A APPENDIX

This section includes supplementary information for our survey and it consists of 14 pages.

A.1 Paper Collection and Review Schema

This section contains a figure for the cumulative number of papers published ranging from 2005 to 2020 and a table for the publication venues of code search studies.

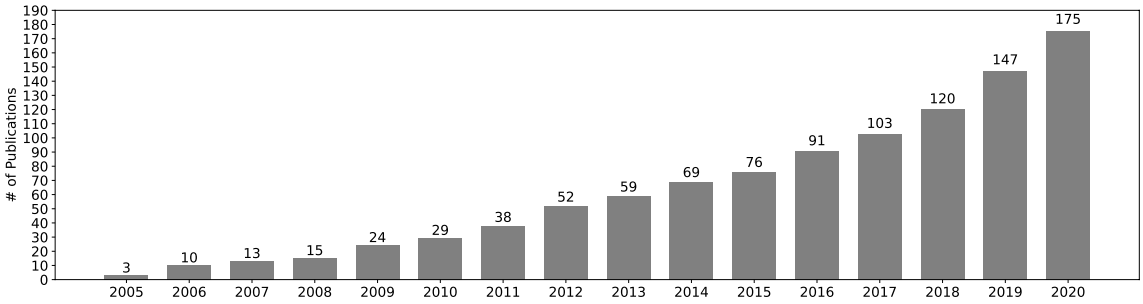

Fig. 7. Cumulative number of papers published ranged from 2005 to 2020.

Table 1. Publication venues of code search studies.

Category	Abbreviation	Full Name	Count
Conference	ICSE	International Conference on Software Engineering	20
	ASE	Automated Software Engineering	13
	MSR	International Conference on Mining Software Repositories	8
	SUITE	Workshop on Search-Driven Development-Users, Infrastructure, Tools and Evaluation	5
	PLDI	ACM SIGPLAN Conference on Programming Language Design and Implementation	4
	OOPSLA	Object-Oriented Programming, Systems, Languages & Applications	4
	RSSE	International Workshop on Recommendation Systems for Software Engineering	4
	SANER	IEEE International Conference on Software Analysis, Evolution and Reengineering	3
	COMPSAC	Annual Computer Software and Applications Conference	3
	CSMR-WCRE	IEEE Conference on Software Maintenance, Reengineering, and Reverse Engineering	3
	ESEC/FSE	European Software Engineering Conference and Symposium on the Foundations of Software Engineering	2
	SAC	ACM Symposium on Applied Computing	2
	WWW	The World Wide Web Conference	2
	SBES	Brazilian Symposium on Software Engineering	2
	SCAM	International Working Conference on Source Code Analysis & Manipulation	2
	VL/HCC	Visual Languages and Human-Centric Computing	2
	ISSTA	International Symposium on Software Testing and Analysis	1
	MAPL	ACM SIGPLAN International Workshop on Machine Learning and Programming Languages	1
	FASE	International Conference on Fundamental Approaches to Software Engineering	1
	RecSys	ACM Conference on Recommender Systems	1
	ACIIDS	Intelligent Information and Database Systems	1
	UIST	ACM Symposium on User Interface Software and Technology	1
	WEH	International Workshop on Exception Handling	1
	SBCARS	Brazilian Symposium on Software Components, Architectures, and Reuse	1
	ACL	Annual Meeting of the Association for Computational Linguistics	1
	ICoICT	International Conference on Information and Communication Technology	1
	WSDM	ACM International Conference on Web Search and Data Mining	1
	ICCIT	International Conference on Computer and Information Technology	1
	CCS	ACM SIGSAC Conference on Computer and Communications Security	1
	RCoSE	International Workshop on Rapid Continuous Software Engineering	1
	Programming	International Conference on the Art, Science and Engineering of Programming	1
	Internetware	Asia-Pacific Symposium on Internetware	1
	MOBILESoft	International Conference on Mobile Software Engineering and Systems	1
	IWSC	International Workshop on Software Clones	1
	SERVICES	IEEE World Congress on Services	1
	ASC	ACM Southeast Conference	1
	ICSEW	International Conference on Software Engineering Workshops	1
	IJCNN	International Joint Conference on Neural Networks	1
	CIRCLE	CEUR Workshop	1
		Subtotal (Conference)	102
Journal	TSE	Transactions on Software Engineering	3
	EMSE	Empirical Software Engineering	3
	JSS	Journal of Systems and Software	3
	IEEE Access	IEEE Access	3
	SPE	Practice and Experience	3
	TOSEM	Transactions on Software Engineering and Methodology	2
	ASE_Journal	Automated Software Engineering Journal	2
	IST	Information and Software Technology	2
	TSC	IEEE Transactions on Services Computing	2
	SCIS	Science China Information Sciences	2
	JIFS	Applications in Engineering and Technology	1
	ISF	Information Systems Frontiers	1
	JPCS	Conference Series	1
	PACMPL	ACM on Programming Languages	1
	IEEE Software	IEEE Software	1
	KBS	Knowledge-Based Systems	1
	KIES	International Journal of Knowledge-based and Intelligent Engineering Systems	1
	WUJNS	Wuhan University Journal of Natural Sciences	1
	JIT	Journal of Internet Technology	1
	SEKE	International Journal of Software Engineering and Knowledge Engineering	1
		Subtotal (Journal)	35
		Total	137

