

Putting Software Testing Terminology to the Test

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Abstract—Testing is a critical part of every software development project that is often complicated, expensive, or overlooked. This is in part due to the unstable knowledge base; there is no standard, consistent, and “complete” taxonomy for software testing, which inhibits unambiguous communication. Discrepancies and ambiguities are widespread throughout the literature, and sometimes exist between different parts of the same document! We systematically investigate the current state of software terminology by 1) identifying established standards (including IEEE, ISO/IEC, and SWEBOK) and other prominent testing resources, 2) capturing relevant testing terms from these sources, along with their definitions and relationships (both explicit and implied), and 3) building graphs to visualize and analyze these data. Throughout this process, over five hundred test approaches were uncovered, as well as some methods for describing “implied” test approaches. In addition, a tool was built to generate graphs of the relations between test approaches and track their ambiguities, in addition to those captured manually through the research process. Our results show ten terms are given as synonyms to two (or more) disjoint test approaches and fourteen pairs of test approaches may be synonyms and/or have a child-parent relationship. There is also confusion surrounding functional, recovery, scalability, and performance testing, along with over fifty more “minor” discrepancies. Overall, there is a need for testing terminology to be standardized to make the discussion, analysis, and implementation of various test approaches more coherent, and we provide some preliminary advice on how to accomplish this.

Index Terms—Software testing, terminology, taxonomy, literature review, test approaches

I. Background

Testing software is complicated, expensive, and often overlooked. Therefore, automating the software testing process is an area of interest. In particular, test case generation for Drasil, a framework for “generating all of the software artifacts for (well understood) research software” [1] was desired.

Before attempting to automate a knowledge-based process in ad hoc manner, it is important to understand the underlying domain. This allows the information itself to drive the scope, including both what is possible and what is needed. In this case, the goal was to uncover the various approaches towards testing, as well as which prerequisites (e.g., input files, oracles) existed for each. A search for a systematic, rigorous, and “complete” taxonomy revealed that existing software testing taxonomies are inadequate:

- [2] focuses on parts of the testing process (e.g., test goal, testable entity)
- [3] prioritizes organizing testing approaches over defining them
- [4] provides a foundation for classification but not how it applies to software testing terminology

The “solution” to this gap was to define the scope of what kinds of “software testing” were of interest (II), then examine the existing literature for this subsection (III); this quickly reinforced the need for a taxonomy! Despite the amount of well understood and organized knowledge (IV), there are still many discrepancies and ambiguities, either within the same source or between various sources (V). We provide some potential solutions to some of these (VI).

II. Scope

Since the motivation for this project is the generation of test cases for code, only the “testing” component of Verification and Validation (V&V) is considered. For example, design reviews (see [5, p. 132]) and documentation reviews (see [p. 132]) are out of scope, since they focus on the V&V of the design and documentation of the code, respectively, and not on the code itself. Likewise, ergonomics testing and proximity-based testing (see [6]) are out of scope since they are for testing hardware systems. Security audits that focus on “an organization’s ... processes and infrastructure” [6], are also out of scope, but security audits that “aim to ensure that all of the products installed on a site are secure when checked against the known vulnerabilities for those products” [7, p. 28] are not.

Sometimes, wider decisions must be made on whether a whole category of testing is in scope or not. For example, while all the examples of domain-specific testing given by [8, p. 26] are focused on hardware, this might not be representative of all types (e.g., ML model testing seems domain-specific).

This also means that only some aspects of some testing approaches are relevant. This mainly manifests as a testing approach that can verify both the V&V itself and the code. For example:

- 1) Error seeding is the “process of intentionally adding known faults to those already in a computer program”, done to both “monitor[] the rate of detection

and removal”, which is a part of V&V of the V&V itself, “and estimat[e] the number of faults remaining” [5, p. 165], which helps verify the actual code.

- 2) Fault injection testing, where “faults are artificially introduced into the SUT”, can be used to evaluate the effectiveness of a test suite [9, p. 5-18], which is a part of V&V of the V&V itself, or “to test the robustness of the system in the event of internal and external failures” [10, p. 42], which helps verify the actual code.
- 3) “Mutation [t]esting was originally conceived as a technique to evaluate test suites in which a mutant is a slightly modified version of the SUT” [9, p. 5-15], which is in the realm of V&V of the V&V itself. However, it “can also be categorized as a structure-based technique” and can be used to assist fuzz and metamorphic testing [9, p. 5-15].

A. Static Testing

Sometimes, the term “testing” excludes static testing [11, p. 222], [8, p. 13], restricting it to “dynamic validation” [9, p. 5-1] or “dynamic verification” “in which a system or component is executed” [5, p. 427]. Since “terminology is not uniform among different communities, and some use the term testing to refer to static techniques¹ as well” [9, p. 5-2], the scope of “testing” for the purpose of this project will include both “static testing” and “dynamic testing”, as done by [10, p. 17], [12, pp. 8-9], and even a source that explicitly excluded static testing [5, p. 440]!

Static testing tends to be less systematic/consistent and often requires human intervention, which makes it less relevant to this project’s end goal: generating test cases automatically. However, understanding the breadth of testing approaches provides a more complete picture of how software can be tested, how the various approaches are related to one another, and potentially how even parts of these “out-of-scope” approaches may be generated in the future! Therefore, these “out-of-scope” approaches are within the scope of this research (at least in the preliminary phase) and will be identified systematically and excluded before analysis. Even some dynamic methods, such as demonstrations and dynamic analysis, which fall under the realm of “evaluation” as opposed to “testing” [8, p. 13] may be ineligible for automatic generation, due to their reliance on human intervention.

III. Methodology

A. Source Order

To gain the most accurate picture of how software testing terminology is used, sources from multiple authors were selected. By looking at a variety of sources, discrepancies both within and between them can be uncovered, and

¹Not formally defined, but distinct from the notion of “test technique” described in [IEEE Testing Terminology](#).

the various classifications of terminology can be analyzed. Other sources can then be found by “snowballing” to other sources to further investigate specific test approaches.

