeling	Image analysis, patient prediction
Weka	Machine learning	Open-source, install	Simple ML classification models	Anomaly detection, clustering
Snipe-IT	Inventory management	Web-based, open-source	Track assets and resources	Lab equipment tracking
Bioconductor	Genomic data analysis	Open-source, requires R	Genomic data processing	Gene expression analysis
Galaxy	Bioinformatics, sequencing	Web-based, open-source	Large-scale biological data analysis	General research data analysis
ChatGPT	Coding assistance, text generation	Web-based, easy to use	Generate scripts, troubleshoot	Generate Python scripts

PRACTICAL APPLICATION

Miscrosoft SQL server

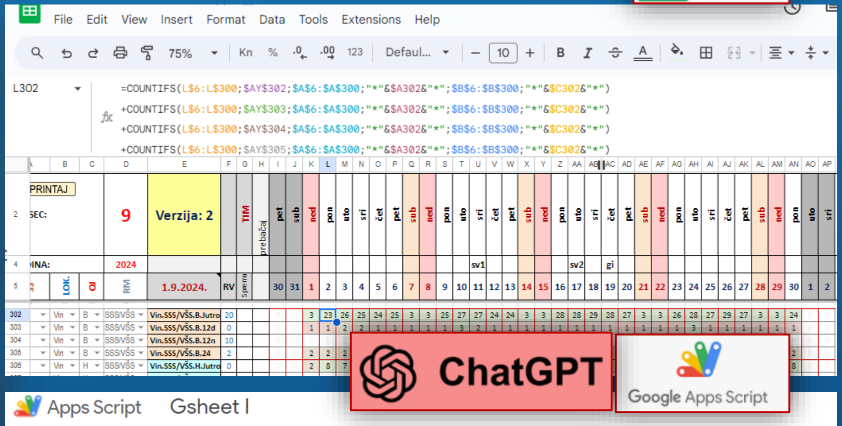


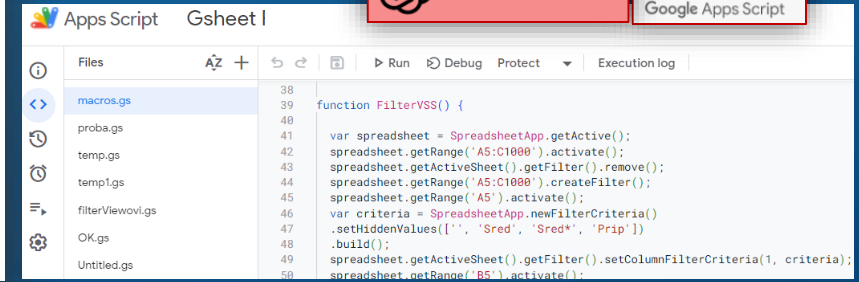
daj mi sql kod koji će na MSSQL serveru povezati tablice prema ovom prikazu na slici
Tablica [dbo].[PACIJENT] sad[...]enja [RODJEN] (godina) i spola [...]
pripremi query koji će povu[...] podatke iz tih tri tablice:
[SIF_TESTA]='S-K' or S-Na' or 'S-Cl'
[SIF_NALAZA] je veće od 202201010001 i manje od 202202010001

Na temelju priloženog dijagrama tablica, mogu pretpostaviti da su veze između tablica već postavljene na odgovarajući način putem vanjskih ključeva. SQL upit koji povezuje ove tri tablice prema uvjetima koje si naveo, te povlači podatke o pacijentima, datumima rođenja i spolu, mogao bi izgledati ovako:

```sql
SELECT
    NALAZ_TEST.SIF_NALAZA,
    NALAZ_TEST.SIF_TESTA,
    PACIJENT.RODJEN,
    PACIJENT.SPOL
FROM
    [dbo].[NALAZ_TEST]
INNER JOIN
    [dbo].[NALAZ] ON NALAZ_TEST.SIF_NALAZA = NALAZ.SIFRA
INNER JOIN
    [dbo].[PACIJENT] ON NALAZ.SIF_PAC = PACIJENT.SIF_PAC
WHERE
    (NALAZ_TEST.SIF_TESTA IN ('S-K', 'S-Na', 'S-Cl'))
    AND (NALAZ_TEST.SIF_NALAZA > '202201010001' AND NALAZ_TEST.SIF_NALAZA < '202202010001'
```

