Systematic Literature Review Protocol

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1 Introduction

This document presents the systematic methods used to identify and select the relevant papers to review. Starting from the research questions, search terms, data retrieval and selection criteria.

1.1 Research questions

The scope of this review is defined by the research questions (RQ) since the research questions are been driven by the focus of this study. The fundamental objective of the research questions is to postulate the understanding of the context of fault detection in CPS research. Table 1 presents the research questions while the explanation of each question is done in turn.

Table 1: Definition of the research questions

RQs	Description
RQ1	What are the common types of faults in CPS?
RQ2	How is fault detection and diagnosis performed in CPS?
RQ3	What are the emerging research gaps in CPS fault management to be considered for future studies?

The first research question (RQ1) is to identify the different typical types of faults that occur in CPS as well as uncovering the types of faults that can be injected into the systems. The manifestation of each type of fault is different from one domain to another. This also explores how faults are formulated to provide a controlled environment for learning, optimisation and the development of resilient CPS capable of handling unexpected challenges. The question also explores the possibility of extracting information about fault types from datasets generated during the operational phase of CPS. It considers whether real-world data can be analysed to identify and categorise faults.

The second research question (RQ2) aims to understand the different fault detection and diagnosis approaches used in CPS, such as model-based, data-driven, and hybrid techniques. It also investigates methods, tools, and processes by which faults can be deliberately injected into the system for analysis, testing, or experimentation. It further seeks information on the latest developments and innovations in the field of fault detection within CPS. This could include emerging technologies, novel approaches, or improved methodologies.

The aim of the third research question (RQ3) is to investigate and identify areas withing the field of CPS fault management that require further research and development, highlighting potential opportunities to be considered for future studies. This includes potential challenges, unexplored areas, or evolving trends.

Summarily, these research questions collectively aim to comprehensively explore the landscape of faults in CPS, the processes involved in fault detection and diagnosis, recent advancements in fault detection, and potential areas for future research within CPS fault management.

1.2 Search Process & Strategy

Fundamental to the search strategy of papers is the definition of search terms, which in turn depends on the manually searched papers and selected search engine or database. The strategy of searching relevant studies is expected to be in a systematic way with iterative refinement of the search terms. We ran a manual search to find a set of relevant studies, from which we formulate a search string. The venues from which we ran the manual search are shown in Table 2.

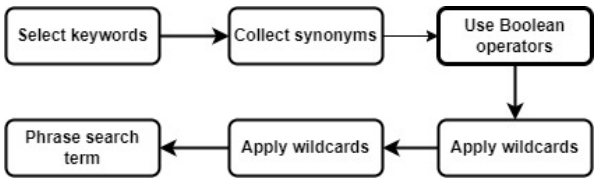

Figure 1: Search term formulation process

This search string was then utilised to carryout an automated search, followed by a snowballing search to complement the search results. This method offers maximal coverage while minimising the chance of omission. Following that, we used a series of filtering procedures to find the most pertinent papers.

Table 2: Manual publication venues

Acronym	Publication venues
ASE	International Conference on Automated Software Engineering
FSE	ACM International Conference on the Foundations of Software Engineering
ICSE	International Conference on Software Engineering
ISSTA	International Symposium on Software Testing and Analysis
TAAS	ACM Transactions on Autonomous and Adaptive Systems
TCPS	ACM Transactions on Cyber-Physical Systems
DependSys	International Conference on Dependability in Sensor, Cloud and Big Data Systems and Application

1.2.1 Search terms

The definition of the search terms was guided by the various usage of faults in fault management of CPS. The summary of the terms is depicted in Table 3.

Table 3: Terms used for literature retrieval

(Faults OR Anomalies) AND
((detection OR diagnosis OR management) OR
(methods OR strategies OR techniques)) AND
(Cyber Physical System OR IoT)

The efficiency of the search process is believed to be greatly improved by using well crafted search terms. Therefore, it is allowed to iteratively improve the search terms as the process unfolds in order to identify literature that is pertinent to the research topic. The process of developing search terms involves finding the main keywords, i.e. the key ideas that best describe the research question. Then the variation of the identified keywords are discovered because different authors can express the same concept using different terminologies. These terms are combined together using Boolean operators such as AND, OR, and NOT. For instance, "fault detection OR anomaly detection" would ensure more coverage of the results. The process of searching the terms is depicted in Fig. 1.