- 0) Textbooks trusted at McMaster [13, 14, 15]
 - Ad hoc and arbitrary; not systematic
 - Colored [maroon](#)
- 1) Established standards (such as IEEE, ISO/IEC, and SWEBOK) [5, 6, 9, 10, 16, 17, 18, 19, 20, 21]
 - Standards organizations colored [green](#)
 - “Meta-level” commentaries or collections of terminology (often based on these standards), such as [8], colored [blue](#)
- 2) Other resources: less-formal classifications of terminology (such as [22]), sources investigated to “fill in” missing definitions (see [Undefined Terms](#)), and testing-related resources that emerged for unrelated reasons
 - Colored black, along with any “surface-level” analysis that followed trivially

B. Procedure

Except for some sources in [Undefined Terms](#), all sources were looked through in their entirety to “extract” as much terminology as possible. Heuristics were used to guide this process, by investigating...

- ...glossaries and lists of terms
- ...testing-related terms
e.g., terms that included “test(ing)”, “validation”, “verification”, “review(s)”, or “audit(s)”
- ...terms that had emerged as part of already-discovered testing approaches, especially those that were ambiguous or prompted further discussion
e.g., terms that included “performance”, “recovery”, “component”, “bottom-up”, “boundary”, or “configuration”
- ...terms that implied testing approaches² (see [Derived Test Approaches](#))

If a term’s definition had already been recorded, either the “new” one replaced it if the “old” one wasn’t as clear/concise or parts of both were merged to paint a more complete picture. If any discrepancies or ambiguities arose, they were investigated to a reasonable extent and documented. If a testing approach was mentioned but not defined, it was still added to the glossary to indicate it should be investigated further (see [Undefined Terms](#)). A similar methodology was used for tracking software qualities, albeit in a separate document (see [Derived Test Approaches](#)).

During the first pass of data collection, all software-testing-focused terms were included. Some of them are

²Since these methods for deriving test approaches only arose as research progressed, some examples would have been missed during the first pass(es) of resources investigated earlier in the process. While reiterating over them would be ideal, this may not be possible due to time constraints.

less applicable to test case automation (such as **Static Testing**) or too broad (such as **Attacks**), so they will be omitted over the course of analysis.

C. Undefined Terms

This process also led to some testing approaches without definitions; [10] and [8] in particular introduced many. Once more “standard” sources had been exhausted, a strategy was proposed to look for sources that explicitly defined these terms, with the added benefit of uncovering more terms to explore, potentially in different domains. This also uncovered some out-of-scope testing approaches, including EMSEC testing, HTML testing, and aspects of loop testing and orthogonal array testing; since these are out of scope, relevant sources were not investigated fully.

The following terms (and their respective related terms) were explored, bringing the number of testing approaches from 432 to 515 and the number of undefined terms from 153 to 171 (the assumption can be made that about 78% of added terms also included a definition):

- Assertion Checking
- Loop Testing
- EMSEC Testing
- Asynchronous Testing
- Performance(-related) Testing
- Web Application Testing
 - HTML Testing
 - DOM Testing
- Sandwich Testing
- Orthogonal Array Testing
- Backup Testing

IV. Observations

A. Categories of Testing Approaches

Different sources categorized software testing approaches in different ways; while it is useful to record and think about these categorizations, following one (or more) during the research stage could lead to bias and a prescriptive categorization, instead of letting one emerge descriptively during the analysis stage. Since these categorizations are not mutually exclusive, it also means that more than one could be useful (both in general and to this specific project); more careful thought should be given to which are “best”, and this should happen during the analysis stage.

For classifying different kinds of tests, [10] provides some terminology (see **Table I**). Related testing approaches may be grouped into a “class” or “family” to group those with “commonalities and well-identified variabilities that can be instantiated”, where “the commonalities are large and the variabilities smaller”. Examples of these are the classes of combinatorial [21, p. 15] and data flow testing [p. 3] and

the family of performance-related testing [23, p. 1187]³, and may also be implied for security testing, a test type that consists of “a number of techniques⁴” [21, p. 40].

It also seems that these categories are orthogonal. For example, “a test type can be performed at a single test level or across several test levels” [10, p. 15], [21, p. 7]. Due to this, a specific test approach can be derived by combining test approaches from different categories; for some examples of this. However, the boundaries between items within a category may be unclear: “although each technique is defined independently of all others, in practice [sic] some can be used in combination with other techniques” [21, p. 8]. For example, “the test coverage items derived by applying equivalence partitioning can be used to identify the input parameters of test cases derived for scenario testing” [p. 8]. Even the categories themselves are not consistently defined, as some approaches are categorized differently by different sources; these differences will be tracked noted so that they can be analyzed more systematically. There are also several instances of inconsistencies between parent and child test approach categorizations (which may indicate they aren’t necessarily the same, or that more thought must be given to classification/organization). Examples of discrepancies in test-approach categorization:

- 1) Experience-based testing is categorized as both a test design technique and a test practice on the same page [10, pp. 22, 34]!
- 2) The following are test approaches that are categorized as test techniques in [21, p. 38], followed by sources that categorize them as test types:
 - a) Capacity testing [10, p. 22], [17, p. 2] (implied by [8, p. 53] and by its quality [20], [21, Tab. A.1])
 - b) Endurance testing [17, p. 2] (implied by [8, p. 55])
 - c) Load testing [10, pp. 5, 20, 22], [5, p. 253], [6] (implied by [8, p. 54])
 - d) Performance testing [10, pp. 7, 22, 26-27], [21, p. 7] (implied by [8, p. 53])
 - e) Stress testing [10, pp. 9, 22], [5, p. 442] (implied by [8, p. 54])
- 3) Model-based testing is categorized as both a test practice [10, p. 22], [21, p. viii] and a test technique [24, p. 4] (implied by [21, p. 7], [5, p. 469]).
- 4) Data-driven testing is categorized as both a test practice [10, p. 22] and a test technique [24, p. 43].

³The original source describes “performance testing ... as a family of performance-related testing techniques”, but it makes more sense to consider “performance-related testing” as the “family” with “performance testing” being one of the variabilities.

⁴This may or may not be distinct from the notion of “test technique” described in **IEEE Testing Terminology**.

