Università degli Studi di Pavia

CLINICAL TRIALS SEARCH ENGINE

Information Retrieval & Recommender Systems

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The Project 

System aim and usage

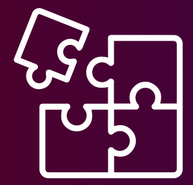
- Develop a search engine to retrieve relevant clinical trials based on written summaries of patients' medical conditions.
- The SE will be used by medic personnel to fasten up the triage of a patient basing on previous trials.

Dataset exploration

What are we looking for?

- After analyzing the TREC CDS dataset we observed key features such as the condition, the description, and more (see a few below).
- We used all the data avaible in the document to build the best search engine we could.

nct_id	brief_title	brief_summary	detailed_description	condition
NCT00977769	Carbetocin Versus Oxytocin and Hemodynamic Eff...	A randomized double-blind trial of oxytocin 5 ...	Healthy pregnant women sheduled for elective c...	Effects of Anesthesia, in Pregnancy

Workflow 

💡 **First Idea**

💻 **Development**

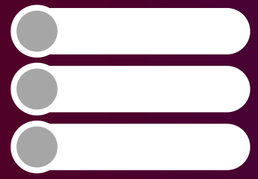
- Experiments → New Features → Test & debug 🔄

📤 **Deployement**

Intuition 

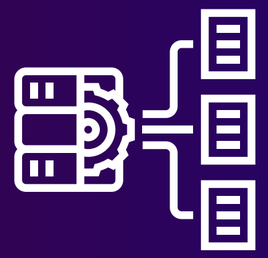
Which features can be useful for our users?

- Use a Large Language Model (LLM) to expand and upgrade the query.
- Implement a reranking sys based on user feedback can henance the experience, since the search is supposed to read more then one study.



Pipeline

Extraction & Parsing



How do we get the TREC CDS documents?

From **XML** files:

- Recursively extract
- Parse each xml

From **Pickle** file:

- Load the database

Preprocessing & Indexing

How do we process the raw text from the documents?

Using spaCy we implemented the following steps:

1. **Punctuation Removal**
2. **Stop-Words Removal**
3. **Lemmatization**

Then we indexex all the processed documents using PyTerrier.

Query Formulation

How do we manage the queries?

1. User Input → Processing → Expansion (PyTerrier) → Original Query
2. **Translation** → Processing → Translated Query
3. **PMC Extraction** (LLM) → Processing → Query + PMC

Translation 文A

Why translate?

It improves the query results and it can be language inclusive.

Simple is better

- Using large lenguage models or local solutions resulted in non optimal solutions.
- We chose to use an open **Google Translate Endpoint** to make it better.

Expansion 

We both expanded the queries with PyTerrier default methods.
In particular the best results were obtained with the methods applying Relevance Models and the Divergence from Randomness Framework.

Reference Paper:

- Nasreen Abdul-Jaleel, James Allan, W Bruce Croft, Fernando Diaz, Leah Larkey, Xiaoyan Li, Mark D Smucker, and Courtney Wade. UMass at TREC 2004: Novelty and HARD. In Proceedings of TREC 2004.
- Amati, Giambattista (2003) Probability models for information retrieval based on divergence from randomness. PhD thesis, University of Glasgow

LLM PMC Extraction

Extracting Primary Medical Condition

Given a query we try to expand it extracting the PMC with a large lanuage model. We use the following prompt instructions:

```
instructions = (
    "Your must extract a medical condition from the given prompt. "
    "If a medical condition is found, your answer must be just the medical condition. "
    "You should not answer if no medical condition is found! "
    "Your answer must not include comments or opinions!"
)
```

