PITTSBURGH, PENNSYLVANIA
ICSE 2022
INTERNATIONAL CONFERENCE ON SOFTWARE ENGINEERING

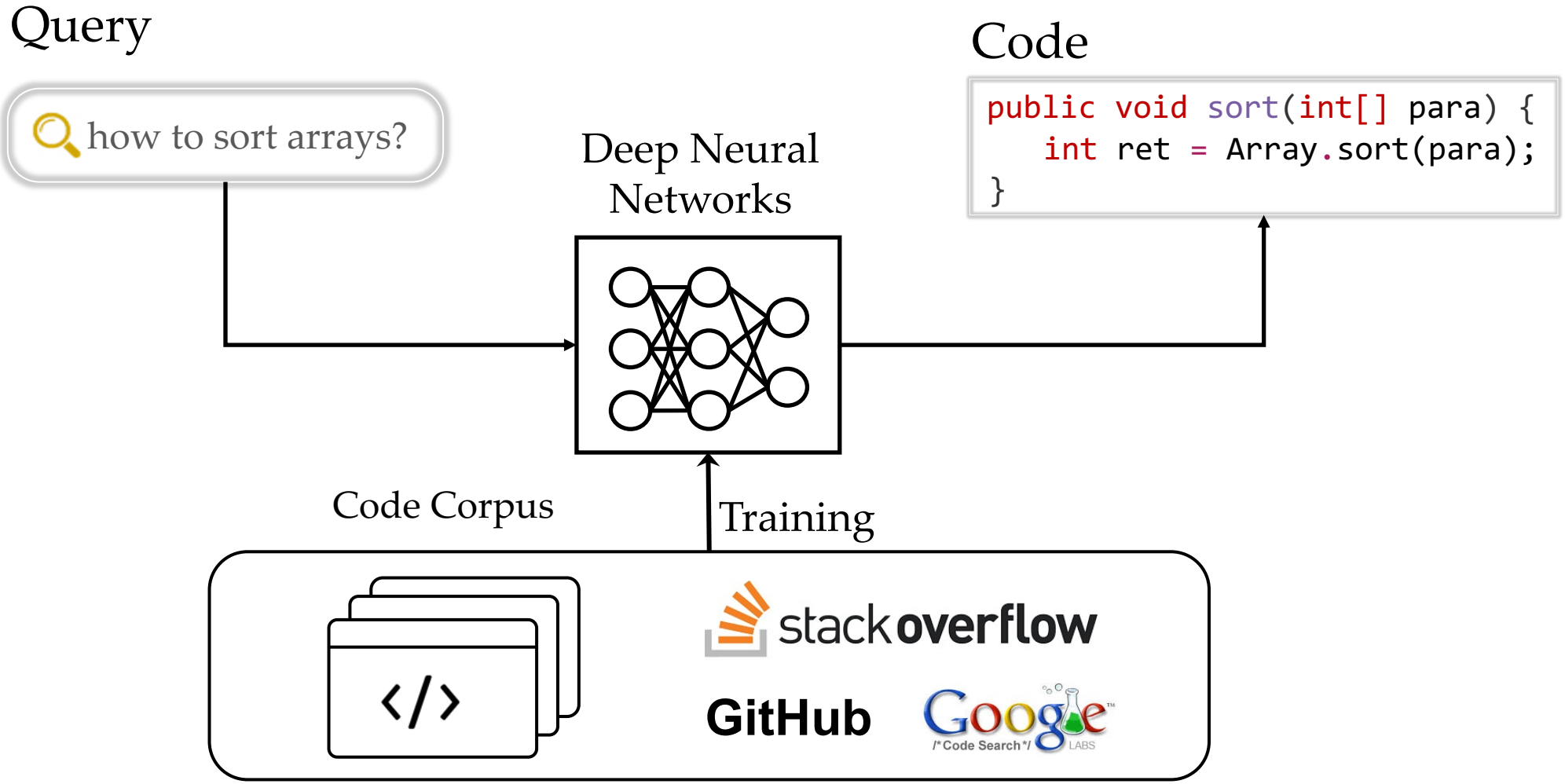
Cross-Domain Deep Code Search with Meta Learning

- Yitian Chai[1], Hongyu Zhang[2], Beijun Shen[1], Xiaodong Gu[1]

[1]School of Software, Shanghai Jiao Tong University
[2]The University of Newcastle