TABLE I
IEEE Testing Terminology

| Term | Definition | Examples |
|---|--|--|
| Approach | A “high-level test implementation choice, typically made as part of the test strategy design activity” that includes “test level, test type, test technique, test practice and the form of static testing to be used” [10, p. 10]; described by a test strategy [5, p. 472] and is also used to “pick the particular test case values” [5, p. 465] | black or white box, minimum and maximum boundary value testing [5, p. 465] |
| (Design) ^a Technique | A “defined” and “systematic” [5, p. 464] “procedure used to create or select a test model, identify test coverage items, and derive corresponding test cases” [10, p. 11] (similar in [5, p. 467]) “that ... generate evidence that test item requirements have been met or that defects are present in a test item” [21, p. vii]; “a variety ... is typically required to suitably cover any system” [10, p. 33] and is “often selected based on team skills and familiarity, on the format of the test basis”, and on expectations [10, p. 23] | equivalence partitioning, boundary value analysis, branch testing [10, p. 11] |
| Level ^b (sometimes “Phase” ^c or “Stage” ^d) | A stage of testing “typically associated with the achievement of particular objectives and used to treat particular risks”, each performed in sequence [10, p. 12], [21, p. 6] with their “own documentation and resources” [5, p. 469]; more generally, “designat[es] ... the coverage and detail” [5, p. 249] | unit/component testing, integration testing, system testing [10, p. 12], [21, p. 6], [5, p. 467] |
| Practice | A “conceptual framework that can be applied to ... [a] test process to facilitate testing” [10, p. 14], [5, p. 471]; more generally, a “specific type of activity that contributes to the execution of a process” [5, p. 331] | scripted testing, exploratory testing, automated testing [10, p. 20] |
| Type | “Testing that is focused on specific quality characteristics” [10, p. 15], [21, p. 7], [5, p. 473] | security testing, usability testing, performance testing [10, p. 15], [5, p. 473] |

^a“Design technique” is sometimes abbreviated to “technique” [10, p. 11], [6].

^b“Test level” can also refer to the scope of a test process; for example, “across the whole organization” or only “to specific projects” [10, p. 24].

^c“Test phase” can be a synonym for “test level” [5, p. 469], [17, p. 9] but can also refer to the “period of time in the software life cycle” when testing occurs [5, p. 470], usually after the implementation phase [5, pp. 420, 509], [25, p. 56].

^d[9, pp. 5-6 to 5-7], [6], [12, pp. 9, 13].

B. Derived Test Approaches

In addition to methods of categorizing test approaches, the literature also provides multiple methods to derive new ones. Since the field of software is ever-evolving, being able to adapt to new developments, as well as being able to talk about and understand them, is crucial.

1) Coverage-driven Techniques: Test techniques are able to “identify test coverage items ... and derive corresponding test cases” [10, p. 11] (similar in [5, p. 467]) in a “systematic” way [5, p. 464]. This means that a given coverage metric implies a test approach aimed to maximize it; for example, “path testing” is testing that “aims to execute all entry-to-exit control flow paths in a SUT’s control flow graph” [9, p. 5013], thus maximizing the path coverage (see also [26, Fig. 1]).

2) Quality-driven Types: Since test types are “focused on specific quality characteristics” [10, p. 15], [21, p. 7], [5, p. 473], they can be derived from software qualities: “capabilit[ies] of software product[s] to satisfy stated and implied needs when used under specified conditions” [5, p. 424]. This is supported by reliability and performance testing, which are both examples of test types [10, 21] that are based on their underlying qualities [27, p. 18].

After discussing this further, it was decided that tracking software qualities, in addition to testing approaches, would be worthwhile. This was done by capturing their definitions and any rationale for why it might be useful to

consider an explicitly separate “test type” in a separate document, so this information could be captured without introducing clutter. Over time, software qualities were “upgraded” to test types when mentioned (or implied) by a source.

3) Requirements-driven Approaches: While not as universally applicable, some types of requirements have associated types of testing (e.g., functional, non-functional, security). This may mean that categories of requirements also imply related testing approaches (such as “technical testing”). Even assuming this is the case, some types of requirements do not apply to the code itself, and as such are out of scope:

- Nontechnical Requirement: a “requirement affecting product and service acquisition or development that is not a property of the product or service” [5, p. 293]
- Physical Requirement: a “requirement that specifies a physical characteristic that a system or system component must possess” [5, p. 322]

4) Attacks: Since attacks are given as a test practice [10, p. 34], different kinds of software attacks, such as code injection and password cracking, can also be used as test approaches.

V. Discrepancies and Ambiguities

Many subsets of the current state of testing literature contain discrepancies and ambiguities. The following sections outline some of the larger ones, followed by more

Minor Discrepancies, both among sources and within individual ones, that may be areas for further investigation.

A. Synonyms

There exist many test approaches with multiple synonyms. For example, synonyms for specification-based testing include:

- 1) Black-Box Testing [10, p. 9], [21, p. 8], [5, p. 431], [9, p. 5-10], [6], [8, p. 46] (without hyphen), [28, p. 344], [15, p. 399]
- 2) Closed-Box Testing [10, p. 9], [5, p. 431]
- 3) Functional Testing [5, p. 196], [24, p. 44], [15, p. 399] (implied by [21, p. 129], [5, p. 431])
- 4) Domain Testing [9, p. 5-10]
- 5) Input Domain-Based Testing (implied by [16, p. 4-8])

While some of these synonyms may be incorrect, the legitimate ones carry different connotations. I use the terms “specification-based” and “structure-based testing” since they articulate the source of the information for designing test cases, but a team or project also using gray-box testing may prefer the terms “black-box” and “white-box testing” for consistency. Because of this, the existence of synonyms is not inherently a discrepancy.

