A Preliminary Mapping Study of Software Metrics Thresholds

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Abstract: Many papers deal with the topic of thresholds in software metrics to determine the quality level of a software project. This paper aims to identify the status of influential software metrics thresholds papers. We use search facilities in the SCOPUS Web tool to establish the cited papers published from 1970 to 2015. We classified the selected papers according to different factors, such as the main topic and the general type. The cited papers were more frequently on journals than conference proceedings. We observed three main problems: an unclear explanation of the method for selecting the technique that calculates thresholds; a direct application of the metric threshold values to different code context; a lack of objective analysis for the calculated thresholds. To our knowledge, this paper is the only one that performs this kind of study. It can provide baselines to assist new research and development efforts. Due to the page limit, this paper contains a summary of the results.

1 INTRODUCTION

Different organizations have proposed software metrics to measure code characteristics. For instance, the IEEE defines software metrics as *the quantitative measure of the degree to which a system, component or process possesses a given software attribute* [1].

Metrics have been used successfully for quantification, whereas they have generally failed to support subsequent decision-making (Fenton and Neil, 2000). The use of metrics entails thresholds to determine if a certain value is normal or anomalous. Thresholds give semantics to metrics enabling them to become a decision-making tool (Lorentz and Kidd, 1994). However, the determination of suitable threshold values is arduous as detailed in the following studies: Nagappan et al. (Nagappan et al., 2006) have shown that thresholds obtained by performing a correlation analysis are only valid for a limited set of similar software systems; Zhang et al. (Zhang et al., 2013) have claimed that thresholds cannot be generalized and depend on specific domains (such as aerospace and student exercises) and programming language characteristics.

Organizations and computer scientists have given many definitions of software quality over time: the IEEE defines quality as *the degree to which a system, component, or process meets specified requirements or customer or user needs or expectations* [2]. However, a good definition must lead us to measure quality meaningfully. According to Fenton and Bieman (Fenton and Bieman, 2014), *measurement is the process by which numbers or symbols are assigned to attributes of entities in the real world in such a way as to describe them according to clearly defined rules.* In our study, we found many papers that talk about the topic of thresholds, but none of them is able to provide objective rules to use them effectively: they usually use threshold directly without explaining clearly the techniques used to calculate them nor the context in which they are derived. Therefore, this paper aims at identifying the influential software metrics thresholds papers with the purpose of leading developers and scientists to improve their knowledge in this field. Our methodology leverages the evidence-based software engineering (Kitchenham et al., 2004), which (Kitchenham and Charters, 2007): relies on empirical software engineering research; suggests collecting best available evidence on specific topic; uses secondary studies such as systematic literature reviews and mapping studies. This paper introduces a preliminary mapping study of software metrics thresholds research. It intends to identify and categorize influential software metrics thresholds research. Thus, it addresses two research questions: 1. What papers are currently most important in the software met-

[1] IEEE Standard Glossary of Software Engineering Terminology. IEEE Std 610.12-1990.

[2] IEEE Standard Glossary of Software Engineering Terminology. IEEE Std 610.12-1990.

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Table 1: Search queries.

$Search_{Id}$	Goal	Search String
$Search_1$	papers 2015	(TITLE-ABS-KEY (software) AND TITLE-ABS-KEY (metrics) AND TITLE-ABS-KEY (thresholds)) AND SUBJAREA (mult OR ceng OR CHEM OR comp OR eart OR ener OR engi OR envi OR mate OR math OR phys) AND PUBYEAR = 2015
$Search_2$	papers 2015	(TITLE-ABS-KEY (metrics) AND TITLE-ABS-KEY (for) AND TITLE-ABS-KEY (object-oriented)) AND SUBJAREA (mult OR ceng OR CHEM OR comp OR eart OR ener OR engi OR envi OR mate OR math OR phys) AND PUBYEAR = 2015
$Search_3$	papers 1970-2014	(TITLE-ABS-KEY (software) AND TITLE-ABS-KEY (metrics) AND TITLE-ABS-KEY (thresholds)) AND SUBJAREA (mult OR ceng OR CHEM OR comp OR eart OR ener OR engi OR envi OR mate OR math OR phys) AND PUBYEAR $>$ 1969 AND PUBYEAR $<$ 2015
$Search_4$	papers 1970-2014	(TITLE-ABS-KEY (metrics) AND TITLE-ABS-KEY (for) AND TITLE-ABS-KEY (object-oriented) AND TITLE-ABS-KEY (software)) AND SUBJAREA (mult OR ceng OR CHEM OR comp OR eart OR ener OR engi OR envi OR mate OR math OR phys) AND PUBYEAR $>$ 1969 AND PUBYEAR $<$ 2015

rics thresholds research community? 2. Can software metrics thresholds papers be meaningfully aggregated? We refer to this as a preliminary study, because we make no claim for completeness. We have focused on the years 1970-2015: to the best of our knowledge, there are no surveys in the thresholds' field. We have used the SCOPUS tool [3] to search for relevant peer-reviewed papers and the AlmaDL service [4] of the University of Bologna to download their complete text. So far we have decided to leave other tools (such as ACM, IEEE and CiteSeer digital libraries) for further studies.