A.2 Taxonomy of Code Search Techniques

This section presents detailed information reflecting the proposed taxonomy. Each table classifies all the investigated techniques based on their characteristics.

Table 2. Dissection of code search techniques based on static information.

Category	Approach	Output		Dataset					Indexing				Input							Retrieval					Presentation			Languages
		General Code	API Usage	Specific Open Source Projects	Super Repositories	Developer Q&A	Language/API Documentation	Others	Inverted	Database (B+ Tree)	Graph Index	File Prefix	Natural Language	Code Fragment	Input/Ouput	Software Specification	Query Language	Binary	Class/Interface Type	Textual Similarity	Graph Similarity	Solver	Type Links	Embedding Vector Similarity	Search Engine	Idea	IDE Extension	
Keyword-based	Jsearch [245]	✓									✓			✓						✓							✓	Java
	CoCaBu [247]	✓			✓	✓			✓				✓							✓					✓			Java
	Murakami et al. [189]	✓		✓						✓				✓						✓						✓		Java
	McMillan et al. [180]		✓	✓					✓				✓							✓					✓			Java
	Exemplar [75, 76, 177]	✓			✓				✓				✓							✓					✓			Java
	Example Overflow [305]	✓				✓			✓				✓							✓					✓			Java
	Selene [188, 266]	✓		✓					✓					✓						✓					✓		✓	Java
	SoCeR [112]	✓		✓					✓				✓											✓	✓			Python
Structure-based	Aroma [163]	✓			✓					✓				✓							✓			✓	✓			Java, Javascript, Python
	Prospector [168]	✓					✓												✓		✓						✓	Java
	Portfolio [44, 178, 181]	✓		✓					✓				✓							✓	✓				✓			C, C++, Java
	XSnippet [231]	✓					✓			✓									✓		✓						✓	Java
	PARSEWeb [268]	✓				✓	✓					✓							✓		✓						✓	Java
	Chan et al. [35]		✓	✓							✓		✓							✓	✓				✓			Java
	RACS [148]		✓	✓		✓	✓			✓			✓							✓	✓				✓			Javascript
	YOGO [209]	✓				✓				✓				✓							✓				✓			Python, Java
	Akhin et al. [3]	✓		✓							✓			✓							✓					✓		
	Coogle [230]	✓		✓										✓							✓						✓	Java
	Mendel [160]	✓		✓										✓							✓				✓			
	Hsu and Lin. [98]	✓			✓				✓				✓							✓					✓			Java
	Sourcerer [10]	✓			✓				✓				✓							✓					✓			Java
	Murakami et al. [189]	✓		✓						✓				✓						✓						✓		Java
	Barbosa et al. [16, 17]	✓			✓					✓				✓						✓					✓			Java
	AUSearch [8]		✓		✓												✓						✓		✓			Java
	MAPO [290]	✓	✓										✓							✓					✓			Java
	SUSHI [195]	✓						✓						✓				✓		✓				✓	✓			Android
	PropER-Doc [170]		✓	✓												✓							✓				✓	Java
	PRIME [183]	✓	✓	✓									✓							✓					✓			Java
	LibFinder [203]	✓			✓									✓										✓			✓	Java
	SWIM [210]	✓	✓		✓								✓							✓					✓			C#
	APIREC [191]	✓	✓											✓						✓	✓						✓	Java
	Lee et al. [137]		✓		✓								✓							✓							✓	Java
Interface-driven	Strathcona [93–95]									✓				✓					✓								✓	
	Lemos et al. [141]	✓			✓					✓			✓						✓	✓					✓			Java
Semantic-based	ANNE [273]	✓				✓							✓							✓					✓		✓	Java
	CodeMatcher [156]	✓			✓				✓				✓							✓					✓			
	Hill et al. [90]	✓		✓									✓							✓					✓			Java
	JECO [7]	✓				✓							✓							✓					✓			Java
	Vinayakarao [272]	✓				✓				✓				✓						✓						✓		Java
	McMillan et al. [179]	✓			✓					✓			✓							✓					✓			Java, C#
	Lancer [309]	✓			✓					✓				✓						✓	✓						✓	Java
	Test Recommender [206]	✓		✓						✓				✓						✓							✓	Java
Constraint-based	Satsy [254–256]	✓		✓					✓					✓	✓							✓			✓	✓		Java, C
	Extended Satsy [257]	✓		✓					✓		✓				✓	✓					✓	✓			✓			Java
	Quebio [119]	✓			✓									✓	✓						✓	✓			✓			Java
	Extended Quebio [42]	✓			✓	✓							✓		✓					✓		✓			✓			Java
Clone-based	Keivanloo et al. [124]	✓			✓				✓											✓					✓			
	CodeNuance [159]	✓			✓				✓											✓								
	Rahman and Roy [214]	✓			✓				✓					✓							✓						✓	Java
	MUSE [185]		✓	✓																	✓						✓	Java

