QUESTION ANSWERING

Information Retrieval System

DATA SCIENCE INTENSIVE CAPSTONE

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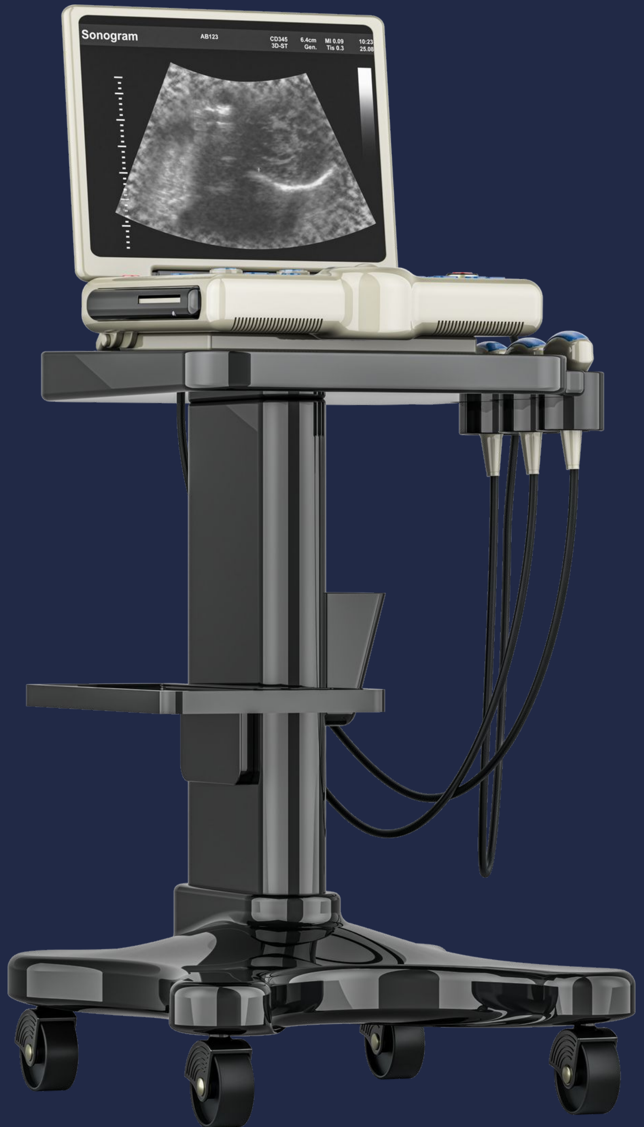
Our Client

2D Imaging, Inc. is a small, family-owned business specializing in medical ultrasound equipment sales, repairs, refurbishing, and servicing.

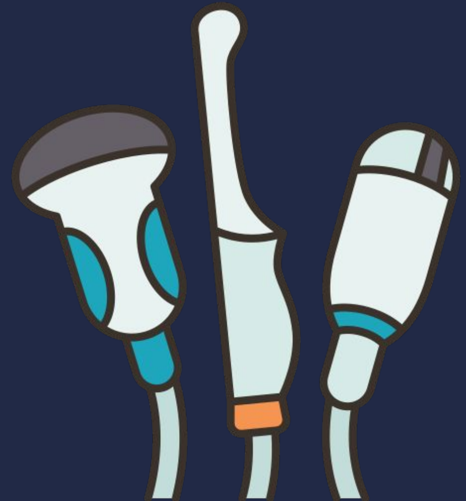
The company is currently expanding its e-commerce capabilities and online sales presence.

- Highly specialized, expensive medical equipment **requires** good customer service
- Customer support infrastructure for increased volume and diversity of inquiries



Goal

- Develop a Question Answering (QA) system to provide accurate, timely, and relevant information to customers



Preparing the knowledgebase

- Loop through tabular data and transcribe into human-readable sentences

	Model	Manufacturer	Array Type	Frequency Range	Compatibility	Applications
	C5-2	ATL	Convex	2.0-5.0 MHz	HDI 1500, HDI 3000	general, abdominal

“The manufacturer of the C5-2 probe is ATL.”