2 BACKGROUND

Software metrics thresholds represent a way to determine the quality of code through a quantitative criterion. Metrics can measure some features of the code such as the size of the final program, the complexity of the software design, the modularity of a class and the quality characteristics of the software. **Size metrics** quantify code size. They are estimators of software cost and effort. **Complexity metrics** measure the relative simplicity of the system design. **Object-oriented metrics** (Chidamber and Kamerer, 1994) measure complexity, cohesion, coupling and inheritance (Brito e Abreu and Carapuca, 1994). **Quality metrics** also compute the length of time between occurrences of defects (mean time between failures) or defects density (e.g., defects per size). Let us start illustrating criteria for thresholds identification. We briefly summarize the various approaches to determine metrics thresholds (Alves et al., 2010). **Personal experience of software quality experts** is very common. Many authors (McCabe, 1976) (Nejmeh, 1988) have defined thresholds according to their know-how. This complicates the reproduction or generalization of their results and leads to arguments about their values. **Descriptive statistics**, such as average and standard deviation, provide reasonable thresholds when the data distribution is Gaussian. **Other techniques**, such as error information and cluster analysis, are recently exploited by researchers.

[3]Scopus, https://www.elsevier.com/solutions/scopus

[4]Libraries, digital resources and study rooms, http://www.unibo.it/en/services-and-opportunities/libraries-digital-resources-and-study-rooms/

3 RESEARCH METHODS

For the preliminary mapping study we defined all the steps that compose the methodology we decided to adopt.

Let us start detailing how we have identified relevant papers. We used SCOPUS to search for software metrics thresholds papers published from 1970 up to 2015. SCOPUS is a general indexing system that includes publishers, such as IEEE, ACM, Elsevier, Wiley and Springer Lecture Notes publications. The search process has been split in two phases ended in January 2016: the first one considered studies up to 2014; the second one only regarded year 2015. The papers were separated in two categories because we included number of citations only amongst the filtering criteria of the first group. Table 1 shows the search queries whose identifier is $Search_{Id}$ with $Id = 1, ..., 4$. Due to the high number of papers found by the different searches, we decided to filter them according to various criteria, as explained in the following paragraphs.

Papers 2015 - $Search_1$ found 24 articles many of which were irrelevant, for example papers that reported in the title the following words: *biodiversity, watermaking, MOSFET, dielettric, FFT, routing, spectrum, dosimetry, reverberation, MPSoCs, MIC and analog*. We removed all the papers with the words above in the title and one paper with no au-

Table 2: Main topic of thresholds and general type of paper.

Main Topic of thresholds	
Category	**Meaning**
Development	The paper is about a specification of a new technique for calculating thresholds.
Assessment	The paper is about the assessment of existing thresholds or techniques.
Analysis	The papers discuss and or illustrate methods for analyzing software metrics thresholds.
Framework	The paper is about general or automated process by which thresholds are defined, extracted and analyzed.
Literature survey	The paper summarizes the literature on some aspect of thresholds.
Application	The paper is only an application of existing or calculated values of thresholds.
General type of paper	
Category	**Meaning**
Empirical	The paper assesses existing thresholds or a technique for calculating them.
Theoretical	The paper discusses some issues about software engineering and may consider some theoretical aspects of software metrics thresholds.
Both	The paper is a mixed theoretical and empirical paper.

Table 3: Citations per publication type for year 1970-2014.