Table 3. Dissection of code search techniques based on dynamic information.

Category	Approach	Output		Dataset		Index			Input						Retrieval				Presentation			Language
		General Code	*Test Case/Test Code*	*Specific Open Source Projects*	*Super Repositories*	*Database (B+ Tree)*	*Graph Index*	*File Prefix*	*Natural Language*	*Code Fragment*	*Query Language*	*Test Case*	*Class/Interface Type*	*Software Specification*	*Textual Similarity*	*Graph Similarity*	*Test Case/Tested Input*	*Linear Programming*	*Search Engine*	*Idea*	*IDE Extension*	
Test-driven	CodeGenie [134–136, 138]	✓				✓				✓						✓					✓	Java
	Lemos et al. [140]	✓			✓	✓				✓					✓						✓	Java
	Code Conjurer [109, 115]		✓			✓				✓					✓						✓	Java
	EQMINER [118]		✓	✓				✓		✓						✓	✓		✓			C
	S6 [27, 28, 218–221]					✓			✓					✓		✓			✓			Java
	Marcus and Atkinson [126]	✓			✓	✓				✓							✓			✓		
	HUNTER [281]	✓			✓	✓					✓	✓						✓	✓			Java
Execution-based	CodeHint [69]	✓		✓		✓								✓	✓						✓	Java
	DyCLINK [259]	✓		✓			✓			✓						✓					✓	MYSQL

Table 4. Dissection of code search techniques based on query reformulation.