上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

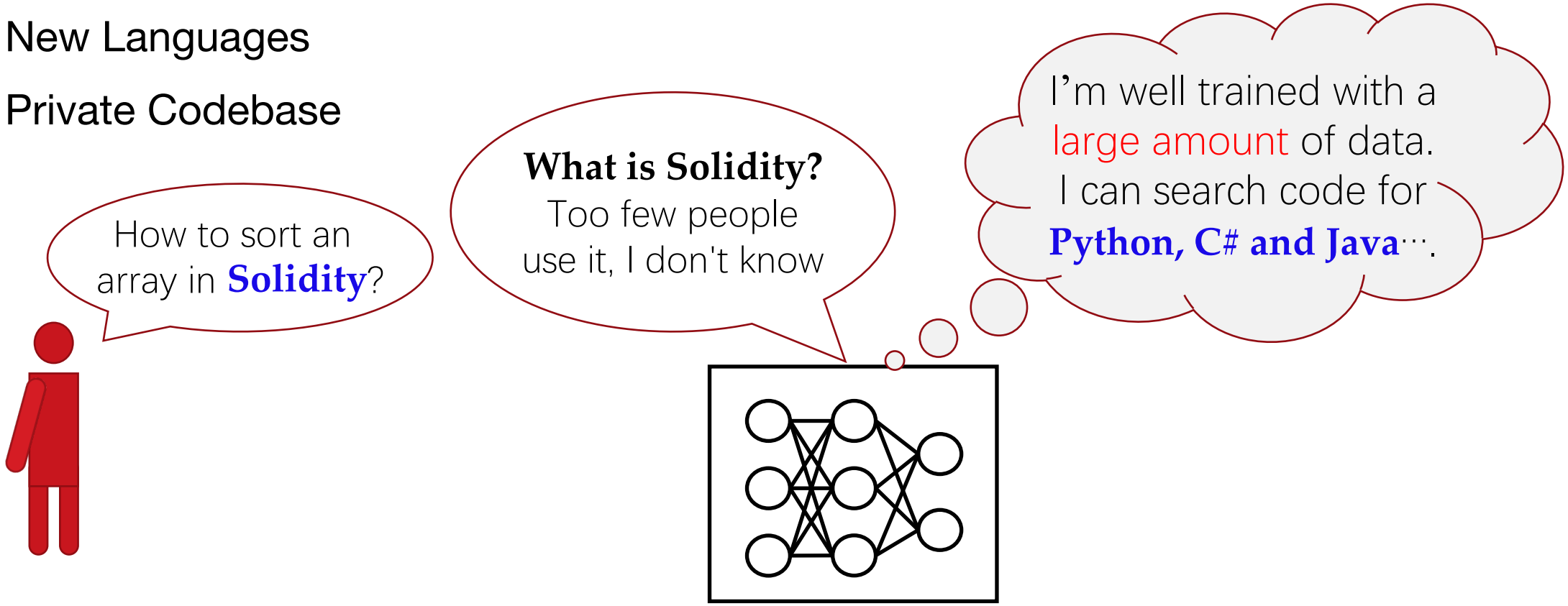
Deep Learning Based Code Search



When Deep Learning Met Uncommon Languages

Main Challenges:

- Domain-Specific Languages
- New Languages
- Private Codebase

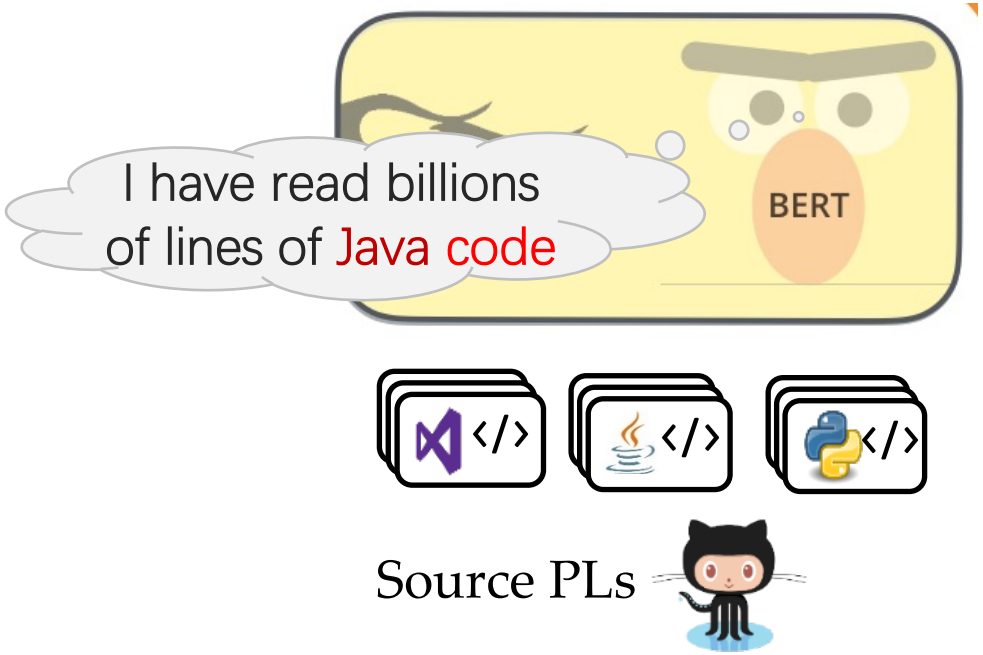


Our Idea

- Towards Few-Shot Learning

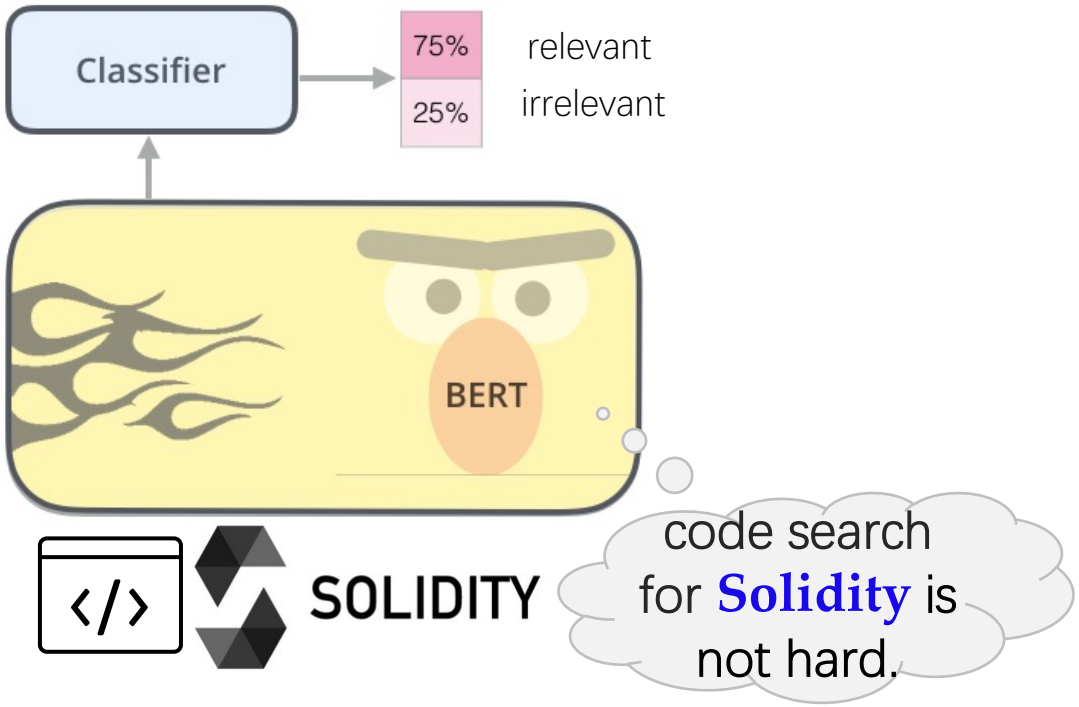
Pre-Training & Fine-Tuning ?

Unsupervised pre-training on large-scale common programming language



Phase1: Pre-Training

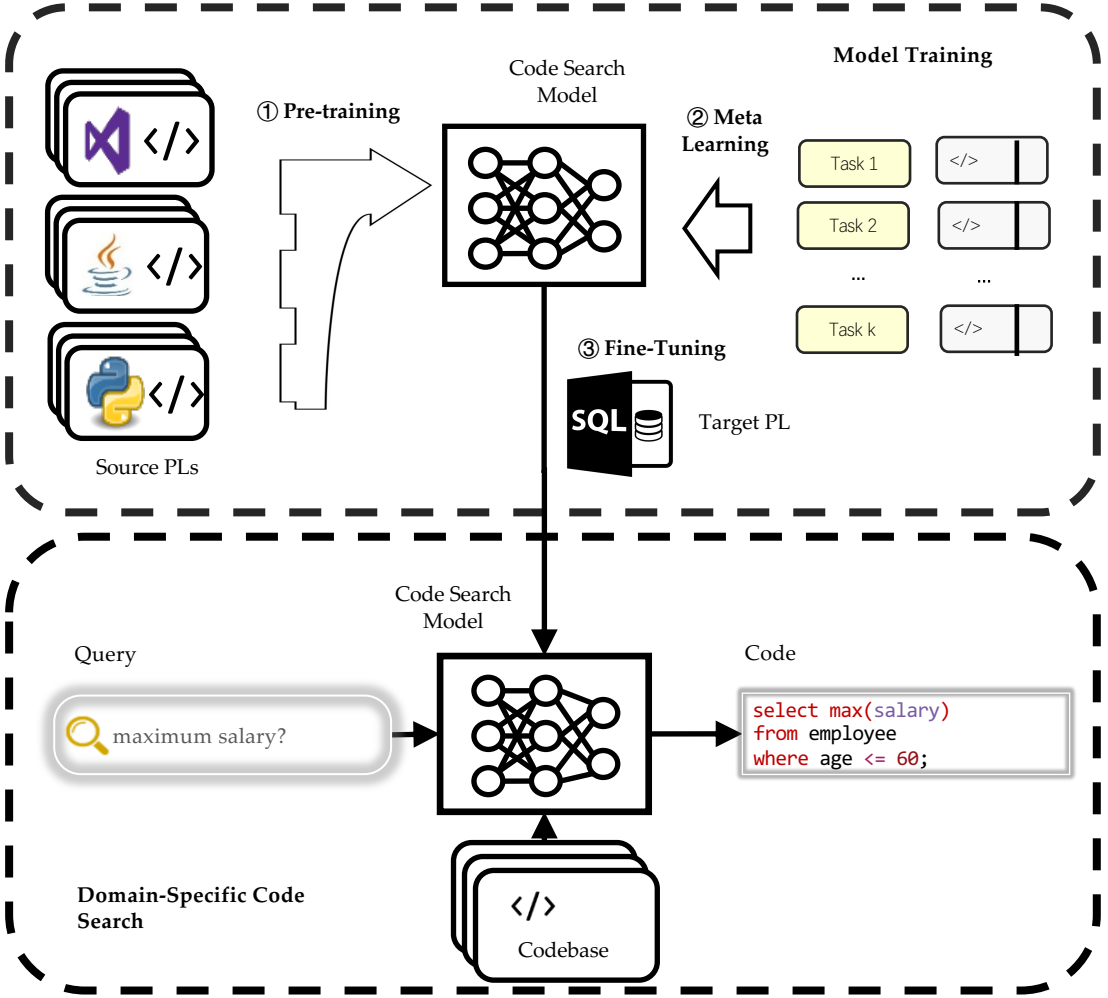
Fine-tuning on small-scale domain-specific programming language