However, there are instances in which a term is given a synonym to two (or more) disjoint, unrelated terms, which would be a source of ambiguity to teams using these terms. The following are some examples that have arisen:

- 1) Invalid Testing:
 - Error Tolerance Testing [24, p. 45]
 - Negative Testing [6], implied by [21, p. 10]
- 2) Soak Testing:
 - Endurance Testing [21, p. 39]
 - Reliability Testing [7, Tab. 1, p. 26], [12, Tab. 2]Endurance testing is given as a kind of reliability testing by [8, p. 55], but the two are not described as synonyms.
- 3) User Scenario Testing:
 - Scenario Testing [6]
 - Use Case Testing [24, p. 48]“Scenario testing” and “use case testing” are given as synonyms by [6] and [24, pp. 47-49], but listed separately by [10, p. 22] and [21, p. 20]; the latter gives use case testing as a “common form of scenario testing”. Since the actor in a use case “can be a user or another system” [21, p. 20], “use case testing” may instead be a child of “user scenario testing”.
- 4) Link Testing:
 - Branch Testing (implied by [21, p. 24])
 - Component Integration Testing [24, p. 45]
 - Integration Testing (implied by [12, p. 13])

There are also some pairs of synonyms where one is sometimes described as a sub-approach of the other, making the relationship between them unclear. As above,

some examples are given below, with as many sources given as possible (any relationships without a source provided are inferred from their definitions):

- 1) “All transitions testing” is called a sub-approach of “state transition testing” in [21, p. 19], but the two are called synonyms in [24, p. 15].
- 2) “Co-existence testing” is called a sub-approach of “compatibility testing” in (20; 10, p. 3; 21, Tab. A.1), but the two are called synonyms in [21, p. 37].
- 3) “Fault tolerance testing” is called a sub-approach of “robustness testing” in [8, p. 56], but the two are called synonyms in [6].
- 4) “Functional testing” is called a sub-approach of “specification-based testing” in [21, p. 38], but the two are called synonyms in (5, p. 196; 24, p. 44; 15, p. 399; implied by 21, p. 129; 5, p. 431).
- 5) “Orthogonal array testing” is called a sub-approach of “pairwise testing” in [29, p. 1055], but the two are called synonyms in (9, p. 5-11; 30, p. 473).
- 6) “Performance testing” is called a sub-approach of “performance-related testing” in (10, p. 22; 21, p. 38), but the two are called synonyms in [23, p. 1187].
- 7) “Use case testing” is called a sub-approach of “scenario testing” in (21, p. 20), but the two are called synonyms in ([6]; 24, pp. 47-49).
- 8) “Condition testing” is implied to be a sub-approach of “decision testing” in [6], but the two are called synonyms in (9, p. 5-13).
- 9) “Dynamic analysis” is implied by its static counterpart to be a sub-approach of “dynamic testing” in (10, pp. 9, 17, 25, 28; [6]), but the two are called synonyms in [5, p. 149].
- 10) “Beta testing” is implied to be a sub-approach of “user testing” in [8, p. 39], but the two are implied to be synonyms in [8, p. 39].
- 11) “Functionality testing” may be a sub-approach of “functional suitability testing”, but the two are called synonyms in [6].
- 12) “Programmer testing” is called a sub-approach of “developer testing” in [8, p. 39], but the two may be synonyms.
- 13) “Structured walkthroughs” may be a sub-approach of “walkthroughs”, but the two are called synonyms in [6].
- 14) “Functionality testing” may be a sub-approach of “functional suitability testing”, but the two are implied to be synonyms in [6].

The relationships between the following pairs of approaches aren’t given in any investigated sources and are also ambiguous, based on their definitions. In each pair, the first may be a sub-approach of the second, or they may be synonyms.

- Field testing and operational testing
- Organization-based testing and role-based testing

- System qualification testing and system testing

Some interesting notes about these two lists of discrepancies:

- Fault tolerance testing may also be a subtype⁵ of reliability testing [5, p. 375; 9, p. 7-10], which is distinct from reliability testing [8, p. 53].
- The distinction between organization- and role-based testing in [8, pp. 17, 37, 39] seems arbitrary, but further investigation may prove it to be meaningful.

B. Parent Relations

There are also some issues with how parent relations are defined in the literature, the most trivial being self-cycles, where a source describes a test approach as a subset of itself:

- 1) Performance Testing (12, Tab. 2; 7, Tab. 1)
- 2) Usability Testing (12, Tab. 2; 7, Tab. 1)

Interestingly, [12, Tab. 2] and [7, Tab. 1] do not describe performance testing as a sub-category of usability testing, which would have been more meaningful.

C. Functional Testing

Throughout the literature, “functional testing” seems to be described in many ways, alongside other, potentially related, terms:

- Specification-based Testing: This is defined as “testing in which the principal test basis is the external inputs and outputs of the test item” [10, p. 9], which agrees with a definition of “functional testing”: “testing that ... focuses solely on the outputs generated in response to selected inputs and execution conditions” [5, p. 196]. Notably, [5] lists both as synonyms of “black-box testing” (pp. 431, 196, respectively). However, they are sometimes defined as separate terms: “specification-based testing” as “testing based on an analysis of the specification of the component or system” (including “black-box testing” as a synonym) and “functional testing” as “testing performed to evaluate if a component or system satisfies functional requirements” (specifying no synonyms) [6]. This definition of “functional testing” references [5, p. 196] (“testing conducted to evaluate the compliance of a system or component with specified functional requirements”) which has “black-box testing” as a synonym, and mirrors [10, p. 21] (testing “used to check the implementation of functional requirements”). Overall, specification-based testing [10, pp. 2-4, 6-9, 22] and black-box testing (9, p. 5-10; 3, p. 3) are test design techniques used to “derive corresponding test cases” [10, p. 11] (from given “selected inputs and execution conditions” [5, p. 196]).

⁵Not formally defined, but distinct from the notion of “test type” described in [IEEE Testing Terminology](#).