“The ATL C5-2 is a convex array type probe.”

“The ATL C5-2 probe is compatible with the following systems: HDI 1500, HDI 3000.”

Final corpus contains 324 text documents

Generating Question-Document Pairs

- Used large language model (Llama3) to generate 3 questions for each document

```
"""
Generate three concise questions that can be answered using the following
information, similar to the example provided. Provide only the questions,
numbered as follows:

1. [insert question here]
2. [insert question here]
3. [insert question here]

Example 1:
Information: The manufacturer of the C3 probe is ATL.
Questions:
1. Who is the manufacturer of the C3 probe?
2. Who makes the C3 transducer?
3. Is the C3 probe made by ATL?

Example 2:
Information: The G.E. RIC5-9D probe is compatible with the following
systems: Voluson E6, Voluson E8, Voluson E10, LOGIQ S7, LOGIQ S8, Vivid
E95, LOGIQ E9, LOGIQ E10.
Questions:
1. What systems are compatible with the G.E. RIC5-9D probe?
2. Does the G.E. RIC5-9D work with the Voluson E6 system?
3. Is the G.E. RIC5-9D transducer compatible with the LOGIQ S7 system?

Example 3:
Information: The Siemens Acuson 15L8W probe has a variant with a cartridge
connection.
Questions:
1. Does the Siemens Acuson 15L8W probe have a cartridge connection?
2. What kind of connector does the Siemens Acuson 15L8W transducer use?
3. Does the Siemens Acuson 15L8W probe use a cartridge connector?
```

Prompt Engineering

- Provide examples for each type of document
- Provide clear instructions for parseable output structure (e.g. numbered list)

```
Here are the three questions generated for the documents:

1. Who is the manufacturer of the C3 probe?
2. Who makes the C3 transducer?
3. Is the C3 probe made by ATL?
```

```python
def extract_questions(response):
    pattern = r'\d+\.\s(.+?\?)'
    questions = re.findall(pattern, response)
    return questions
```

```
["Who is the manufacturer of the C3 probe?", "Who makes the C3 transducer?", "Is the C3 probe made by ATL?"]
```

Generating Question-Document Pairs

- Used llama3 to filter out poorly generated question-document pairs
- Any question-document pairs marked as irrelevant were manually reviewed
- Final dataset: **932 queries**, **324 documents**

```
grading_prompt_template = PromptTemplate(
    input_variables=["content", "question"],
    template="""
    Given the content: "{content}"
    Can the following question be sufficiently answered?
    Question: "{question}"
    Your response should only consist of one number, either a 0 (meaning No) or 1 (meaning Yes).

    Example 1:
    Content: "The manufacturer of the C3 probe is ATL."
    Question: "Who is the manufacturer of the C3 probe?"
    Response: 1

    Example 2:
    Content: "Who manufactures the EPIQ 7 ultrasound system?"
    Question: "The Siemens Acuson 12L3 probe is compatible with the following systems: Juniper."
    Response: 0
    """
)
```

Evaluating Pre-trained Models

all-mpnet-base-v2

- General-purpose model based on the MPNet architecture
- Trained on diverse corpus of 1B+ sentences
- https://huggingface.co/sentence-transformers/all-mpnet-base-v2

multi-qa-mpnet-base-dot-v1

- mpnet-base model fine-tuned using 215M question-answer pairs
- https://huggingface.co/sentence-transformers/multi-qa-mpnet-base-dot-v1