Phase2 : Fine-Tuning

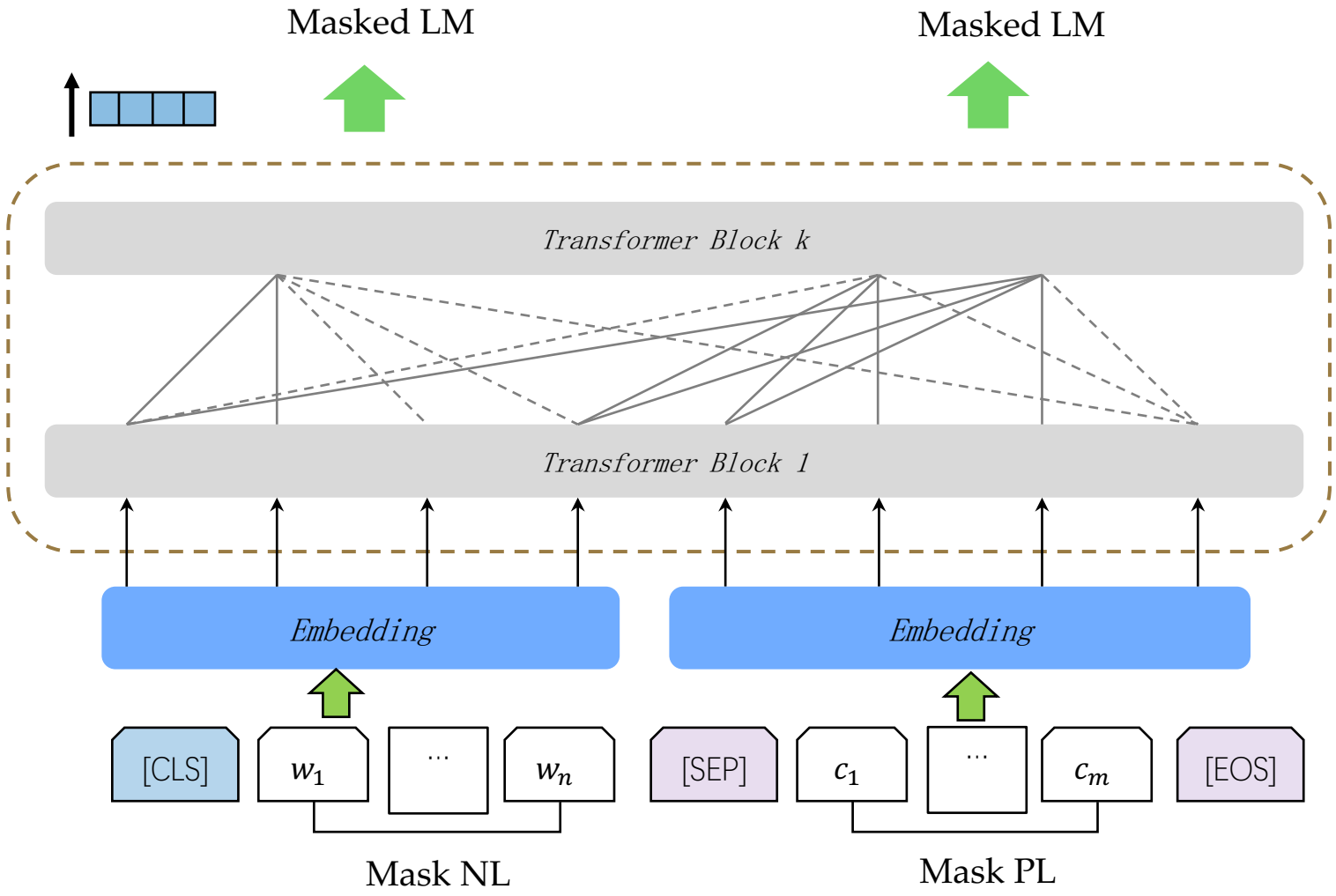
Cross-Domain Deep Code Search with Meta Learning