Set	#Citations	#Books	#Journals	#Proceedings	Total
	< 10	0	5	4	9
	10-19	0	1	0	1
$Search_{34}$	20-29	0	2	0	2
	30-39	0	0	0	0
	40-49	0	1	0	1
	50+	0	0	0	0
	Total	0	9	4	13
Set	**#Citations**	**#Books**	**#Journals**	**#Proceedings**	**Total**
	< 10	0	15	16	31
	10-19	0	2	3	5
$Search_{3_3}$	20-29	0	2	1	3
	30-39	0	0	0	0
	40-49	0	0	1	1
	50+	0	1	1	2
	Total	0	20	22	42
Set	**#Citations**	**#Books**	**#Journals**	**#Proceedings**	**Total**
	< 10	2	78	77	157
	10-19	1	21	17	39
$Search_{4_3}$	20-29	0	12	4	16
	30-39	0	10	1	11
	40-49	0	3	3	6
	50+	0	24	7	31
	Total	3	148	109	260

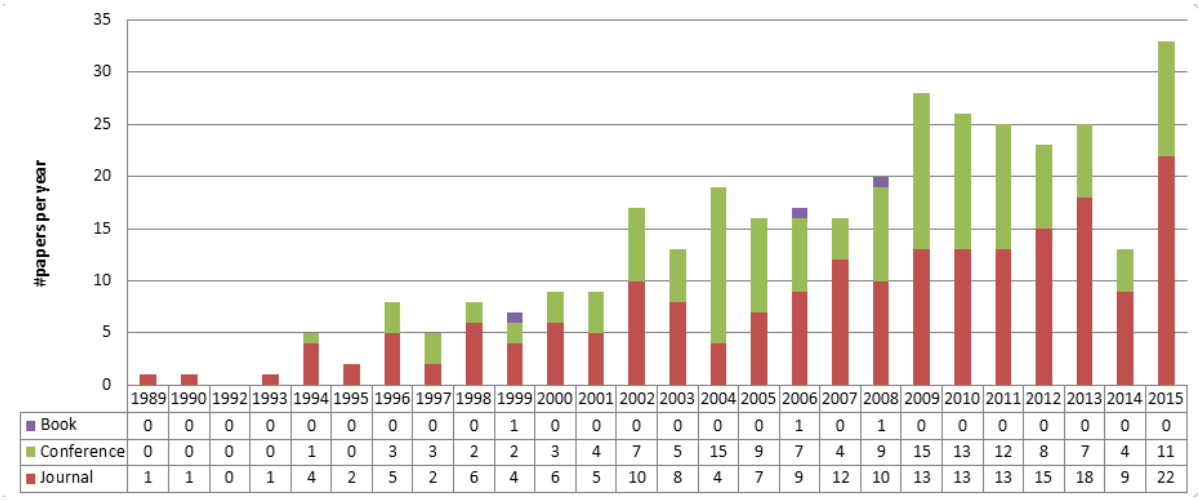
Table 4: Topic per paper type.

Year 2015				
Topic	**Empirical**	**Theoretical**	**Both**	**Total**
Development	0	0	1	1
Assessment	2	1	3	6
Analysis	0	0	1	1
Framework	0	0	0	0
Application	2	0	0	2
Literature Survey	0	0	0	0
Total	4	1	5	10
Years 1970-2014				
Topic	**Empirical**	**Theoretical**	**Both**	**Total**
Development	30	20	49	99
Assessment	20	13	3	36
Analysis	10	0	1	11
Framework	11	23	34	68
Application	2	6	0	8
Literature Survey	1	1	0	2
Total	74	63	88	225

thors: as a consequence, there were 10 records left with no citations that we call $Search_{1_1}$. $Search_2$ found 77 articles many of which were relevant. We removed one paper with the *mobile* word and 3 papers with no authors: as a consequence, there were 73 records left (only one contains a citation) that we call $Search_{2_1}$.

After the filtering operations, we found that $Search_{1_1}$ and $Search_{2_1}$ have two relevant papers in common. We identify this set with $Search_{12}$ and we decided to exclude them from the set of $Search_{1_1}$ and $Search_{2_1}$ that we call $Search_{1_2}$ and $Search_{2_2}$ respectively. A more detailed review of the abstract and text in the papers belonging to $Search_{1_2}$ found 4 papers no relevant to the topic of this paper. Therefore, there are 4 papers left named $Search_{1_3}$. For what concerns $Search_{2_2}$, 44 papers are not relevant, therefore 27 records left named $Search_{2_3}$. The total number of relevant papers are 33 obtained adding together $Search_{1_3} + Search_{2_3} + Search_{12}$. Among them there are 9 papers requested to their authors.