- Correctness Testing: [9, p. 5-7] says “test cases can be designed to check that the functional specifications are correctly implemented, which is variously referred to in the literature as conformance testing, correctness testing or functional testing”; this mirrors previous definitions of “functional testing” (10, p. 21; 5, p. 196) but groups it with “correctness testing”. Since “correctness” is a software quality (5, p. 104; 9, p. 3-13) which is what defines a “test type” [10, p. 15], it seems consistent to label “functional testing” as a “test type” [10, pp. 15, 20, 22]. This is listed separately from “functionality testing” by [8, p. 53].
- Conformance Testing: As mentioned above, [9, p. 5-7] says testing “that the functional specifications are correctly implemented” can be called “conformance testing” or “functional testing”. The definition of “conformance testing” is later given as testing used “to verify that the SUT conforms to standards, rules, specifications, requirements, design, processes, or practices” [9, p. 5-7]. This definition seems to be a superset of the testing mentioned earlier; the former only lists “specifications” while the latter also includes “standards”, “rules”, “requirements”, “design”, “processes”, and “practices”! Another complicating factor is that “compliance testing” is also given as a synonym of “conformance testing” [24, p. 43], which seems plausible. However, “conformance testing” can also be defined as testing that evaluates the degree to which “results ... fall within the limits that define acceptable variation for a quality requirement” [5, p. 93], which seems to describe something different. Perhaps this second definition of “conformance testing” should be used, and the previous definition of “compliance testing” be used for describing compliance with external standards, rules, etc. to keep them distinct.
- Functional Suitability Testing: Procedure testing is called a “type of functional suitability testing” [10, p. 7], but no definition of “functional suitability testing” is given. “Functional suitability” is the “capability of a product to provide functions that meet stated and implied needs of intended users when it is used under specified conditions”, including meeting “the functional specification” [20]. This seems to align with the definition of “functional testing” as related to “black-box/specification-based testing”. “Functional suitability” has three child terms: “functional completeness” (the “capability of a product to provide a set of functions that covers all the specified tasks and intended users’ objectives”), “functional correctness” (the “capability of a product to provide accurate results when used by intended users”), and “functional appropriateness” (the “capability of a product to provide functions that facilitate the accomplishment of specified tasks and objectives”) [20]. Notably, “functional correctness”, which includes precision and

accuracy [20; 6]), seems to align with the quality/ies that would be tested by “correctness” testing.

- **Functionality Testing:** “Functionality” is defined as the “capabilities of the various ... features provided by a product” [5, p. 196] and is said to be a synonym of “functional suitability” [6], although it seems like it should really be its “parent”. Its associated test type is implied to be a sub-approach of build verification testing [6] and made distinct from “functional testing”; interestingly, security is described as a sub-approach of both non-functional and functionality testing [12, Tab. 2]. This is listed separately from “correctness testing” by [8, p. 53].

D. Operational (Acceptance) Testing

Some sources refer to “operational acceptance testing” (10, p. 22; [6]) while some refer to “operational testing” (9, p. 6-9, in the context of software engineering operations; 31; 5, p. 303; 16, pp. 4-6, 4-9). A distinction is sometimes made [8, p. 30] but without accompanying definitions, it is hard to evaluate its merit. Since this terminology is not standardized, I propose that the two terms are treated as synonyms (as done by other sources [32, 33]) as a type of acceptance testing (10, p. 22; [6]) that focuses on “non-functional” attributes of the system [32].

A summary of given definitions of “operational (acceptance) testing” is that it is “test[ing] to determine the correct installation, configuration and operation of a module and that it operates securely in the operational environment” [31] or “evaluate a system or component in its operational environment” [5, p. 303], particularly “to determine if operations and/or systems administration staff can accept [it]” [6].

E. Recovery Testing

There are many terms related to “recovery testing”, which is “testing ... aimed at verifying software restart capabilities after a system crash or other disaster” [9, p. 5-9] including “recover[ing] the data directly affected and re-establish[ing] the desired state of the system” [20] (similar in [9, p. 7-10]) so that the system “can perform required functions” [5, p. 370]. It is also called “recoverability testing” [24, p. 47] and potentially “restart & recovery (testing)” [12, Fig. 5]. The following terms, along with “recovery testing” itself [10, p. 22] are all classified as test types, and the relations between them can be found in Figure 1.

- **Recoverability Testing:** Testing “how well a system or software can recover data during an interruption or failure” [9, p. 7-10] (similar in [20]) and “re-establish the desired state of the system” [20]. Given as a synonym for “recovery testing” by [24, p. 47].
- **Disaster/Recovery Testing:** Testing to evaluate if a system can “return to normal operation after a hardware or software failure” [5, p. 140] or if “operation of the test item can be transferred to a different

operating site and ... be transferred back again once the failure has been resolved” [21, p. 37]. These two definitions seem to describe different aspects of the system, where the first is intrinsic to the hardware/software and the second might not be.

- **Backup and Recovery Testing:** Testing “that measures the degree to which system state can be restored from backup within specified parameters of time, cost, completeness, and accuracy in the event of failure” [17, p. 2]. This may be what is meant by “recovery testing” in the context of performance-related testing and seems to correspond to the definition of “disaster/recovery testing” in [5, p. 140].
- **Backup/Recovery Testing:** Testing that determines the ability “to restor[e] from back-up memory in the event of failure, without transfer[ing] to a different operating site or back-up system” [21, p. 37]. This seems to correspond to the definition of “disaster/recovery testing” in [21, p. 37]. It is also given as a sub-type of “disaster/recovery testing”, even though that tests if “operation of the test item can be transferred to a different operating site” [p. 37].
- **Failover/Recovery Testing:** Testing that determines the ability “to mov[e] to a back-up system in the event of failure, without transfer[ing] to a different operating site” [21, p. 37]. This is given as a sub-type of “disaster/recovery testing”, even though that tests if “operation of the test item can be transferred to a different operating site” [p. 37].
- **Failover Testing:** Testing that “validates the SUT’s ability to manage heavy loads or unexpected failure to continue typical operations” [9, p. 5-9] by entering a “backup operational mode in which [these responsibilities] ... are assumed by a secondary system” [6]. While not explicitly related to recovery, “failover/recovery testing” also describes the idea of “failover”, and [8, p. 56] uses the term “failover and recovery testing”, which could be a synonym of both of these terms.

F. Scalability Testing

There were three ambiguities around the term “scalability testing”, given below. The relations between these test approaches (and other relevant ones) are shown in Figure 3.

- 1) Reference [21, p. 39] gives “scalability testing” as a synonym of “capacity testing” while other sources differentiate between the two [8, p. 53], [34, pp. 22-23]
- 2) Reference [21, p. 39] includes the external modification of the system as part of “scalability”, while [20] implies that it is limited to the system itself
- 3) SWEBOK V4’s definition of “scalability testing” [9, p. 5-9] is really a definition of usability testing!

G. Minor Discrepancies

The following sections outline more “minor” discrepancies/ambiguities found in the literature, group by the “categories” of sources outlined in [Methodology](#).