1. Pre-Training
2. **Meta-Learning**
3. Fine-Tuning
4. Code Search



Step 1. Pre-Training

- Masked Language Modeling (MLM)
  - Input: natural language text+code snippet
  - Task: Randomly mask 15% tokens, and let the model predict the original tokens



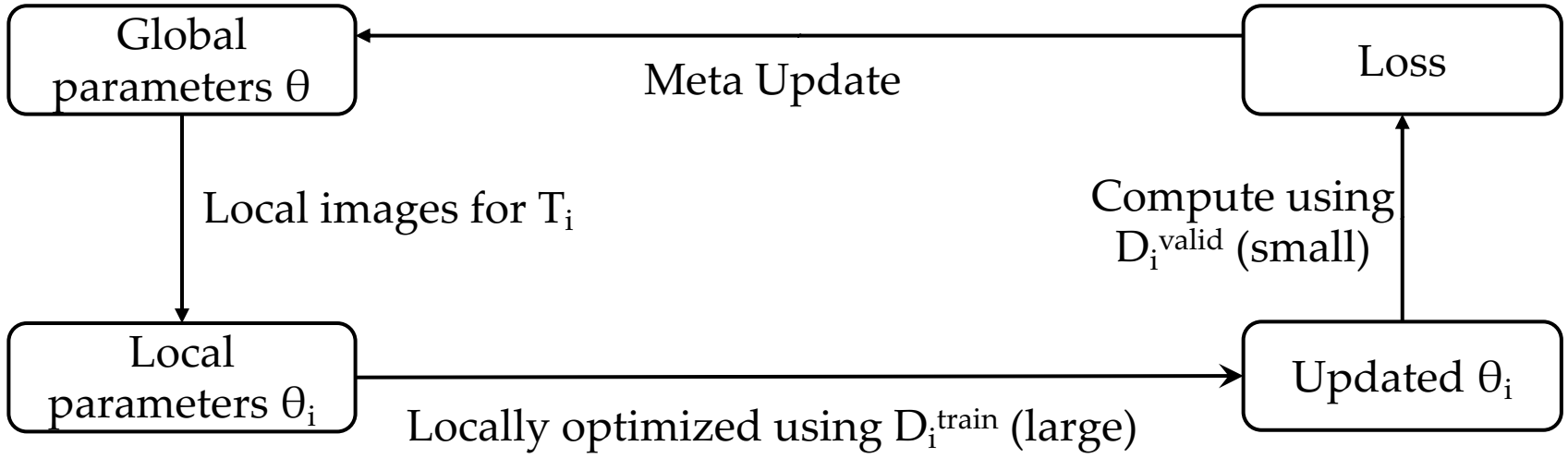
Step 2. Meta-Learning and Few-Shot Learning

Meta Learning

Also known as “Learning to learn”, a series of learning tasks are constructed and a meta learner collects the information of each learning task and adjusts the learning strategy according to the learning situation of each task.