Papers 1970-2014 - $Search_3$ found 213 articles that becomes 128 after having removed those with no citations. Many left papers were irrelevant, for example those reported in the title the following words: *forest, vehicle, voting, landscape, healths, social, UMLS, neuronal, organs, PAM, genes, clinical, cloud anomalies, breast, LC-MS/MS, proteomic, ECG, gyrokinetic, tensor, mammography, satellite, macro-invertebrates, water-making, hue, car hood, routing, network, circuit, cellular, MOSFET, ionospheric, cortical, urban, multi antenna, wireless, MLSDA, diagnostically, DIBL, agriculture, vestibular, radio, history sensitive, laser optics, fog events, SIFT, WLAN, WAAS, ultrasound, traffic, spatial vision, flood attack, portfolio and filtering*. We removed all the papers with the words above in the title; as a consequence, there were 72 records left that we call $Search_{3_1}$. $Search_4$ found 1403 articles that becomes 832 after having removed those with no citations. We removed one paper with



	1989	1990	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Book	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
Conference	0	0	0	0	1	0	3	3	2	2	3	4	7	5	15	9	7	4	9	15	13	12	8	7	4	11
Journal	1	1	0	1	4	2	5	2	6	4	6	5	10	8	4	7	9	12	10	13	13	13	15	18	9	22

Figure 1: The number of publications per year: books, proceedings and journals.

Table 5: Source of conference and journal papers for year 2015.

Conferences	#papers	Journals	#papers
ACM Symposium on Applied Computing	1	Expert Systems	1
ACM International Conference Proceeding Series	3	Advances in Computers	1
Ibero-American Conference on Software Engineering, CIbSE 2015	1	Procedia Computer Science	1
International Conference on Knowledge and Smart Technology, KST 2015	1	Software and Systems Modeling	1
International Workshop on Software Architecture and Metrics, SAM 2015	1	Journal of Systems and Software	4
IEEE International Conference on Software Testing, Verification and Validation Workshops, ICSTW 2015	1	Information and Software Technology	1
International Conference on Advances in Computing, Communications and Informatics, ICACCI 2015	1	Lecture Notes in Electrical Engineering	3
IEEE International Conference on Emerging Technologies and Factory Automation, ETFA	1	Journal of Software: Evolution and Process	1
IEEE International Conference on Computational Intelligence and Communication Technology, CICT 2015	1	Advances in Intelligent Systems and Computing	2
		Frontiers in Artificial Intelligence and Applications	1
		International Journal of Applied Engineering Research	2
		International Journal of Software Engineering and its Applications	3
		International Journal of Software Engineering and Knowledge Engineering	1
Total	11	Total	22

the *satellite* word in the title; as a consequence, there were 831 records left that we call $Search_{4_1}$.

After the filtering operations, we found that $Search_{3_1}$ and $Search_{4_1}$ have 15 papers in common, two of which are not relevant being out of topic. We identify this set with $Search_{34}$ and we decided to exclude them from the set of $Search_{3_1}$ and $Search_{4_1}$ that we call $Search_{3_2}$ and $Search_{4_2}$ respectively. A more detailed review of the abstract and text in the papers belonging to $Search_{3_2}$ found 14 papers no relevant to the topic of this paper. In addition, we removed 1 paper that we were unable to find. Therefore, there are 42 papers left named $Search_{3_3}$. For what concerns $Search_{4_2}$, 556 papers are not relevant, therefore 260 records left named $Search_{4_3}$. The total number of relevant papers are 314 obtained adding together $Search_{3_3} + Search_{4_3} + Search_{34}$. Among them there are 60 papers requested to their authors.

Let us explain how we have extracted data. Starting from the relevant papers, we collected some standard information about all papers, such as the authors, the full reference, whether the paper was related to a conference or a journal, the total number of citations. So far we have not observed for the selected papers changes in the number of citations. We aim to classify all the papers according to the following criteria:

Table 6: Source of conference papers for years 1970-2014.