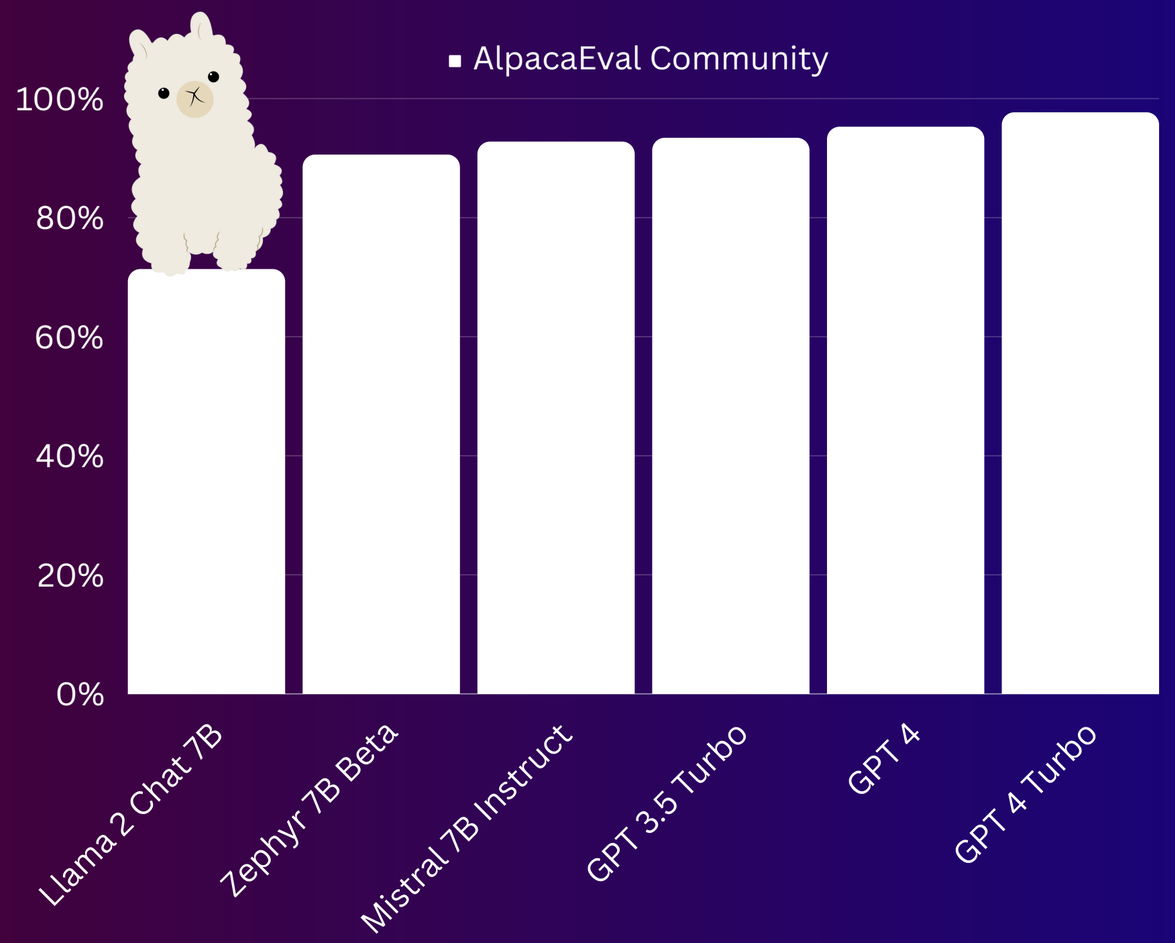
LLM Digression

Models

We implemented models such as:

- **Mistral** 7B Instruct v0.2
- **Zephyr** 7B Beta
- **Llama 2** Chat 7B

These are not the best models overall but a good starting point on how to implement also the bigger ones.



Retrieval & Ranking

How do the documents are retrieved?

Given the union of all the processed queries we do the following steps:

- Using PyTerrier we first search and retrieve the ranked documents list using a baseline (BM25 or TF-IDF) and a default PyTerrier Query Expansion (not applied in case of LLM QE).
- We then rank the list using a policy for optimizing the combined results of the original, translated and the expanded query (optional).