multi-qa-distilbert-cos-v1

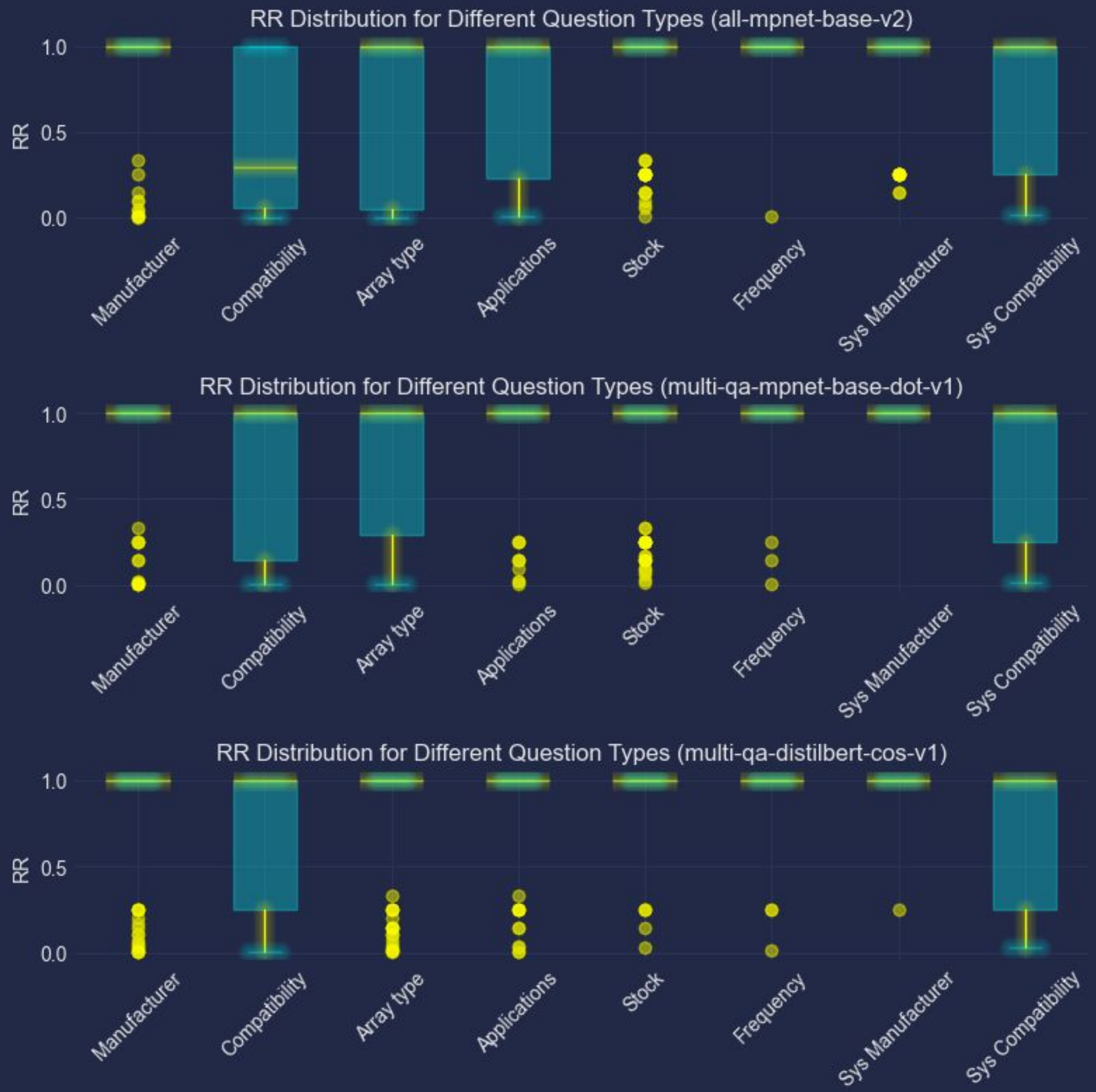
- Fine-tuned using 215M question-answer pairs
- Based on the DistilBERT architecture, which is a lighter and faster version of the popular BERT model
- https://huggingface.co/sentence-transformers/multi-qa-distilbert-cos-v1

Evaluation Metric:

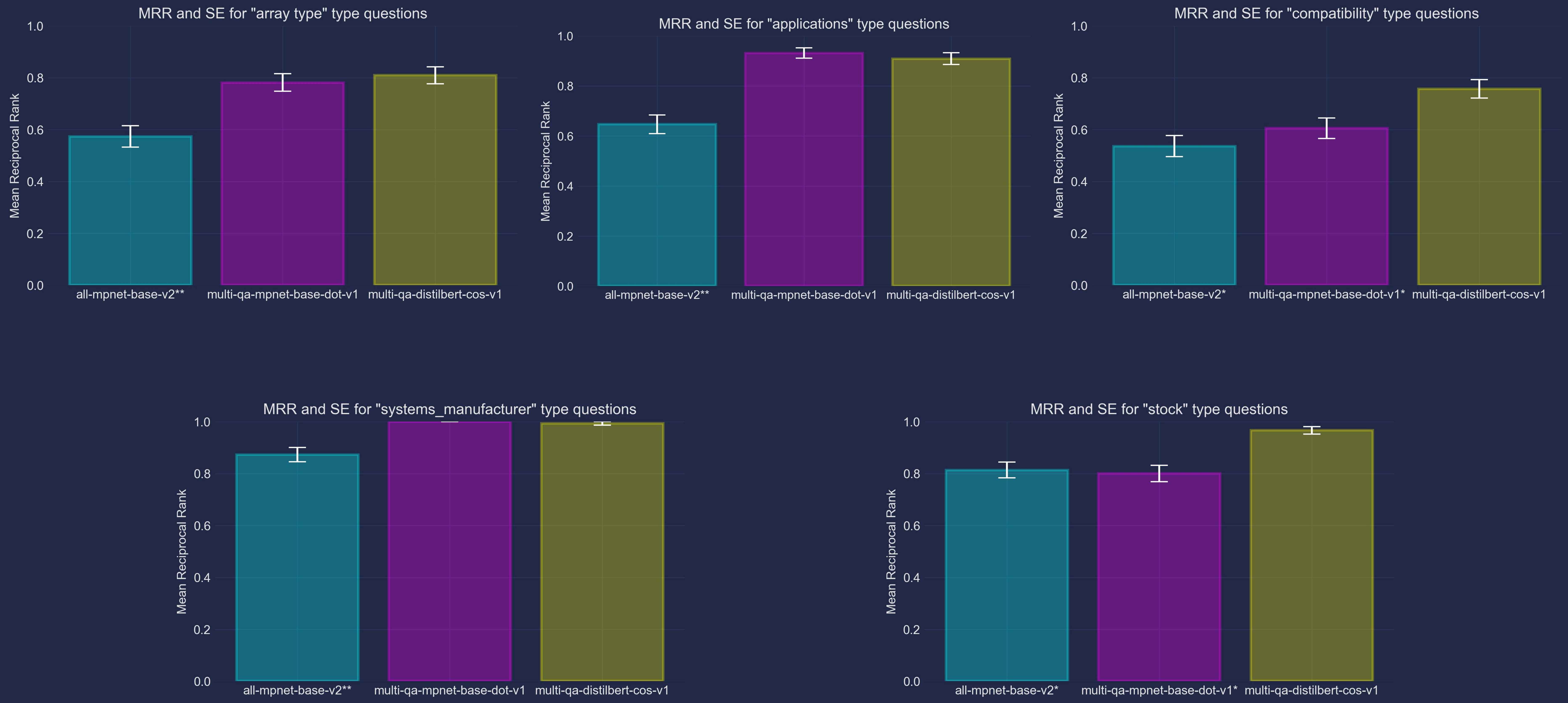
Mean Reciprocal Rank (MRR)

- Documents ranked based on their cosine similarity scores to the query
- Calculates reciprocal rank (1/rank) of the “correct” document

Distribution of Reciprocal Rank Scores by Question-type and Embedding Model



Mean Reciprocal Rank and SE across Various Question Categories



Hyperparameter Tuning

- **Base model:** *multi-qa-distilbert-cos-v1*

- Create training/validation/testing (70/15/15) PyTorch Datasets

- Bayesian Optimization for hyperparameter tuning
  - per_gpu_batch_size: (16, 64) → 56
  - weight_decay: (0, 0.3) → 0.21
  - learning_rate: (1e-5, 5e-5) → 3.6e-5
  - warmup_steps: (0, 500) → 106
  - num_epochs: (2, 5) → 4