Conferences	#papers	Conferences	#papers
International Conference and Exhibition on Technology of Object-Oriented Languages and Systems, TOOLS 39	1	International Symposium on Empirical Software Engineering and Measurement, ESEM 2009	1
Central and Eastern European Software Engineering Conference in Russia, CEE-SECR 2009	1	International Conference on Signal Processing Systems, ICSPS 2009	1
World Congress on Software Engineering, WCSE 2009	1	International Conference on Research Challenges in Information Science, RCIS 2010	1
Malaysian Conference in Software Engineering, MySEC 2011	1	International Workshop on Emerging Trends in Software Metrics, WETSoM 2012	1
International Conference on Innovations in Information Technology, IIT 2012	1	International Conference on Computing, Management and Telecommunications, ComManTel 2013	1
IEEE Conference on Software Maintenance, Reengineering, and Reverse Engineering, CSMR-WCRE 2014	1	International Conference on Aspect-Oriented Software Development	1
ACS/IEEE International Conference on Computer Systems and Applications, 2005	1	Annual Conference of the North American Fuzzy Information Processing Society, NAFIPS	1
Canadian Conference on Electrical and Computer Engineering	1	Conference on Software Maintenance	4
Genetic and Evolutionary Computation Conference, GECCO 2006	1	International Conference on Software and Data Technologies, ICSOFT 2010	1
IEEE Aerospace Applications Conference Proceedings	1	IEEE International Conference on Automation Science and Engineering	1
IEEE International Conference on Neural Networks	1	IEEE International Conference on Program Comprehension	5
IEEE International Conference on Software Maintenance, ICSM	9	IEEE International Working Conference on Mining Software Repositories	2
IEEE/ACM International Conference on Computer-Aided Design, Digest of Technical Papers, ICCAD	1	International Software Metrics Symposium	4
International Symposium on Software Testing and Analysis, ISSTA'08	1	International Conference on Information and Communications Technology ICICT 2005	1
International Conference on Information Technology: New Generations, ITNG 2009	1	International Joint Conference on Computer Science and Software Engineering, JCSSE 2012	1
Conference on Power Electronics and Intelligent Transportation System, PEITS 2009	1	IEEE International Working Conference on Source Code Analysis and Manipulation, SCAM 2010	1
International Conference on Automated Software Engineering, ASE 2004	1	International Symposium on Search Based Software Engineering, SSBSE 2009	1
International Conference on Fuzzy Systems and Knowledge Discovery, FSKD 2010	1	IEEE International Conference on Granular Computing, GrC 2010	1
IEEE Software Engineering Workshop, SEW 2011	1	IEEE International Conference on Control System, Computing and Engineering, ICCSCE 2013	1
Brazilian Symposium on Software Engineering, SBES 2010	1	International Conference on Software Maintenance and Evolution, ICSME 2014	1
IEEE International Workshop on Source Code Analysis and Manipulation, SCAM 2003	1	IEEE/ACIS International Conference on Computer and Information Science, ICIS 2007; IEEE/ACIS International Workshop on e-Activity, IWEA 2007	1
European Dependable Computing Conference, EDCC-7	1	International Conference on the Quality of Information and Communications Technology, QUATIC 2010	1
IEEE International Working Conference on Source Code Analysis and Manipulation, SCAM 2008	1	ACM Computer Science Conference	1
Asia-Pacific Software Engineering Conference, APSEC	3	Workshop on Interaction between Compilers and Computer Architectures, INTERACT-8 2004	1
International Conference on Quality Software, QSIC 2004	2	IEEE Computer Society's International Computer Software and Applications Conference	1
International Computer Software and Applications Conference	1	International Conference on Advanced Information Networking and Applications, AINA	1
International Conference on Computer Science and Software Engineering, CSSE 2008	1	International Conference on Dependability of Computer Systems, DepCoS - RELCOMEX 2007	2
International Conference on Quality Software	1	International Conference on Software Engineering	4
International Conference on Tools with Artificial Intelligence, ICTAI	1	International Software Metrics Symposium	4
International Symposium on Software Reliability Engineering, ISSRE	2	Joint Conference of the 21st International Workshop on Software Measurement, IWSM 2011 and the 6th International Conference on Software Process and Product Measurement, MENSURA 2011	1
International Conference onInformation Technology: New Generations, ITNG 2006	1	Working Conference on Reverse Engineering, WCRE	3
International Conference on Reliability, Maintainability and Safety, ICRMS 2009	1	IEEE International Symposium on High Assurance Systems Engineering	1
International Society for Optical Engineering, SPIE	2	IEEE International Requirements Engineering Conference, RE'08	1
International Conference on Software Testing, Verification and Validation, ICST 2008	1	International Conference on Computational Aspects of Social Networks, CASoN 2012	1
Joint Working Conference on Software Architecture and 6th European Conference on Software Architecture, WICSA/ECSA 2012	1	International Florida Artificial Intelligence Research Society, FLAIRS - 24	1
International Conference on Confluence 2014: The Next Generation Information Technology Summit	1	International Conference on Generative Programming and Component Engineering, GPCE'06	1
International Conference on Applied Computer Science, ACS '09	1	ACM Symposium on Applied Computing	2
Australian Software Engineering Conference, ASWEC	2	Conference on Object-Oriented Programming Systems, Languages, and Applications, OOPSLA	2
European Conference on Software Maintenance and Reengineering, CSMR	9	Hawaii International Conference on System Science	1
IASTED International Conference on Computational Intelligence	1	IASTED International Conference on Software Engineering	1
International Conference on Computer and Communication Engineering, ICCCE08	1	International Conference on Software Engineering Research and Practice, SERP'04	3
International Symposium on Software Reliability Engineering, ISSRE	1	International Conference on Software Engineering and Data Engineering, SEDE 2011	1
IEEE International Workshop on Visualizing Software for Understanding and Analysis, VISSOFT 2009	1	Working Conference on Reverse Engineering	1
International Conference on Software Engineering and Knowledge Engineering, SEKE 2011	2	Joint WOSP/SIPEW International Conference on Performance Engineering, WOSP/SIPEW'10	1
Total	67	Total	68

Table 7: Source of journal papers for years 1970-2014.