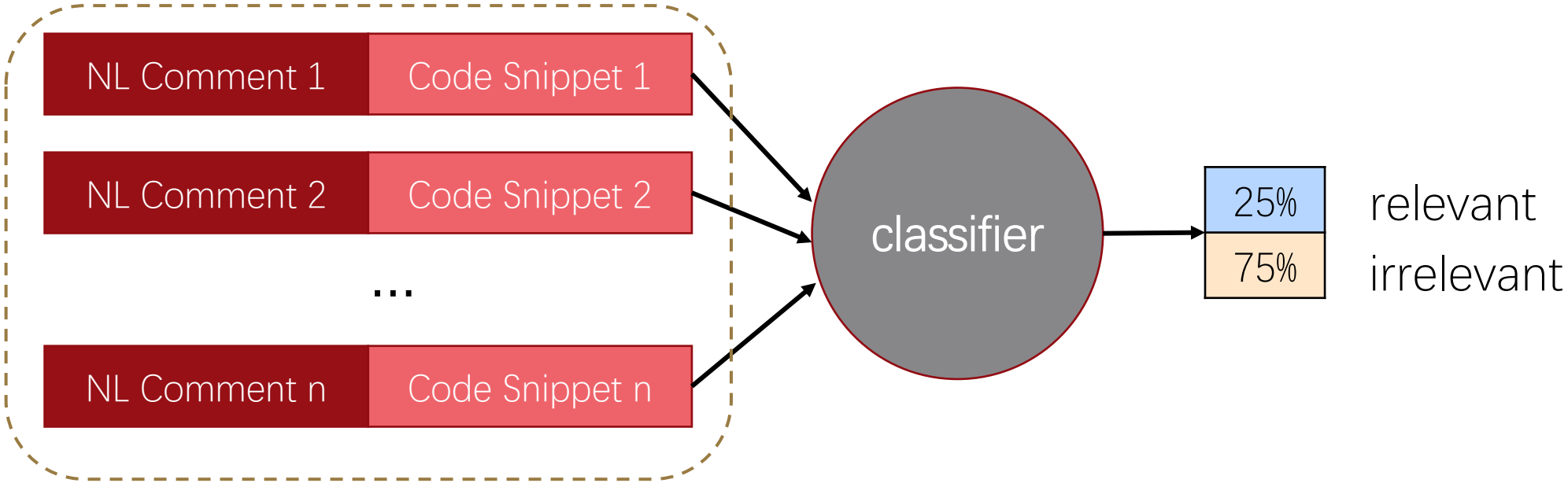
Few-Shot Meta Learning

A series of few-shot learning tasks are constructed. A meta learner collects the information of each few-shot task and adjusts the learning strategy according to the learning situation of each few-shot task.

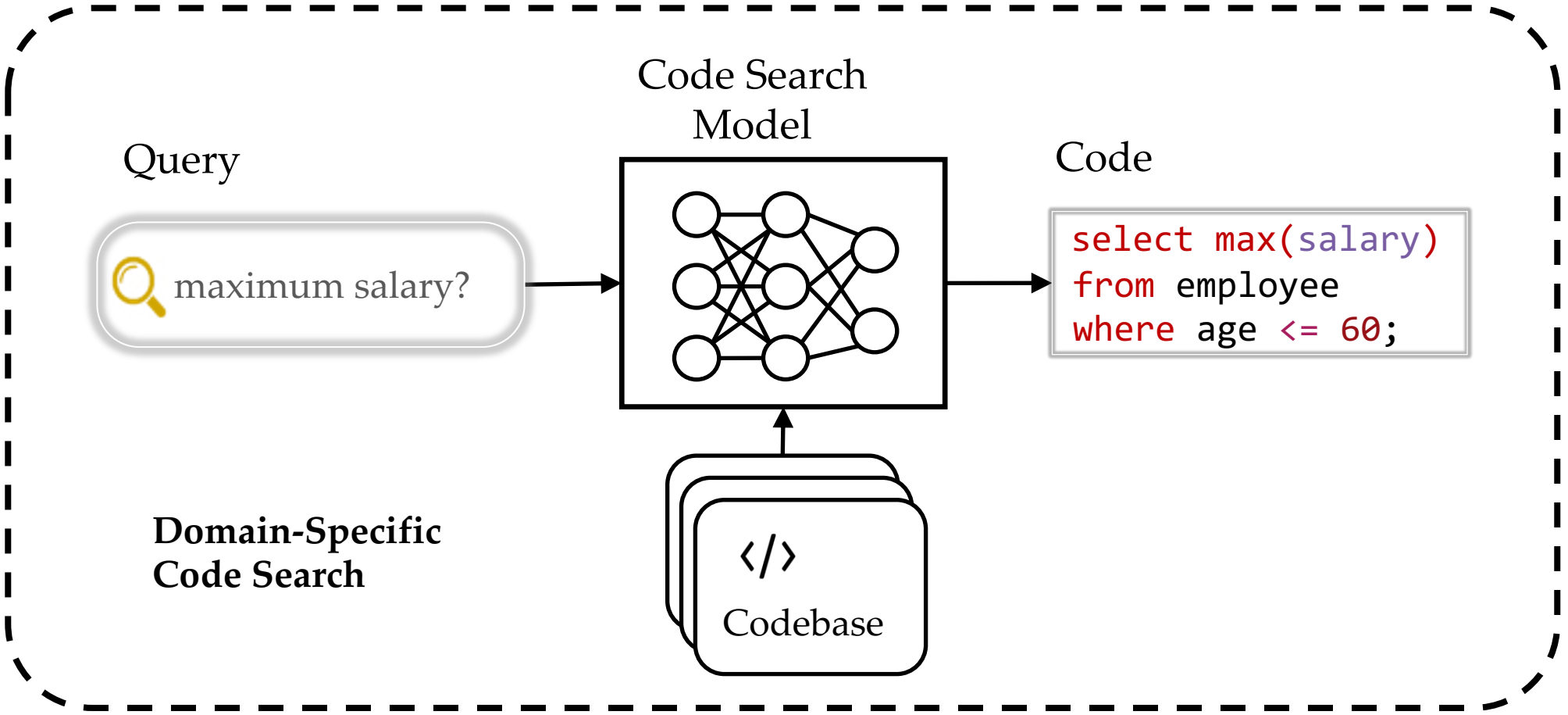


Step 3. Fine-Tuning on the Target Language

- Code Search → Binary Classification



Step 4. Code Search on the Target Language



Research Questions

1. How effective is CDCS in cross-domain code search?
2. What is the impact of data size on the performance of cross-domain code search?
3. How effective is CDCS applied to other pre-trained programming language models?
4. How do different hyperparameters affect the performance of CDCS?