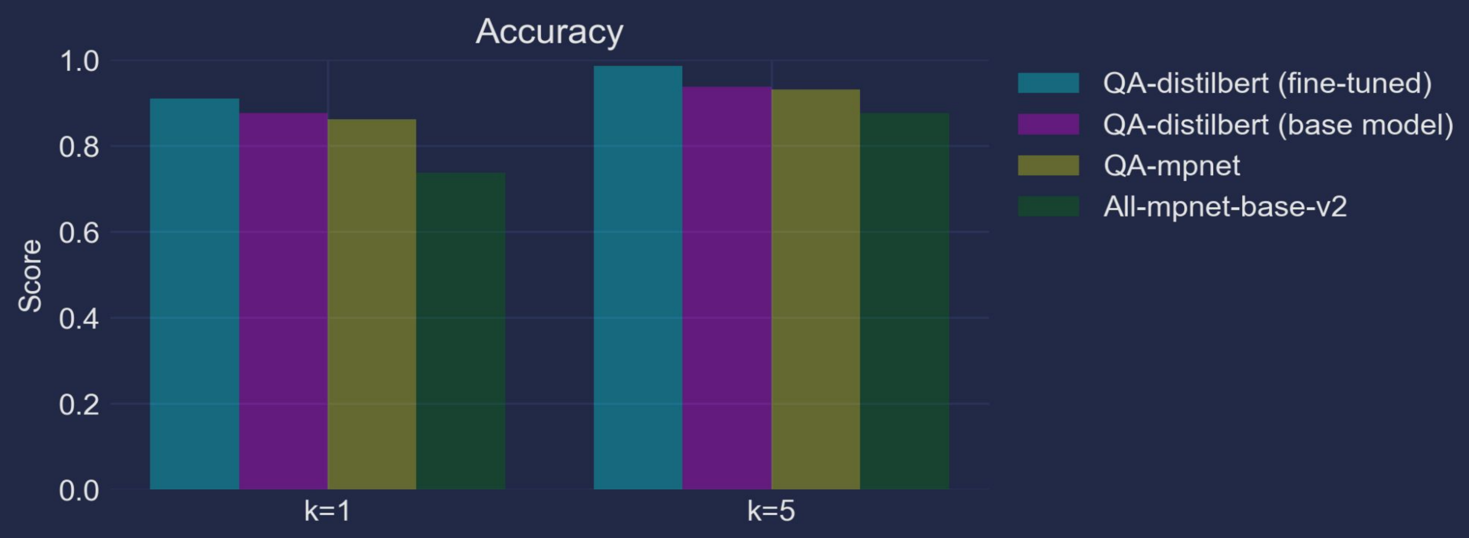
Fine-tuning (training)