Journals	#papers	Journals	#papers
ACM Computing Surveys	1	ACM SIGPLAN Notices	1
Computer Journal	1	IBM Systems Journal	1
IET Software	4	Informatica (Ljubljana)	1
Information Sciences	2	Journal of Software	2
SpringerPlus	1	Neurocomputing	1
Pattern Recognition	1	Procedia Computer Science	1
Software Quality Journal	3	The Scientific World Journal	1
Ruan Jian Xue Bao/Journal of Software	3	Software - Practice and Experience	3
Software Process Improvement and Practice	1	Journal of Systems Architecture	1
Tien Tzu Hsueh Pao/Acta Electronica Sinica	1	Software Testing Verification and Reliability	1
Wuhan University Journal of Natural Sciences	1	Information Processing Letters	2
Empirical Software Engineering	9	Expert Systems With Applications	2
Applied Artificial Intelligence	1	IEEE Transactions on Reliability	1
Journal of Electronic Imaging	1	Journal of Object Technology	5
Journal of Software Maintenance	1	Conference on Software Maintenance	4
Journal of Systems and Software	18	Lecture Notes in Computer Science	13
Information and Software Technology	18	Lecture Notes in Electrical Engineering	1
European Journal of Operational Research	1	Advances in Intelligent Systems and Computing	1
ACM International Conference Proceeding Series	1	IEEE Transactions on Software Engineering	19
IEICE Transactions on Information and Systems	4	Innovations in Systems and Software Engineering	2
International Review on Computers and Software	3	JOOP - Journal of Object-Oriented Programming	2
Journal of Zhejiang University: Science C	1	Journal of software: Evolution and Process	1
Journal of Computer Science and Technology	1	Journal of Information Processing Systems	1
Journal of Object-Oriented Programming	1	Journal of Software Maintenance and Evolution	6
Journal of Integrated Design and Process Science	1	Lecture Notes in Business Information Processing	1
Monthly Notices of the Royal Astronomical Society	1	Communications in Computer and Information Science	2
IEEE Transactions on Parallel and Distributed Systems	1	International Journal of Computers and Applications	1
World Academy of Science, Engineering and Technology	1	International Journal of Machine Learning and Cybernetics	1
ACM Transactions on Software Engineering and Methodology	3	International Journal on Artificial Intelligence Tools	1
International Journal of Computer Applications in Technology	3	Journal of Computational Methods in Sciences and Engineering	1
WSEAS Transactions on Information Science and Applications	1	International Journal of Digital Content Technology and its Applications	1
International Journal of Software Engineering and Knowledge Engineering	7		
Total	97	Total	81

1. the main topic (see Table 2); 2. the type of paper (i.e., empirical, theoretical or both (see Table 2); 3. the type of publication (i.e., proceedings, journal, book); 4. the software licence (i.e., open source or commercial software) of the analysed projects; 5. the considered dataset of metrics (i.e., name, public or private); 6. the programming languages of the analysed projects; 7. the type of metrics; 8. the type of presented technique (e.g., statistical or artificial intelligence based). Let us detail why we have aggregated data. The main hindrance to the adoption of thresholds is the lack of guidelines for their exploration and exploitation. As a consequence, one of the purposes of this paper is to define several classification criteria to acquire valid aggregations that can facilitate the way scientists and developers search information related to thresholds. Since they have been always calculated in specific applicability domain (characterized by, e.g., a particular software license or programming language), we established to track all the information about the environment where thresholds were determined and used.

4 RESULTS

In this section we present some tabulations of the results of categorizing the identified papers. They concern the following information: number of publications per year (see Figure 1); number of citations per publication type for year 1970-2014 (see Table 3); topic per paper type for year 2015 (see Table 4); topic per paper type for years 1970-2014 (see Table 4); source of conference papers for year 2015 (see Table 5); source of journal papers for year 2015 (see Table 5); source of conference papers for years 1970-2014 (see Table 6); source of journal papers for years 1970-2014 (see Table 7); details of common ($Search_{12}$ and

Table 8: Common pubblications in detail.