Datasets

- Datasets for pre-training and meta-learning

Phase		Python	Java
pre-training	# functions	412,178	454,451
	# comments	412,178	454,451
meta learning	# functions	824,342	908,886
	# comments	824,342	908,886

- Datasets for fine-tuning

Language	Train(Fine-tune)	Valid	Test
Solidity	56,976	4,096	1,000
SQL	14,000	2,068	1,000

Metrics

- **MRR**
  - $\mathrm{MRR} = \frac{1}{N}\sum_{i=1}^{N}\frac{1}{\mathrm{Rank(i)}}$
- **Top-k accuracy**
  - measures how many answers in the first k results hit the query.

Comparison Methods

1. Code Search with Pre-training
2. Code Search based on pre-trained model with Natural Language
3. Within-domain Code Search with CodeBERT
4. Cross-Language Code Search with CodeBERT

Experimental Results

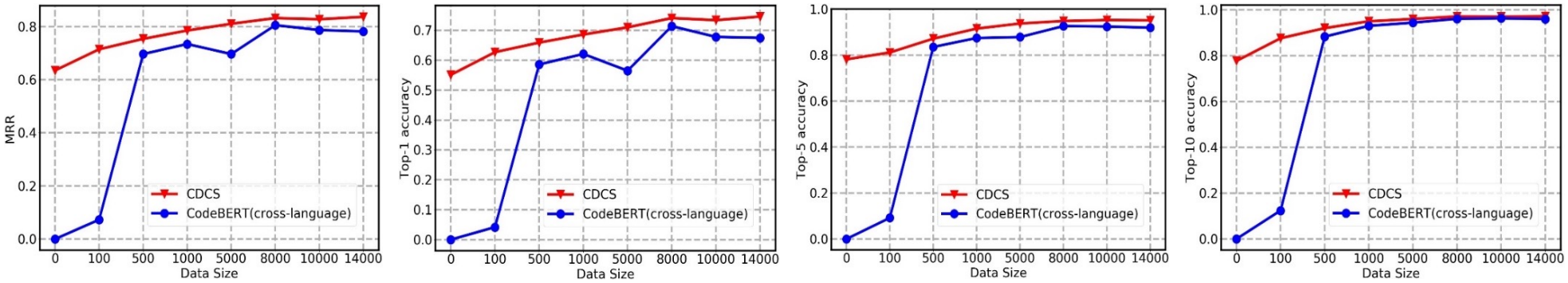
- Effectiveness in Cross-Domain Deep Code Search (RQ1)

Language	Model	Acc@1	Acc@5	Acc@10	MRR
SQL	No-Pretraining	0.002	0.010	0.022	0.0124
	CodeBERT(NL-based)	0.652	0.926	0.966	0.7690
	CodeBERT(within-domain)	0.607	0.899	0.945	0.7351
	CodeBERT(cross-language)	0.675	0.920	0.960	0.7818
	CDCS	**0.746**	**0.952**	**0.972**	**0.8366**
Solidity	No-Pretraining	0.002	0.008	0.014	0.0101
	CodeBERT(NL-based)	0.453	0.732	0.821	0.5801
	CodeBERT(within-domain)	0.515	0.798	0.857	0.6383
	CodeBERT(cross-language)	0.532	0.779	0.848	0.6436
	CDCS	**0.658**	**0.829**	**0.879**	**0.7336**

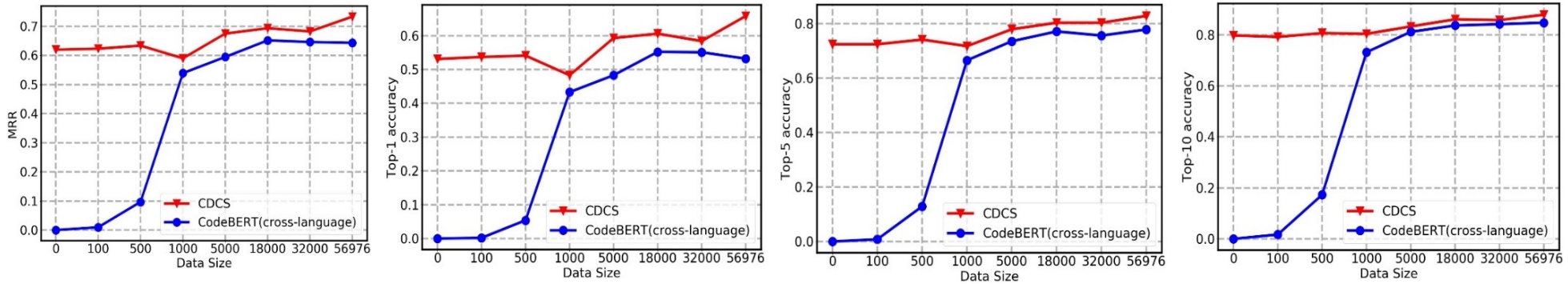
Experimental Results

- Effect of Data Size (RQ2)