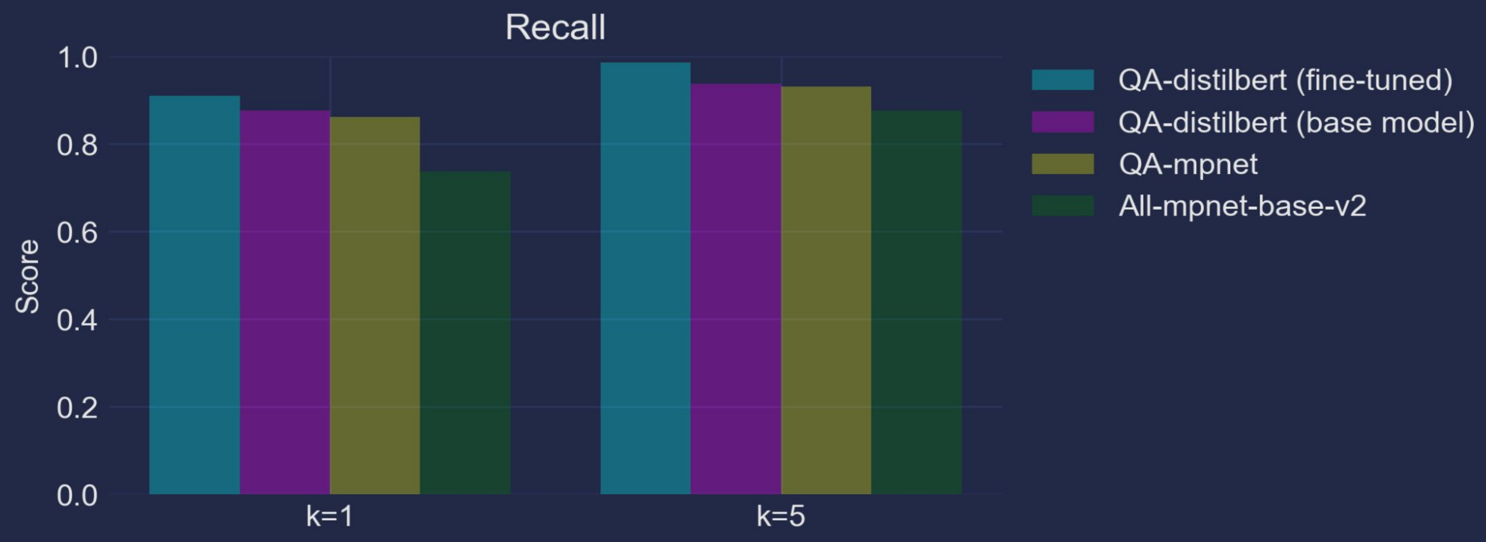
- **Loss function:** *MultipleNegativesRankingLoss*
  - Designed for training models with only positive pairs of data (e.g. query, relevant document)
  - Minimizes negative log-likelihood of softmax-normalized similarity scores

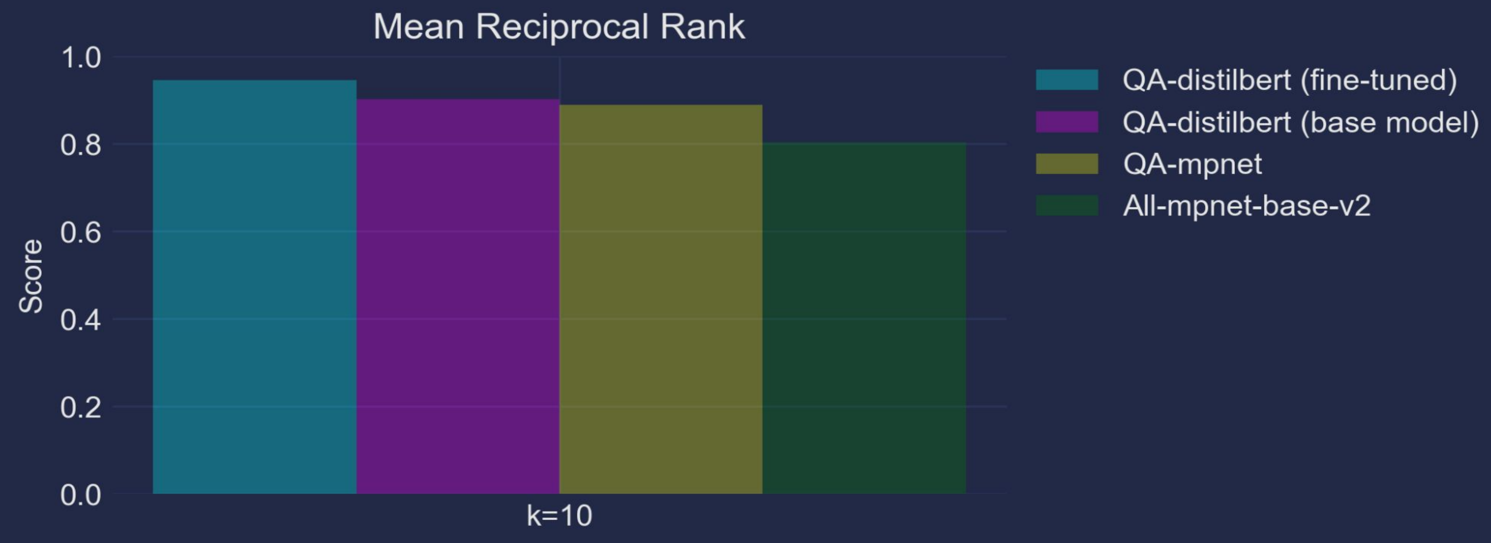
- Performance metrics collected at different top-k values (e.g., @1, @5, @10)
  - Accuracy, Recall, MRR, NDCG (Normalized Discounted Cumulative Gain)