Reference	Main Topic	Empirical/Theoretical	Number of SW projects	Open Source SW project	Public Data Set	Programming Language	Type of Metrics	Statistical/Artificia Intelli-gence/other	Threshold Values
(Alves et al., 2010)	Development	Empirical	100 projects	Proprietary and open source	Not public	Java, C#	Size, Complexity	Statistical	McCabe <= 6 low risk,]6,8] moderate risk,]8,15] high risk, > 15 very high risk
(Al Dallal, 2012)	Assessment	Empirical and Theoretical	6 projects: Art of illusion, FreeMind, etc	Open source	Not public	Java	Size, coupling and cohesion	Statistical	
(Aman et al., 2005)	Development	Empirical	5 projects: Jboss, Relaxer, etc	Open source	Not used	Java	Statements	Statistical	Statements = 113 (class)
(Ampatzoglou et al., 2011)	Application	Empirical and Theoretical	Not used	Not used	Not used	Not used	Size, Complexity, C& K	Not used	Table 5 reports data for 5 imaginary case studies
(Barkmann et al., 2009)	Assessment	Empirical	146 projects	Open source	Not public	Java	Size, C& K	Statistical	
(El Emam et al., 2002)	Application	Empirical and Theoretical	3 systems	Industrial commercial and open source	Not public	C++, Java	Size and some C& K	Statistical	
(Ferreira et al., 2012)	Development	Empirical	40 projects from sourceforge	Open source	Not public	Java	Size, C&K	Statistical	Different thresholds calculated by different application domain, software types, software size.
(Mihancea and Marinescu, 2005)	Development	Empirical	7 projects	Open source	Not public	Java, C++	Size and metrics derived from C&K	Genetic Algorithm	WMC > 31, TCC < 0.33, WOC < 0.95
(Rodriguez et al., 2013)	Development	Empirical	Not used	Not used	Yes (Promise Repo)	C, C++, Java	Size, Complexity, C&K	Artificial intelligence	Different thresholds for individual datasets
(Shatnawi, 2010)	Development	Empirical and Theoretical	Mozilla and Rhino systems, Eclipse version 2.0 and 2.1	Yes	Not used	Java	A subset of C&K metric suites	Statistical	CBO = 9, RFC = 40, WMC = 20
(Shatnawi et al., 2009)	Development	Empirical	3 release of Eclipse	Open source	Not public	Java	C&K, LK	Statistical, ROC analysis	CBO = 13, RFC = 44, WMC = 24, CTM = 33, NOC = 9 to identify low, medium and high risk
(Sodiya, 2012)	Application	Empirical and Theoretical	Not used	Not used	Not used	No	McCabe Cyclomatic Complexity, Size	Not used	Used thresholds listed by Olague et al., 2006 and Rosenberg, 1998
(Malhotra and Bansal, 2015)	Evaluation	Empirical	NASA software, Apace Ivy, JEdit	All open source except NASA software	Open DataSet, KC1	Java, C++	C&K metrics	Statistical	Different thresholds for individual datasets

Search$_{34}$) publications 1970-2015 (see Table 8). As regards this table we list here the meaning of the metrics' acronyms used in the "threshold values" column: WMC (Weighted Method Count), TCC (Tight Class Cohesion), WOC (Weight of a Class), CBO (Class Between Objects), RFC (Response for Class), CTM

(Coupling Through Message passing), NOC (Number of Child classes), C&K (Chidamber and Kemerer), LK (Lorentz and Kidd).

For the years 1970-2014 we identified 3 books whose titles are: Model-Driven Software Development: Integrating Quality Assurance; Object-Oriented Design Knowledge: Principles, Heuristics and Best Practices; Theory and Practice of Object Systems. We have hitherto received 4 papers out of the 69 requested to the authors.

5 CONCLUSIONS

We believe this study is useful, in spite of its limitations, because it may act as the starting point for more detailed work. This paper: identifies the most influential papers, in terms of citations, published from 1970 to 2014; collects some standard information about all the papers in the range 1970-2015 in terms of whether the paper was related to a conference or journal, the total number of citations; establishes some criteria according to which papers can be classified (such as main topic, whether the paper is theoretical or empirical, the programming language of the software employed for thresholds extraction and validation, the type of software license, the type of metrics used, the type of the presented technique and some threshold values); starts a meaningful aggregation of all the material based on the established criteria, in order to facilitate the selection of papers;

We may extend this work by taking into consideration other criteria to provide further classification results. Furthermore, we could use other tools (such as ACM, IEEE and CiteSeer digital libraries) in order to have a comparison with the results obtained by SCOPUS.

To fully analyze the current status in the field of thresholds, we will firstly undertake the mapping study (Kitchenham & Charters, 2007) and secondly the systematic review (Cronin et al, 2008). The former allows identifying the set of primary works highlighting their gaps according to the established question. The latter provides a list as complete as possible of all the published and unpublished studies relating to a particular subject area.