Category	Approach	Output		Database						Index				Input			Retrieval				Presentation			Language
		General Code	*API Usage*	*Specific Open Source Projects*	*Super Repositories*	*Developer Q&A or Tutorial*	*Language/API Documentation*	*Code Clone*	*Challenge/Competition*	*Inverted*	*Database (B+ Tree)*	*ID-based*	*Positional*	*Natural Language*	*Code Fragment*	*Query Language*	*Textual Similarity*	*Matrix Computation*	*Graph Similarity*	*Embedding Vector Similarity*	*Search Engine*	*Idea*	*IDE Extension*	
Feedback-driven	Mica [258]		✓	✓			✓			✓				✓			✓				✓			Java
	SAS [11]		✓		✓									✓			✓				✓			Java
	Conquer [225]	✓		✓										✓			✓						✓	Java
	Extended Conquer [91]	✓		✓										✓			✓						✓	Java
	Wang et al. [278]	✓		✓										✓			✓				✓			C,C++
	CodeExchange [174]	✓			✓					✓				✓			✓				✓			Java
	CodeLikeThis [173]	✓			✓					✓				✓			✓				✓			Java
	INQRES [161]	✓		✓										✓			✓				✓			Java
	Cosoch [147]	✓				✓								✓			✓				✓			Java
	Contextual Search [89]	✓			✓									✓			✓						✓	Java
	Refoqus [83]	✓		✓						✓				✓			✓						✓	Java, C++
	ALICE [249]	✓		✓										✓		✓				✓			✓	Java
	SNIPR [234]													✓		✓	✓			✓		✓		
	DeepAPIRec [38]		✓		✓										✓					✓	✓			Java
AQR *dagger*	QECK [198]	✓			✓	✓				✓				✓			✓				✓			Android
	Yang et al. [296]	✓		✓										✓			✓				✓			Java
	Durão et al. [59]	✓		✓								✓		✓			✓						✓	Java
	NLP2CODE [33]	✓	✓			✓								✓			✓						✓	Java
	SCP [248]	✓		✓									✓	✓			✓				✓			Java, C, C++
	QExpandator [236]	✓		✓										✓				✓			✓			Java
	FWSMF [237]	✓		✓						✓				✓			✓				✓			Java
	CodeX [235]	✓		✓						✓				✓			✓					✓		N/A
	SnippetGen [103, 288, 298]	✓			✓					✓				✓			✓				✓			C#
	CodeGenie 2.0 [139]	✓			✓					✓				✓			✓						✓	Java
	CoCaBu [247]	✓			✓	✓				✓				✓			✓				✓			Java
	FaCoY [130]	✓			✓	✓		✓	✓	✓					✓		✓				✓			Java
	CodeHow [166]	✓			✓					✓				✓			✓						✓	C#
	RACK [215, 216]	✓			✓	✓	✓							✓			✓						✓	Java
	NLP2API [212]	✓				✓				✓				✓						✓	✓			Java
	NQE [157]	✓			✓	✓				✓				✓						✓	✓			Android
	SENSORY [1]	✓			✓							✓		✓			✓				✓			Java
	QESR [120]	✓			✓		✓			✓				✓			✓				✓			Android, Java
	QECC [107]	✓			✓					✓				✓			✓				✓		✓	Java
	GKSR [105]	✓			✓					✓				✓			✓				✓			C#, Java, Android
	QESC [106, 311]	✓			✓		✓			✓				✓			✓				✓			Java
QL †	AutoQuery [276]	✓		✓							✓				✓				✓		✓			C, C++
	SnipMatch [286]	✓		✓										✓			✓						✓	Java

†: AQR and QL are short terms for Automatic Query Reformulation and Query Language based, respectively.

Table 5. Dissection of learning-based code search techniques.