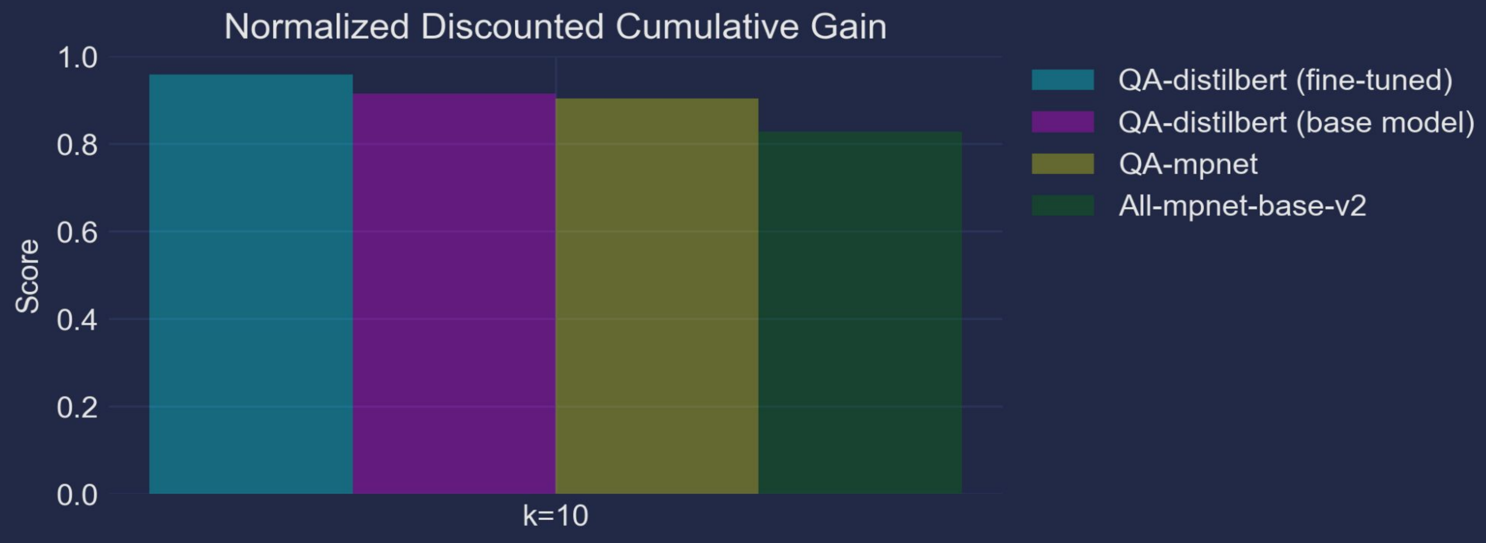
Model Evaluation and Comparison

	Accuracy@1	Accuracy@5	Precision@1	Recall@1	Recall@5	NDCG@10	MRR@10
QA-distilbert (fine-tuned)	0.9103	0.9862	0.9103	0.9103	0.9862	0.9586	0.9449
QA-distilbert (base model)	0.8759	0.9379	0.8759	0.8759	0.9379	0.9142	0.9020
QA-mpnet	0.8621	0.9310	0.8621	0.8621	0.9310	0.9027	0.8892
All-mpnet-base-v2	0.7379	0.8759	0.7379	0.7379	0.8759	0.8276	0.8028