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REFERENCES

Al Dallal, J. (2012). Constructing models for predicting extract subclass refactoring opportunities using object-oriented quality metrics. *Information and Software Technology*, 54:1125–1141.

Alves, T. L., Ypma, C., and Visser, J. (2010). Deriving metrics thresholds from benchmark data. In *The IEEE International Conference on Software Maintenance*, pages 1–10.

Aman, H., Mochiduki, N., Yamada, H., and Noda, M.-T. (2005). A simple predictive method for discriminating costly classes using class size metric. *IEICE Transaction on Information and Systems*, E88-D(6).

Ampatzoglou, A., Frantzeskou, G., and Stamelos, I. (2011). A methodology to assess the impact of design patterns on software quality. *Information and Software Technology*, 54:331–346.

Barkmann, H., Lincke, R., and Love, W. (2009). Quantitative evaluation of software quality metrics in open-source projects. In *International Conference on Advanced Information Networking and Applications Workshops*, pages 1067 – 1072. IEEE.

Brito e Abreu, F. and Carapuca, R. (1994). Object-oriented software engineering: Measuring and controlling the development process. In *4th Int. Conf. on Software Quality QSIC*.

Chidamber, S. R. and Kamerer, C. F. (1994). A metrics suite for object-oriented design. *IEEE Trans. Software Engineering*, SE-20(6):476–493.

El Emam, K., Benlarbi, S., Goel, N., Melo, W., Lounis, H., and Rai, S. (2002). The optimal class size for object-oriented software. *IEEE Transactions on Software Engineering*, 28.

Fenton, N. and Bieman, J. (2014). *Software Metrics: A Rigorous and Practical Approach, Third Edition*. CRC Press.

Fenton, N. E. and Neil, M. (2000). Software metrics: roadmap. *ICSE - Future of SE Track*, pages 357–370.

Ferreira, K. A. M., Bigonha, M. A. S., Bigonha, R. S., Mendes, L. F. O., and Almeida, H. C. (2012). Identifying thresholds for object-oriented software metrics. *Journal of Systems and Software*, 85(2):244–257.

Kitchenham, B. A. and Charters, S. M. (2007). Guidelines for performing systematic literature reviews in software engineering. EBSE Technical Report EBSE-2007-01, Keele University and Durham University.

Kitchenham, B. A., Dyba, T., and Jorgensen, M. (2004). Evidence-based software engineering. In *The 26th International Conference on Software Engineering (ICSE'04)*.

Lorentz, M. and Kidd, J. (1994). *Object-oriented software metrics:a practical guide*. Prentice-Hall, Inc.

Malhotra, R. and Bansal, A. J. (2015). Fault prediction considering threshold effects of object-oriented metrics. *Expert Systems*, 32(2):203–219.

McCabe, T. J. (1976). A complexity measure. *IEEE Transactions on Software Engineering*, SE-2(4):308–320.

Mihancea, P. and Marinescu, R. (2005). Towards the optimization of automatic detection of design flaws in

object-oriented software systems. In *Ninth European Conference on Software Maintenance and Reengineering*, pages 92 – 101. IEEE.

Nagappan, N., Ball, T., and Zeller, A. (2006). Mining metrics to predict component failures. In *The 28th international conference on Software engineering (ICSE '06)*, pages 452–461, New York, NY, USA,. ACM.

Nejmeh, B. A. (1988). Npath: A measure of execution path complexity and its applications. *Communications of the ACM*, 31(2):188–200.

Rodriguez, D., Ruiz, R., Riquelme, J., and Harrison, R. (2013). A study of subgroup discovery approach for defect prediction. *Information and Software Technology*, 55:18101822.

Shatnawi, R. (2010). A quantitative investigation of the acceptable risk levels of object-oriented metrics in open-source systems. *IEEE Transactions on Software Engineering*, 36:216–225.

Shatnawi, R., Li, W., Swain, J., and Newman, T. (2009). Finding software metrics threshold values using roc curves. *Journal of Software Maintenance and Evolution: Research and Practice*, 22(1):1–16.

Sodiya, A. S. (2012). A survability model for object-oriented software systems. In *Fourth International Conference on Computational Aspects of Social Networks (CASoN)*, pages 283 – 290. IEEE.

Zhang, F., Mockus, A., Zou, Y., Khomh, F., and Hassan, A. E. (2013). How does context affect the distribution of software maintainability metrics? In *The 29th IEEE International Conference on Software Maintainability (ICSM'13)*, pages 350–359, Eindhoven. IEEE.