Category	Approach	Output		Dataset							Index		Input		Retrieval				Presentation			Language
		General Code	*API Usage*	*Specific Open Source Projects*	*Super Repositories*	*Developer Q&A*	*Language/API Documentation*	*Code Clone*	*Challenge/Competition*	*Existing Benchmark*	*Inverted*	*Graph Index*	*Natural Language*	*Code Fragment*	*Textual Similarity*	*Graph Similarity*	*Matrix Computation*	*Embedding Vector Similarity*	*Search Engine*	*Idea*	*IDE Extension*	
Machine Learning	MMMF [285]	✓		✓										✓			✓		✓			Java
	Surisetty [262]	✓		✓							✓		✓					✓		✓		
	ROSF [117]	✓		✓							✓		✓		✓			✓	✓			Java
	Source Forager [122]	✓			✓							✓		✓				✓			✓	C/C++
	Zou et al. [312]	✓				✓	✓					✓	✓					✓	✓			Java
	CodeKernel [79]		✓	✓			✓					✓		✓				✓	✓			Java
	CODEC [187]	✓			✓									✓	✓	✓		✓	✓			Java
	ExAssist [194, 196]	✓		✓										✓	✓				✓		✓	Java
	CodeMF [100]	✓				✓							✓		✓				✓			C#, SQL
Neural Network	Nguyen et al. [197]		✓	✓			✓						✓		✓			✓	✓			Java
	CODEnn [78]	✓			✓								✓					✓	✓			Java
	MP-CAT [84]	✓				✓							✓					✓	✓			Python
	CSDA [223]	✓			✓								✓					✓	✓			Java
	CARLCS-CNN [240]	✓			✓								✓					✓	✓			Java
	BVAE [41]	✓				✓							✓					✓	✓			C#, SQL
	SCOR [2]	✓			✓						✓		✓					✓	✓			Java
	SLAMPA [310]	✓						✓						✓				✓	✓			Java
	SCS [110]	✓		✓									✓					✓	✓			Python
	NCS [228]	✓			✓	✓					✓		✓					✓	✓			Android
	UNIF [32]	✓			✓	✓					✓		✓					✓	✓			Android
	Fujiwara et al. [66]	✓						✓						✓				✓	✓			Java
	MMAN [274]	✓			✓								✓					✓	✓			C
	AdaCS [151]	✓			✓								✓					✓	✓			Java
	CoaCor [299]	✓				✓							✓					✓	✓			Python, C#
	CODE-NN [113]	✓				✓							✓		✓				✓			C#, SQL
	Ye et al. [301]	✓				✓							✓					✓	✓			Python, SQL
	TransS^3 [279]	✓			✓								✓					✓	✓			Python
	Yin et al. [303]	✓				✓							✓					✓	✓			Python, SQL
	CDRL [102]	✓			✓								✓					✓	✓			Java
	Schumacher et al. [238]	✓			✓								✓					✓	✓			Python
	HECS [143]	✓				✓							✓					✓	✓			Python, C#
	MSR [57]	✓		✓									✓		✓			✓	✓			Java
	PSCS [261]	✓							✓				✓					✓	✓			Python, Javascript, Java
	Heyman and Cutsem [87]	✓				✓							✓					✓	✓			Python
	COIL [146]	✓			✓					✓			✓					✓	✓			Java
	CoNCRA [51]	✓				✓							✓					✓	✓			Python, SQL
	COSEA [275]	✓				✓							✓					✓	✓			Python, SQL
	DGMS [152]	✓			✓	✓			✓	✓			✓					✓	✓			Java, Python
	APIRec-CST [39]		✓		✓		✓						✓						✓			Java
	Zhao et al. [308]	✓				✓							✓					✓	✓			Python, SQL
	CRaDLe [77]	✓							✓				✓					✓	✓			Python
	NJACS [101]	✓				✓							✓					✓	✓			C#, SQL, Java, Python

Table 6. Dissection of binary code search techniques.

Approach	Output	Dataset			Index		Input	Retrieval				Presentation	Language
	Binary Code	Specific Open Source Projects	Super Repositories	Others	Inverted	Graph Index	Binary	Textual Similarity	Graph Similarity	Execution Trace	Embedding Vector Similarity	Search Engine	
Tracelets [48]	✓		✓		✓		✓		✓	✓		✓	Binary (x86)
Rendezvous [127]	✓			✓	✓	✓	✓	✓		✓		✓	C, C++
BINGO [36]	✓			✓			✓		✓	✓		✓	Binary C
BINGO-E [294]	✓			✓			✓		✓	✓		✓	Binary C
Gemini [293]	✓	✓				✓	✓				✓	✓	Binary C

Table 7. Dissection of code search for graphical user interfaces.

Approach	Input	Dataset		Index			Input			Retrieval		Presentation		Language
	Sketches/GUI	*Specific Open Source Projects*	*Super Repositories*	*Inverted*	*Database (B+ Tree)*	*Graph Index*	*Sketch File*	*Natural Language*	*Code Fragment*	*Textual Similarity*	*Graph Similarity*	*Search Engine*	*IDE Extension*	
GUIFetch [21]	✓		✓		✓		✓	✓		✓		✓		Java GUI
SUSIE [222]	✓		✓					✓	✓	✓		✓		Java GUI
Xie et al. [291]	✓	✓		✓		✓	✓			✓	✓		✓	Java GUI

A.3 Evaluation

This section demonstrates various evaluation methods and metrics used in the field of code search per each approach with tables.