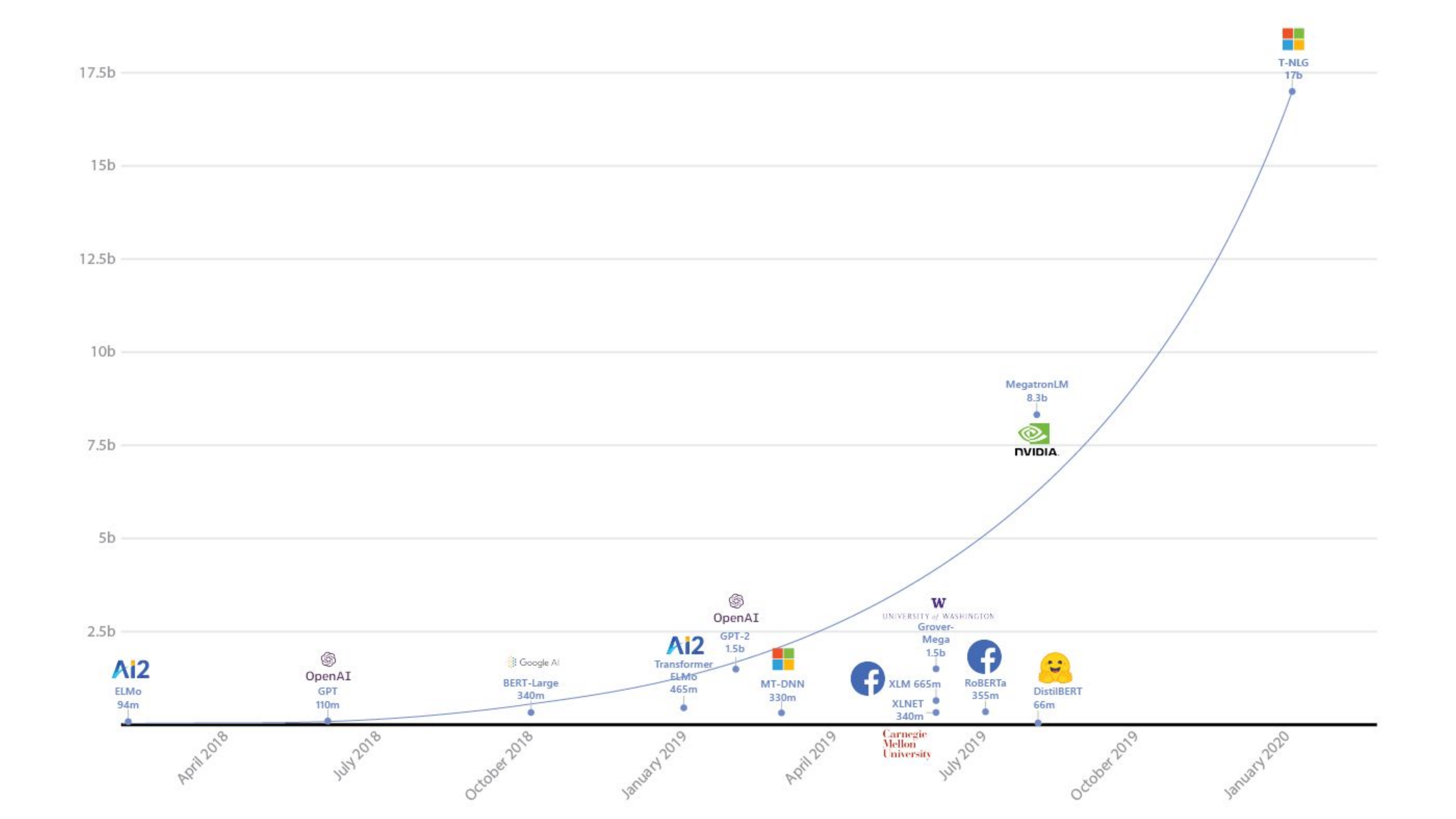


Summary

1. Create the document knowledge base
2. Generate queries for each document using LLM
3. Evaluate pre-trained embedding models
4. Bayesian Optimization
5. Fine-tuning
6. Evaluate

Concluding Remarks

- DistilBERT’s size makes it a practical choice for customer support systems
- Generated queries are relatively simplistic (required only one document to formulate an answer)
- Expand QA system to retrieve multiple relevant documents and LM to synthesize a response
- Integrate LM chains with structured database queries



ANY QUESTIONS?