1.3 Retrieval of data

We chose some digital databases for the data retrieval. In addition to the accessibility of the databases, we also consider their relevance to the field of study. Since this is a science-based research that focuses on the intersection of computer science and software engineering; to provide a more comprehensive understanding and coverage of the literature on our research topic, we have selected the combination of the following databases:

- ScienceDirect
- Springer

Table 4: Criteria for selecting papers that are included and excluded

Inclusion criteria (I)	
I1	The peer-review paper related to Cyber-Physical Systems
I2	The paper with full text accessibility
I3	The paper published from 2006 onward
I4	Papers presenting faults, their classification or detection techniques
Exclusion criteria (E)	
E1	Similar research or duplicate publications by the same authors in various versions
E2	Editorials, encyclopedia and demo of tools
E3	Short papers with pages less than 5
E4	The paper published in other language than English
E5	Grey literature such as reports, newsletter, posters, or white papers
E6	Papers on CPS without mentioning faults nor anomalies
E7	Articles that do not conform with the inclusion criteria
E8	Articles strictly on cyber-security or malicious cyber-attack or intrusion
Quality Criteria (Q)	
Q1	Is the paper relevant to faults in Cyber-Physical System?
Q2	Does the paper address at least one of the RQs?
Q3	Is the context in which the study was conducted adequately described?

- ACM Digital Library
- IEEE Xplore

We carried out the search on the databases in the order they are mentioned. The reason is to start from database that specialises on the research topic before exploring those ones that are more generic. After executing the search terms across the databases, we retrieve the publications and their associated meta-data, then put them in Mendeley - a reference management tool. We also retrieved additional research papers using snowballing (forward and backward), by filtering from the list of references and citations with the aid of Semantic Scholar[1], which is a tool for scientific literature.

All collected data were curated and organised into a comprehensive dataset, which is available in a GitHub repository. This repository includes the list of articles, metadata such as publication year, authors, and abstracts, as well as the inclusion, exclusion, and quality criteria applied during the selection process.

The dataset can be accessed at the following URL: https://github.com/hayatu4islam/systematic_literature_review.git. This ensures transparency and allows other researchers to reproduce or extend our work.

[1]https://www.semanticscholar.org

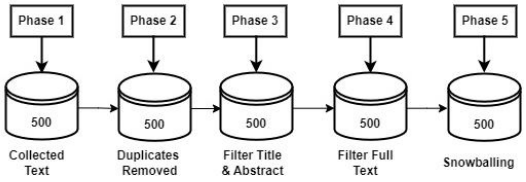

Figure 2: Filtering of papers from search to final selection

1.3.1 Criteria for selection

We defined the criteria for publication inclusion and exclusion. These help in filtering out the irrelevant papers from the list of obtained papers. A paper must satisfy all inclusion criteria, have no exclusion criteria, and meet all quality requirements in order to be accepted. This method helped to lessen prejudice by allowing for a rigid yet systematic approach to discovering relevant resources. For a paper to meet the inclusion criteria, it must be a CPS peer-reviewed paper, have full text accessibility, not published earlier than 2006 and presents faults and/or their classification or detection techniques.

The exclusion and quality criteria are also defined as shown in Table 4.

1.4 Filtering of papers

After obtaining a large pool of initially identified studies, there is a need to filter them to reflect only the relevant studies. Here, we ensure the included studies are appropriate, meet the criteria (both inclusion and exclusion criteria as depicted in Table 4), and address our stated goals i.e. contribute to answering the research questions. The filtering of the papers take a number of phases ranging from removing the duplicates; filtering based on the title, abstract, research area & keywords; up to filtering on the basis of the full text. We then applied snowball sampling also known as snowballing (both forward and backward) to uncover additional studies that may not have been identified through traditional search methods. This enhances comprehensiveness of the review by capturing a broader range of literature. The backward snowballing involves examining the reference lists of already identified relevant studies to find additional sources while forward snowballing involves identifying studies that have cited the primary studies found through the initial search process.

The new list of articles are then evaluated against the selection criteria (inclusion, exclusion, and quality) as shown in Table 4. The intricate depiction of the snowballing process is outlined thoroughly in Algorithm **??**. A flowchart showing the number of studies identified, filtered, and added/removed at each phase is shown in Fig. 2. We had to filter the papers based on the title even though some titles may contain some elements similar to what we are interested in; and this leads to reading the abstracts. A number of papers we can easily drop due to their titles have otherwise been proven useful using this approach. The retrieved articles are subsequently subjected to another filtering stage, involving a thorough examination of their full texts, to ensure their relevance to the research topic.

Table 5: Search Result by Database

Database	Initial result	Inclusion criteria	Final[2]
ScienceDirect	6,767	59	7
Springer	1,473	154	1
ACM Digital Library	1,166	99	6
IEEE Xplore	2,837	142	9
Others[3]	-	-	4
Total	12,243	454	27