Table 8. Evaluation methods used in code search techniques.

Evaluation Method	Techniques
Manual assessment	Prospector [168], Strathcona [93–95], Jsearch [245], XSnippet [231], Coogle [230], PARSEWeb [268], Contextual Search [89], McMillan et al. [180], Wang et al. [280], Selene [188, 266], PropER-Doc [170], Exemplar [75, 76, 177], Example Overflow [305], Mentor [167], Barbosa et al. [16, 17], Chan et al. [35], Yang et al. [296], PRIME [183], SCP [248], CodeHint [69], CodeGenie 2.0 [139], Tracelets [48], Keivanloo et al. [124], JECO [7], Vinayakarao [272], RACS [148], CODE-NN [113], SWIM [210], BINGO [36], QualBoa [55], FWSMF [237], Source Forager [122], LibFinder [203], Gemini [293], CoCaBu [247], FaCoY [130], SLAMPA [310], Quebio [119], GUIFetch [21], CodeNuance [159], ALICE [249], ExAssist [194, 196], BINGO-E [294], Xie et al. [291], Huang et al. [108], SoCeR [112], YOGO [209], CodeMatcher [156], CODEC [187], Extended Quebio [42], AUSearch [8]
Systematic assessment	Strathcona [93–95], XSnippet [231], PARSEWeb [268], Example Overflow [305], Chan et al. [35], Yang et al. [296], SCP [248], Keivanloo et al. [124], CODE-NN [113], LibFinder [203], Gemini [293], CoCaBu [247], FaCoY [130], SLAMPA [310], BINGO-E [294], Xie et al. [291], CodeMatcher [156], CODEC [187], Extended Quebio [42], CodeGenie [134–136, 138], SNIFF [37], S6 [218–220], MMMF [285], Hill et al. [90], Hsu et al. [98], Portfolio [44, 178, 181], Wang et al. [277], McMillan et al. [179], Satsy [254–256], Rahman and Roy [214], Lemos et al. [141], CodeHow [166], DyCLINK [259], QECK [198], QExpandator [236], ROSF [117], Extended Satsy [257], APIREC [191], Niu et al. [200], CodeLikeThis [173], NLP2CODE [33], SnippetGen [103, 288, 298], RACK [215, 216], INQRES [161], NLP2API [212, 213], QECC (InstaRec) [107], Zou et al. [312], CODEnn [78], BVAE [41], NCS [228], Lee et al. [137], Lancer [309], Aroma [163], Cosoch [147], NQE [157], SENSORY [1], QESR [120], GKSR [105], QESC [106, 311], CodeKernel [79], SCOR [2], UNIF [32], MMAN [274], CoaCor [299], Yin et al. [303], CodeMF [100], CSDA [223], CARLCS-CNN [240], AdaCS [151], Ye et al. [301], TranS^3 [279], CDRL [102], HECS [143], MSR [57], PSCS [261], COIL [146], COSEA [275], DGMS [152], APIRec-CST [39], Zhao et al. [308], CRaDLe [77], NJACS [101], CodeGenie 2.0 [139], RACS [148], Source Forager [122], ALICE [249], Sourcerer [10], Durão et al. [59], APPROX [19], Lemos et al. [140], Rendezvous [127], Extended Conquer [91], ANNE [273], Nguyen et al. [197], DeepAPIRec [38], Li et al. [149], PCR [193], MP-CAT [84], Schumacher et al. [238], Heyman et al. [87], CoNCRA [51]
Controlled user study/interview	XSnippet [231], LibFinder [203], CoCaBu [247], CodeGenie [134–136, 138], Portfolio [44, 178, 181], McMillan et al. [179], CodeHow [166], QECK [198], QExpandator [236], Niu et al. [200], CodeLikeThis [173], NLP2CODE [33], INQRES [161], CodeKernel [79], Exemplar [75, 76, 177], GUIFetch [21], CodeNuance [159], ALICE [249], SnipMatch [286], Wang et al. [278], Test Recommender [206], CodeExchange [174], MUSE [185], AutoQuery [276], HUNTER [281]
Live study	CoCaBu [247], SnipMatch [286], CodeExchange [174], TranS^3 [279]

Table 9. Relevancy metrics used for evaluating code search techniques.