User Feedback & Settings 

How do we improve the System-Human Interaction?

- Through the Graphical User Interface we implemented the possibility for the user to tell the SE if the document retrieved is of relevant or not.
- The user can also decide to expand the query or extract the PMC when searching using a simple graphic implementation.

Reranking

How a neural similarity matrix can help in this task?

We implemented a fine-tuned BERT (ClinicalBERT on Huggingface) so that when the system receive a feedback for a document:

- A similarity matrix between the specified documents and all the other results is calculated.
- Based on a specific policy the results are reranked basing on the similarity between the documents

Evaluation 🎯

How to evaluate?

- **Topics**: the queries
- **qrels**: the correct results made by expertise to compare and evaluate the obtained results

Metrics

- **Reciprocal Rank**: RR(rel=n)@X,
- **Precision**: P(rel=n)@X,
- **R-precision**: Rprec(rel=n),
- **Recall**: R(rel=2)@X

Results

Most relevant RS metrics

Blue: rel = 1 - **Red**: rel = 2

Retrieval System	RR@1k	P@1	P@5	Rprec	RR@1k	P@1	P@5	Rprec
TF-IDF	0.681	0.560	0.428	0.192	0.478	0.320	0.256	0.149
TF-IDF > RM3	0.684	**0.600**	**0.544**	0.245	0.454	0.340	0.300	0.179
TF-IDF > Bo1	0.671	0.580	0.528	0.253	**0.493**	0.380	**0.304**	0.191
TF-IDF > Llama 2	0.649	0.540	0.468	0.193	0.489	**0.380**	0.280	0.155
TF-IDF > Mistral	**0.686**	0.580	0.460	0.198	0.466	0.320	0.268	0.158

Adaptations & Limits ⚠

Models

- **LLMs** are not the best in terms of **determinism**, each result can be different.
- The lack of server / client implementation lead to a **slow startup and slow computing** basing on the device's performance.

Live Feedback

- As the name suggest it is not permanent: a new query will erase all the user tuned results.
- The evaluation is not implemented since it would not be simple: it can be very expensive in term of resources and time!

Live Demo

Some Conclusions 

Neural Networks can be useful in IR

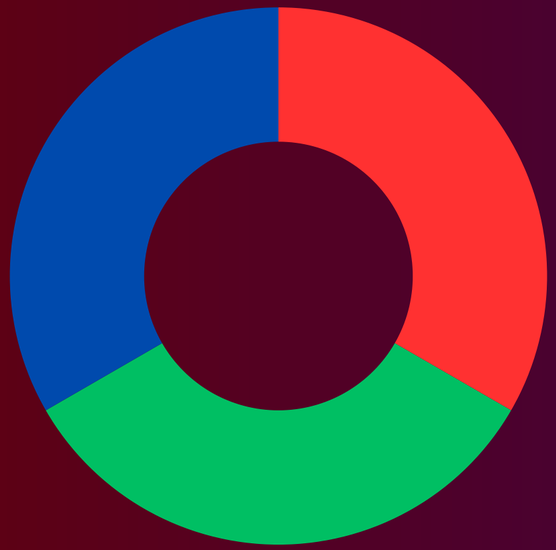
The inner nature of LLMs marks a clear limit between them (ex. chatbot) and search engines but NN can still improve the expirience in using the search engines by being implied in some features.

Developing a Search Engine is not an easy task

A good project require resources, time, multi-level and multi-disciplinary skills, back-end, front-end, data analysts and expertises in the SEO. However we managed to do it.

What we gained

Experience, but also:



- 📚 Practical application of theory
- 🌐 Understanding of LLMs
- 🤝 Collaboration and Teamwork
- ✅ Problem-Solving experience
- 👤 User-Centric design focus
- 📈 Technical proficiency

Questions?

Thanks for watching!