1) Discrepancies in Standards: The following discrepancies are from [5, 10, 17, 18, 19, 20, 21, 31, 35, 36]:

- 1) “Compatibility testing” is defined as “testing that measures the degree to which a test item can function satisfactorily alongside other independent products in a shared environment (co-existence), and where necessary, exchanges information with other systems or components (interoperability)” [10, p. 3]. This definition is nonatomic as it combines the ideas of “co-existence” and “interoperability”. The term “interoperability testing” is not defined, but is used three times [10, pp. 22, 43] (although the third usage seems like it should be “portability testing”). This implies that “co-existence testing” and “interoperability testing” should be defined as their own terms, which is supported by definitions of “co-existence” and “interoperability” often being separate ([6]; 5, pp. 73, 237), the definition of “interoperability testing” from [5, p. 238], and the decomposition of “compatibility” into “co-existence” and “interoperability” by [20]!
 - The “interoperability” element of “compatibility testing” is explicitly excluded by [21, p. 37], (incorrectly) implying that “compatibility testing” and “co-existence testing” are synonyms.
 - The definition of “compatibility testing” in [24, p. 43] unhelpfully says “See interoperability testing”, adding another layer of confusion to the direction of their relationship.
- 2) “Fuzz testing” is “tagged” (?) as “artificial intelligence” [10, p. 5], although I don’t think this is a set-in-stone requirement.
- 3) Integration, system, and system integration testing are all listed as “common test levels” (10, p. 12; 21, p. 6), but no definitions are given for the latter two, making it unclear what “system integration testing” is; it is a combination of the two? somewhere on the spectrum between them? It is listed as a child of integration testing by [6] and of system testing by [8, p. 23].
- 4) Similarly, component, integration, and component integration testing are all listed in [5], but “component integration testing” is only defined as “testing of groups of related components” [5, p. 82]; it is a combination of the two? somewhere on the spectrum between them? Likewise, it is listed as a child of integration testing by [6].
- 5) “Installability testing” is given as a test type (10, p. 22; 21, p. 38) but is sometimes called a test level as “installation testing” [14, p. 445].

- 6) Retesting and regression testing seem to be separated from the rest of the testing approaches [10, p. 23], but it is not clearly detailed why; [37, p. 3] consider regression testing to be a test level.
 - 7) A component is an “entity with discrete structure ... within a system considered at a particular level of analysis” [18] and “the terms module, component, and unit [sic] are often used interchangeably or defined to be subelements of one another in different ways depending upon the context” with no standardized relationship [5, p. 82]. This means unit/component/module testing can refer to the testing of both a module and a specific function in a module. However, “component” is sometimes defined differently than “module”: “components differ from classical modules for being re-used in different contexts independently of their development” [38, p. 107], so distinguishing the two may be necessary.
 - 8) A typo in [21, Fig. 2] means that “specification-based techniques” is listed twice, when the latter should be “structure-based techniques”.
 - 9) (author?) define an “extended entry (decision) table” both as a decision table where the “conditions consist of multiple values rather than simple Booleans” [21, p. 18] and one where “the conditions and actions are generally described but are incomplete” [5, p. 175].
 - 10) The subcategories of “performance-related testing” that are categorized as test types by other sources [5, 10, 17] are categorized as techniques in [21, p. 39].
 - 11) (author?) provide a definition for “inspections and audits” [5, p. 228], despite also giving definitions for “inspection” (p. 227) and “audit” (p. 36); while the first term could be considered a superset of the latter two, this distinction doesn’t seem useful.
 - 12) (author?) say that “test level” and “test phase” are synonyms, both meaning a “specific instantiation of [a] test sub-process” (5, pp. 469, 470; 17, p. 9), but there are also alternative definitions for them. “Test level” can also refer to the scope of a test process; for example, “across the whole organization” or only “to specific projects” [10, p. 24], while “test phase” can also refer to the “period of time in the software life cycle” when testing occurs [5, p. 470], usually after the implementation phase [5, pp. 420, 509], [25, p. 56].
 - 13) (author?) use the same definition for “partial correctness” [5, p. 314] and “total correctness” (p. 480).
- 2) Discrepancies in “Meta-Level” Sources: The following discrepancies are either intrinsic to SWEBOK [9, 16], ISTQB [6], or another collection of testing terminology [so far only 8] (as described in [Methodology](#)), or between one of these and a source from a previous “category”:
- resume
- 1) SWEBOK V4 defines “privacy testing” as testing that “assess[es] the security and privacy of users’

personal data to prevent local attacks” [9, p. 5-10]; this seems to overlap with (author?)’s definition of “security testing”, which is “conducted to evaluate the degree to which a test item, and associated data and information, are protected so that” only “authorized persons or systems” can use them as intended [10, p. 9], both in scope and name.

- 2) Various sources say that alpha testing is performed by different people, including “only by users within the organization developing the software” [5, p. 17], by “a small, selected group of potential users” [9, p. 5-8], or “in the developer’s test environment by roles outside the development organization” [6].
- 3) While correct, ISTQB’s definition of “specification-based testing” is not helpful: “testing based on an analysis of the specification of the component or system” [6].
- 4) “ML model testing” and “ML functional performance” are defined in terms of “ML functional performance criteria”, which is defined in terms of “ML functional performance metrics”, which is defined as “a set of measures that relate to the functional correctness of an ML system” [6]. The use of “performance” (or “correctness”) in these definitions are at best ambiguous and at worst incorrect.
- 5) While ergonomics testing is out of scope (as it tests hardware, not software), its definition of “testing to determine whether a component or system and its input devices are being used properly with correct posture” [6] seems to focus on how the system is used as opposed to the system itself.
- 6) The definition of “math testing” given by [6] is too specific to be useful, likely taken from an example instead of a general definition: “testing to determine the correctness of the pay table implementation, the random number generator results, and the return to player computations”.
- 7) A similar issue exists with multiplayer testing, where its definition specifies “the casino game world” [6].
- 8) Thirdly, “par sheet testing” from [6] seems to refer to this specific example and does not seem more widely applicable, since a “PAR sheet” is “a list of all the symbols on each reel of a slot machine” [39].
- 9) [6] describe the term “software in the loop” as a kind of testing, while the source it references seems to describe “Software-in-the-Loop-Simulation” as a “simulation environment” that may support software integration testing [40, p. 153]; is this a testing approach or a tool that supports testing?
- 10) The source cited for the definition of “test type” from [6] does not seem to provide a definition itself.
- 11) The same is true for “visual testing”.
- 12) The same is true for “security attack”.
- 13) There is disagreement on the structure of tours; they can either be quite general [10, p. 34] or “organized

around a special focus” [6].