Metric	Techniques
Precision	Durão et al. [59], MMMF [285], Hill et al. [90], Portfolio [44, 178, 181], Exemplar [75, 76, 177], Mentor [167], Chan et al. [35], McMillan et al. [179], Yang et al. [296], Satsy [254–256], Rendezvous [127], Keivanloo et al. [124], Rahman and Roy [214], JECO [7], Vinayakarao [272], AutoQuery [276], FWSMF [237], Zou et al. [312], SLAMPA [310], ALICE [249], CodeKernel [79], SoCeR [112], AUSearch [8]
Precision@k	Satsy [254–256], SCP [248], QECK [198], QExpandator [236], ROSF [117], Extended Satsy [257], BINGO [36], SnippetGen [103, 288, 298], LibFinder [203], CoCaBu [247], FaCoY [130], QECC (InstaRec) [107], CODEnn [78], Lee et al. [137], SENSORY [1], SCOR [2], CodeMatcher [156], CODEC [187], CDRL [102], HECS [143], MSR [57], COSEA [275]
MAP	SCP [248], Extended Satsy [257], QualBoa [55], Source Forager [122], SCOR [2], Zhao et al. [308]
MAP@k	Rahman and Roy [214], RACK [215, 216], NLP2API [212, 213], QESR [120], GKSR [105], QESC [106, 311], COIL [146]
Recall	Strathcona [93–95], Sourcerer [10], Durão et al. [59], MMMF [285], Hill et al. [90], Selene [188, 266], Mentor [167], Chan et al. [35], Yang et al. [296], Satsy [254–256], Rendezvous [127], CodeGenie 2.0 [139], Rahman and Roy [214], JECO [7], Vinayakarao [272], Lemos et al. [141], AutoQuery [276], FWSMF [237], FaCoY [130], Zou et al. [312], SLAMPA [310], ALICE [249], CodeKernel [79]
Recall@k	SCP [248], LibFinder [203], NLP2API [212, 213], QECC (InstaRec) [107], CODEnn [78], Aroma [163], SCOR [2], CodeMatcher [156], CodeMF [100], MP-CAT [84], CARLCS-CNN [240], HECS [143], Heyman et al. [87], CRaDLe [77], NJACS [101]
Accuracy	Tracelets [48], Rahman and Roy [214], DeepAPIRec [38], NQE [157], Schumacher et al. [238]
Accuracy@k	SWIM [210], APIREC [191], Nguyen et al. [197], LibFinder [203], INQRES [161], Yin et al. [303], PCR [193], CoNCRA [51], APIRec-CST [39]
SuccessRate	Jsearch [245], HUNTER [281], CodeNuance [159], PSCS [261]
SuccessRate@k	RACS [148], RACK [215, 216], NLP2API [212, 213], CODEnn [78], SLAMPA [310], Lancer [309], MMAN [274], Li et al. [149], CODEC [187], CSDA [223], AdaCS [151], TranS^3 [279], CDRL [102], COIL [146], DGMS [152]
NDCG	Exemplar [75, 76, 177], Wang et al. [278], Extended Satsy [257], SnippetGen [103, 288, 298], Ye et al. [301], TranS^3 [279], COSEA [275], Zhao et al. [308]
NDCG@k	Wang et al. [278], QECK [198], ROSF [117], Niu et al. [200], RACK [215, 216], QECC (InstaRec) [107], Cosoch [147], SENSORY [1], QESR [120], GKSR [105], QESC [106, 311], Li et al. [149], MSR [57]
F-Measure	Durão et al. [59], Contextual Search [89], MMMF [285], Hill et al. [90], Chan et al. [35], Rendezvous [127], AutoQuery [276], ALICE [249], CodeKernel [79]
ROC Curve	Tracelets [48], Gemini [293], Quebio [119]
Sensitivity	EQMINER [118], Extended Satsy [257]

Table 10. Ranking metrics used for evaluating code search techniques.