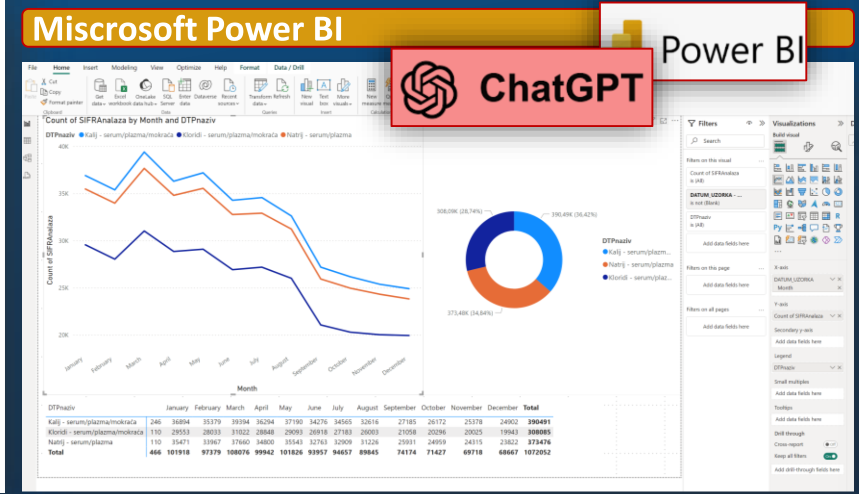
Google Sheets



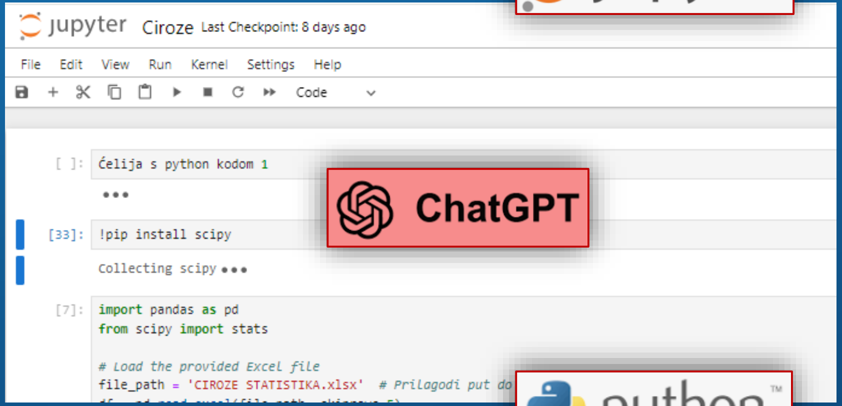


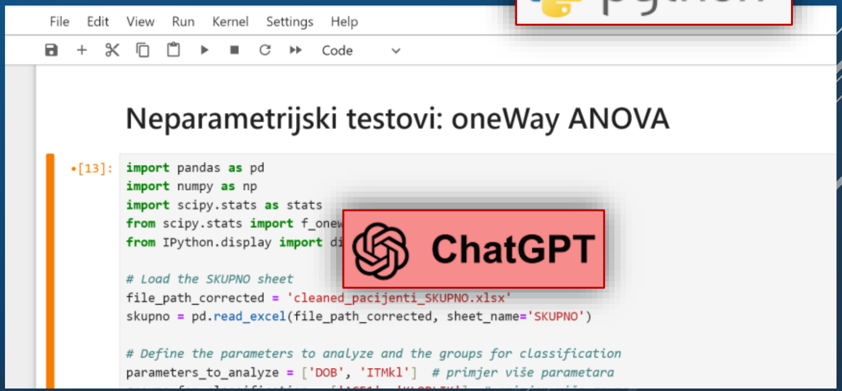

```
function FilterVSS() {

  var spreadsheet = SpreadsheetApp.getActive();
  spreadsheet.getRange('A5:C1000').activate();
  spreadsheet.getActiveSheet().getFilter().remove();
  spreadsheet.getRange('A5:C1000').createFilter();
  spreadsheet.getRange('A5').activate();
  var criteria = SpreadsheetApp.newFilterCriteria()
  .setHiddenValues(['', 'Sred', 'Sred*', 'Prip'])
  .build();
  spreadsheet.getActiveSheet().getFilter().setColumnFilterCriteria(1, criteria);
  spreadsheet.getRange('B5').activate();
```

Miscrosoft Power BI



Jupyter Notebook





ANOVA test results for DOB by ACE1:

	Genotype	N	Mean	Median	Min	Max	F-statistic	P-value
0	DD	640	67.518750	73.0	22.0	89.0	23.562655	7.413576e-11
1	ID	1101	72.107175	74.0	23.0	93.0	23.562655	7.413576e-11
2	II	568	69.183099	69.0	23.0	95.0	23.562655	7.413576e-11

ANOVA test results for DOB by KLOBLIK:

	Genotype	N	Mean	Median	Min	Max	F-statistic	P-value
0	0.0	203	71.763547	68.0	49.0	88.0	180.04125	2.341328e-134
1	1.0	376	55.470745	55.0	22.0	93.0	180.04125	2.341328e-134

PRACTICAL APPLICATION : CHATGPT

Working with Files (Images, PDFs, DOCs)

- Convert image/PDF text into an editable
- Create table from image/text
- Consolidate multiple documents or data into a summary
- Shorten long to concise version

Working with Paragraph Text

- Create table with columns A, B, C from paragraph/organize by category
- Shorten long paragraphs/keep key points
- Reorganize paragraphs/text, improve structure and flow

Working with Long Articles or Documents

- Extract bullet points from long document
- Summarize the content
- Extract key conclusions from long document

Excel/Google Sheets Formulas

- Find a value in *Sheet2* and, if found, write the result in cell *A2* of *Sheet1*
- Extract First Name and Last Name from merged *Name and Surname* cells

Code Creation

- Write Python code descriptive statistics + graphs from *PODACI.xlsx*
- Write AppsScript code to create chart from data in the range *Sheet1!B2*
- Write Python/AppsScript code to generate links for articles list

Problems and Solutions

- Explain what this Windows 11 error message means and suggest solutions

KEY TAKEAWAYS & FUTURE OUTLOOK

AI Enhances Lab Efficiency	Automates data, optimizes tasks, improves decision-making, increased efficiency, accuracy
Quality Assurance	AI ensures reliability and quality in labs
Key Applications	Data automation, task optimization, large dataset management, advanced reporting, custom insights, inventory performance
Challenges	AI limitations, ethics, bias, high adoption costs, trust-building
Data Security	Demands encryption, multi-factor authentication, GDPR compliance

THANK YOU!

LECTURE AVAILABLE AT: https://klinkemija.kbcsm.hr/predmet-laboratorijska-informatika/predavanja/