SQL



Solidity



Experimental Results

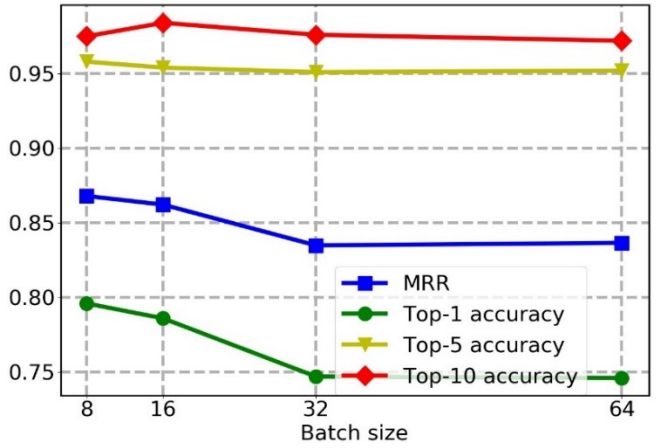
- Performance on other Pre-trained Models(RQ3)

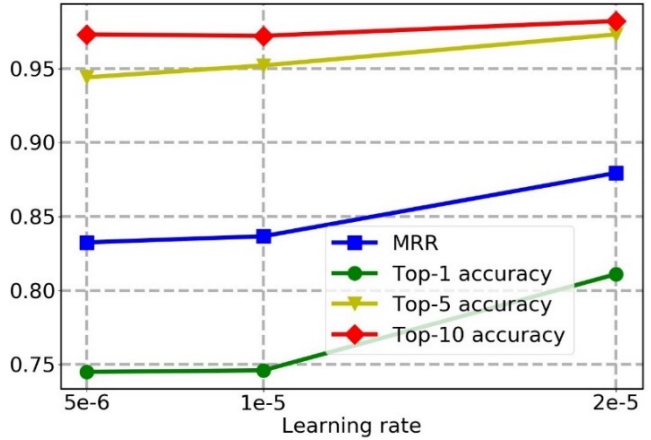
Language	Model	Acc@1	Acc@5	Acc@10	MRR
SQL	No-Pretraining	0.002	0.010	0.022	0.0124
	GPT2(NL-based)	0.481	0.808	0.889	0.6204
	GPT2(within-domain)	0.470	0.785	0.877	0.6088
	GPT2(cross-language)	0.447	0.767	0.875	0.5899
	$CDCS_{GPT-2}$	0.511	0.823	0.905	0.6464
Solidity	No-Pretraining	0.002	0.008	0.014	0.0101
	GPT2(NL-based)	0.484	0.751	0.830	0.6079
	GPT2(within-domain)	0.487	0.772	0.848	0.6073
	GPT2(cross-language)	0.481	0.760	0.827	0.6057
	$CDCS_{GPT-2}$	0.561	0.781	0.846	0.6607

Experimental Results

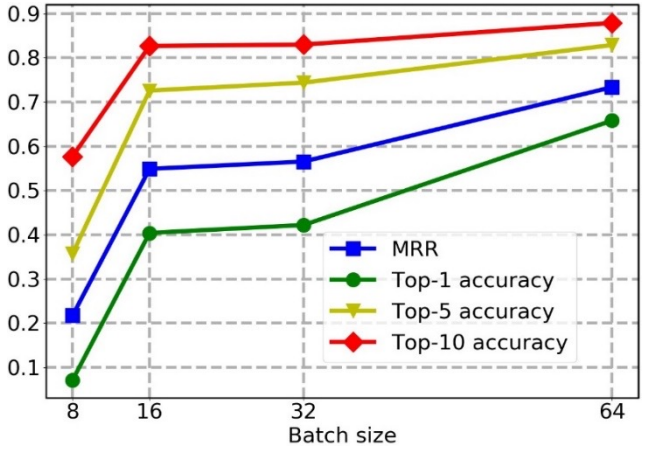
- Impact of Different Hyperparameters (RQ4)

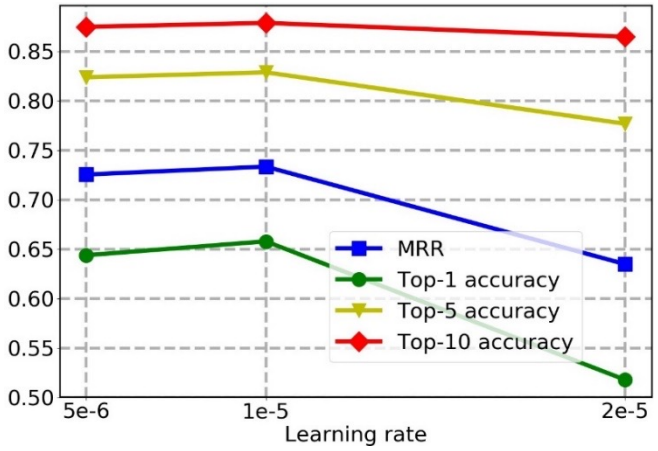
SQL





Solidity





Conclusion

CDCS - cross-domain code search approach.

- extends pre-trained models with meta learning
- achieves significant improvement in domain-specific code search.

Future Work

- more languages
- other software engineering tasks.

Thank You!

Q&A