Metric	Techniques
MRR	Strathcona [93–95], CodeHow [166], CODE-NN [113], Extended Satsy [257], CoCaBu [247], Zou et al. [312], CODEnn [78], BVAE [41], SLAMPA [310], Lancer [309], Cosoch [147], NQE [157], UNIF [32], MMAN [274], CoaCor [299], Yin et al. [303], CodeMatcher [156], CODEC [187], CodeMF [100], MP-CAT [84], CARLCS-CNN [240], AdaCS [151], Ye et al. [301], TranS^3 [279], CDRL [102], HECS [143], PSCS [261], Heyman et al. [87], CoNCRA [51], COSEA [275], DGMS [152], APIRec-CST [39], CRaDLe [77], NJACS [101]
MRR@k	RACK [215, 216]NLP2API [212, 213], CSDA [223], COIL [146]
FRank	PARSEWeb [268], XSnippet [231], SNIFF [37], McMillan et al. [180], Example Overflow [305], SWIM [210],BINGO [36], Quebio [119], CODEC [187], CodeMF [100], CSDA [223], HECS [143]
FRank@k	UNIF [32]
Simple Rank	Prospector [168], PRIME [183], BINGO [36], Huang et al. [108]
ERR	Niu et al. [200]
Significance & cohesiveness	PropER-Doc [170], GUIFetch [21]

Table 11. Supplementary metrics used for evaluating code search techniques.

Metric type	Metric	Approach
Statistical test	Correlation analysis	GUIFetch [21], SCOR [2], Xie et al. [291]
	Mean Squared Error	Xie et al. [291]
	Hypothesis test	Contextual Search [89], Portfolio [44, 178, 181], Exemplar [75, 76, 177], McMillan et al. [179], Lemos et al. [140], SCP [248], Wang et al. [278], CodeGenie 2.0 [139], Lemos et al. [141], CodeExchange [174], MUSE [185], CODE-NN [113], Niu et al. [200], ANNE [273], CodeLikeThis [173], LibFinder [203], QESC [106, 311]
User satisfaction	Experience score	CodeHint [69], Extended Conquer [91], Test Recommender [206], CodeExchange [174], CodeHow [166], MUSE [185], ANNE [273], CodeLikeThis [173], NLP2CODE [33]
	Mouse click	Example Overflow [305]
Counting	Absolute matching	Code Conjurer [109, 115], PRIME [183], Lemos et al. [141], DyCLINK [259], Quebio [119], GUIFetch [21], YOGO [209], Schumacher et al. [238]
	Top k recommendation	INQRES [161], NCS [228], NQE [157], ExAssist [194, 196], BINGO-E [294], Extended Quebio [42]
Time	Retrieval/implementation time	Prospector [168], Jsearch [245], XSnippet [231], CodeGenie [134–136, 138], Code Conjurer [109, 115], S6 [218–220], Wang et al. [280], APPROX [19], Wang et al. [277], SnipMatch [286], Chan et al. [35], Satsy [254–256], Rendezvous [127], CodeHint [69], Tracelets [48], CodeExchange [174], AutoQuery [276], HUNTER [281], DyCLINK [259], Extended Satsy [257], SWIM [210], APIREC [191], ANNE [273], Source Forager [122], LibFinder [203], Gemini [293], Quebio [119], CodeNuance [159], Lancer [309], Aroma [163], DeepAPIRec [38], BINGO-E [294], Li et al. [149], CodeMatcher [156], CODEC [187], MP-CAT [84], AdaCS [151], PSCS [261], APIRec-CST [39], Extended Quebio [42]
Other metrics	External library	Coogle [230]
	Rate of passing test cases	S6 [218–220], APIRec-CST [39]
	BLEU	BVAE [41], CoaCor [299]
	METEOR	BVAE [41]
	QC (Query Coverage)	CodeGenie 2.0 [139], Keivanloo et al. [124]