- 14) While model testing is said to test the object under test, it seems to describe testing the models themselves [8, p. 20]; using the models to test the object under test seems to be called “driver-based testing” (p. 33).
- 15) “System testing” is listed as a subtype of “system testing” by [8, p. 23].
- 16) “Hardware-” and “human-in-the-loop testing” have the same acronym: “HIL”⁶ [8, p. 23].
- 17) The same is true for “customer” and “contract(ual) acceptance testing” (“CAT”) [8, p. 30].
- 18) The acronym “SoS” is used but not defined by [8, p. 23].
- 19) It is ambiguous whether “tool/environment testing” refers to testing the tools/environment themselves or using them to test the object under test; the latter is implied, but the wording of its subtypes [8, p. 25] seems to imply the former.
- 20) (author?) say that performance and security testing are subtypes of reliability testing [20], but these are all listed separately by [8, p. 53].
- 21) The distinctions between development testing [5, p. 136], developmental testing [8, p. 30], and developer testing [8, p. 39; 12, p. 11] are unclear and seem miniscule.

3) Discrepancies in McMaster-Trusted Sources: The following discrepancies are either intrinsic to a textbook trusted at McMaster [13, 14, 15], between these textbooks, or between one of them and a source from a previous “category”:

resume

- 1) “Load testing” is defined as using loads “usually between anticipated conditions of low, typical, and peak usage” [10, p. 5], while (author?) says the loads should as large as possible [13, p. 86].

4) Discrepancies in Other Sources: The following discrepancies are either intrinsic to a source not in one of the above “categories”, between two of these sources, or between one of these and a source from a previous “category”:

resume

- 1) (author?) lists “three [backup] location categories: local, offsite and cloud based [sic]” [34, p. 16], but does not define or discuss “offsite backups” (pp. 16-17).
- 2) (author?) claim that [28] defines “prime path coverage” [42, p. 184], but it doesn’t.
- 3) “State-based” is misspelled by (author?) as “state-base” [24, pp. 13, 15] and “stated-base” (Tab. 1).
- 4) Although ad hoc testing is sometimes classified as a “technique” [9, p. 5-14], it is one in which “no recognized test design technique is used” [24, p. 42].

⁶“HiL” is used for the former by [41, p. 2].

- 5) (author?)’s definition of “boundary value testing” says “See boundary value analysis,” but this definition is not present [24].
- 6) “Conformance testing” is implied to be a synonym of “compliance testing” by (author?), which only makes sense because of the vague definition of “compliance testing”: “testing to determine the compliance of the component or system” [24, p. 43].
- 7) (author?) seems to imply that “mutation testing” is a synonym of “back-to-back testing” [24, p. 46], but these are two quite distinct techniques.
- 8) (author?) also says that the goal of negative testing is “showing that a component or system does not work” [24, p. 46], which is not true; if robustness is an important quality for the system, then testing the system “in a way for which it was not intended to be used” [6] (i.e., negative testing) is one way to help test this!
- 9) “Program testing” is given as a synonym of “component testing” [24, p. 46], although it probably should be a synonym of “system testing” instead.
- 10) (author?) give “white-”, “grey-”, and “black-box testing” as synonyms for “module”, “integration”, and “system testing”, respectively [43, p. 18], but this mapping is incorrect; black-box testing can be performed on a module, for example. This makes the claim that “red-box testing” is a synonym for “acceptance testing” (p. 18) lose credibility.
- 11) Availability testing isn’t assigned to a test priority [12, Tab. 2], despite the claim that “the test types⁷ have been allocated a slot against the four test priorities” (p. 13); I think usability and/or performance would have made sense.
- 12) “Visual browser validation” is described as both static and dynamic in the same table [12, Tab. 2], even though they are implied to be orthogonal classifications: “test types can be static or dynamic” (p. 12, emphasis added).
- 13) (author?) makes a distinction between “transaction verification” and “transaction testing” [12, Tab. 2] and also uses the phrase “transaction flows” (Fig. 5) but doesn’t explain them.
- 14) The phrase “continuous automated testing” [12, p. 11] is redundant since continuous testing is a subcategory of automated testing (10, p. 35, [6]).
- 15) End-to-end functionality testing is not indicated to be functionality testing [12, Tab. 2].
- 16) (author?)’s definition for “security audits” seems too specific, only applying to “the products installed on a site” and “the known vulnerabilities for those products” [7, p. 28].

⁷“Each type of test addresses a different risk area” [12, p. 12], which is distinct from the notion of “test type” described in **IEEE Testing Terminology**.

VI. Recommendations

The following sections provide different recommendations for resolving various discrepancies (see **Discrepancies and Ambiguities**). This was done with the goal of organizing them more logically and making them:

- 1) Atomic (e.g., disaster/recovery testing seems to have two disjoint definitions)
- 2) Straightforward (e.g., backup and recovery testing’s definition implies the idea of performance, but its name does not; failover/recovery testing, failover and recovery testing, and failover testing are all given separately)
- 3) Consistent (e.g., backup/recovery testing and failover/recovery testing explicitly exclude an aspect included in its parent disaster/recovery testing)

A. Recovery Testing

The following terms should be used in place of the current terminology to more clearly distinguish between different recovery-related test approaches:

- Recoverability Testing: “Testing ... aimed at verifying software restart capabilities after a system crash or other disaster” [9, p. 5-9] including “recover[ing] the data directly affected and re-establish[ing] the desired state of the system” [20] (similar in [9, p. 7-10]) so that the system “can perform required functions” [5, p. 370]. “Recovery testing” will be a synonym, as in [24, p. 47], since it is the more prevalent term throughout various sources, although “recoverability testing” is preferred to indicate that this explicitly focuses on the ability to recover, not the performance of recovering.
- Failover Testing: Testing that “validates the SUT’s ability to manage heavy loads or unexpected failure to continue typical operations” [9, p. 5-9] by entering a “backup operational mode in which [these responsibilities] ... are assumed by a secondary system” [6]. This will replace “failover/recovery testing”, since it is more clear, and since this is one way that a system can recover from failure, it will be a subset of “recovery testing”.
- Transfer Recovery Testing: Testing to evaluate if, in the case of a failure, “operation of the test item can be transferred to a different operating site and ... be transferred back again once the failure has been resolved” [21, p. 37]. This replaces the second definition of “disaster/recovery testing”, since the first is just a description of “recovery testing”, and could potentially be considered as a kind of failover testing. This may not be intrinsic to the hardware/software (e.g., may be the responsibility of humans/processes).
- Backup Recovery Testing: Testing that determines the ability “to restor[e] from back-up memory in the event of failure” [21, p. 37]. The qualification that this occurs “without transfer[ing] to a different operating

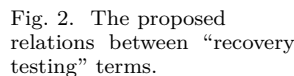
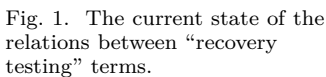
Recovery Performance Testing: Testing “how well a system or software can recover ... [from] an interruption or failure” [9, p. 7-10] (similar in [20]) “within specified parameters of time, cost, completeness, and accuracy” [17, p. 2]. The distinction between the performance-related elements of recovery testing seemed to be meaningful, but was not captured consistently by the literature. This will be a subset of “performance-related testing” as “recovery testing” is in [10, p. 22]. This could also be extended into testing the performance of specific elements of recovery (e.g., failover performance testing), but this be too fine-grained and may better be captured as an orthogonally derived test approach.

Unfortunately, only focusing on future capacity requirements still leaves room for ambiguity. While the previous definition of “scalability testing” includes the external modification of the system, [20] describes it as testing the “capability of a product to handle growing or shrinking workloads or to adapt its capacity to handle variability”, implying that this is done by the system itself. The potential reason for this is implied by SWEBOK V4’s claim that one objective of elasticity testing is “to evaluate scalability” [9, p. 5-9]: [20]’s notion of “scalability” likely refers more accurately to “elasticity”! This also makes sense in the context of other definitions provided by SWEBOK V4 [9]:

This distinction is also consistent with how the terms are used in industry: [44] says that scalability is the ability to “increase ... performance or efficiency as demand increases over time”, while elasticity allows a system to “tackle changes in the workload [that] occur for a short period”.

C. Performance(-related) Testing

⁸While this definition seems correct, it only cites a single source that doesn't contain the words "elasticity" or "elastic"!



The ambiguity around scalability testing found in the literature is resolved and/or explained by other sources! [21, p. 39] gives “scalability testing” as a synonym of “capacity testing”, defined as the testing of a system’s ability to “perform under conditions that may need to be supported in the future” which “may include assessing what level of additional resources (e.g. memory, disk capacity, network bandwidth) will be required to support anticipated future loads”. This focus on “the future” is supported by [6], which defines “scalability” as “the degree to which a component or system can be adjusted for changing capacity”. In contrast, capacity testing focuses on the system’s present state, evaluating the “capability of a product to meet requirements for the maximum

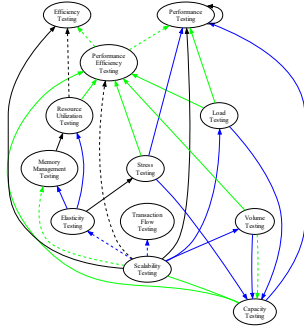


Fig. 3. The current state of the relations between “scalability testing” terms.

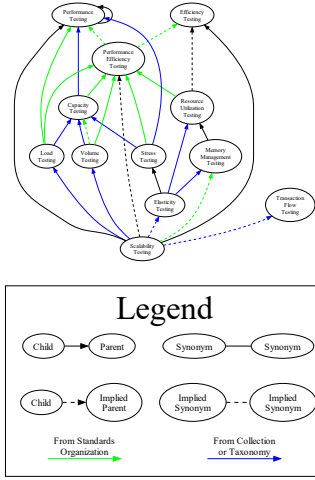


Fig. 4. The proposed relations between “scalability testing” terms.

designated functions” [5, p. 320], [10, p. 7] (similar in [21, pp. 38-39], [23, p. 1187]). It does this by “measuring the performance metrics” [23, p. 1187] (similar in [6]) (such as the “system’s capacity for growth” [7, p. 23]), “detecting the functional problems appearing under certain execution conditions” [23, p. 1187], and “detecting violations of non-functional requirements under expected and stress conditions” [23, p. 1187] (similar in [9, p. 5-9]). It is performed either ...

- 1) ... “within given constraints of time and other resources” [5, p. 320], [10, p. 7] (similar in [23, p. 1187]), or
- 2) ... “under a ‘typical’ load” [21, p. 39].

It is listed as a subset of performance-related testing, which is defined as testing “to determine whether a test item performs as required when it is placed under various types and sizes of ‘load’” [21, p. 38], along with other approaches like load and capacity testing [10, p. 22]. In contrast, [9, p. 5-9] gives “capacity and response time” as examples of “performance characteristics” that performance testing would seek to “assess”, which seems to imply that these are sub-approaches to performance testing instead. This is consistent with how some sources treat “performance testing” and “performance-related testing” as synonyms [9, p. 5-9], [23, p. 1187], as noted in **Synonyms**. This makes sense because of how general the concept of “performance” is; most definitions of “performance testing” seem to treat it as a category of tests.

However, it seems more consistent to infer that the definition of “performance-related testing” is the more general one often assigned to “performance testing” performed “within given constraints of time and other resources” [5, p. 320], [10, p. 7] (similar in [23, p. 1187]), and “performance testing” is a sub-approach of this performed “under

a ‘typical’ load” [21, p. 39]. This has other implications for relations between these types of testing; for example, “load testing” usually occurs “between anticipated conditions of low, typical, and peak usage” [5, p. 253], [6], [10, p. 5], [21, p. 39], so it is a child of “performance-related testing” and a parent of “performance testing”.

Finally, the “self-loops” mentioned in **Parent Relations** provide no new information and can be removed. These changes (along with those from **Recovery Testing** and **Scalability Testing** made implicitly) result in the relations shown in Figure 5.

Acknowledgment

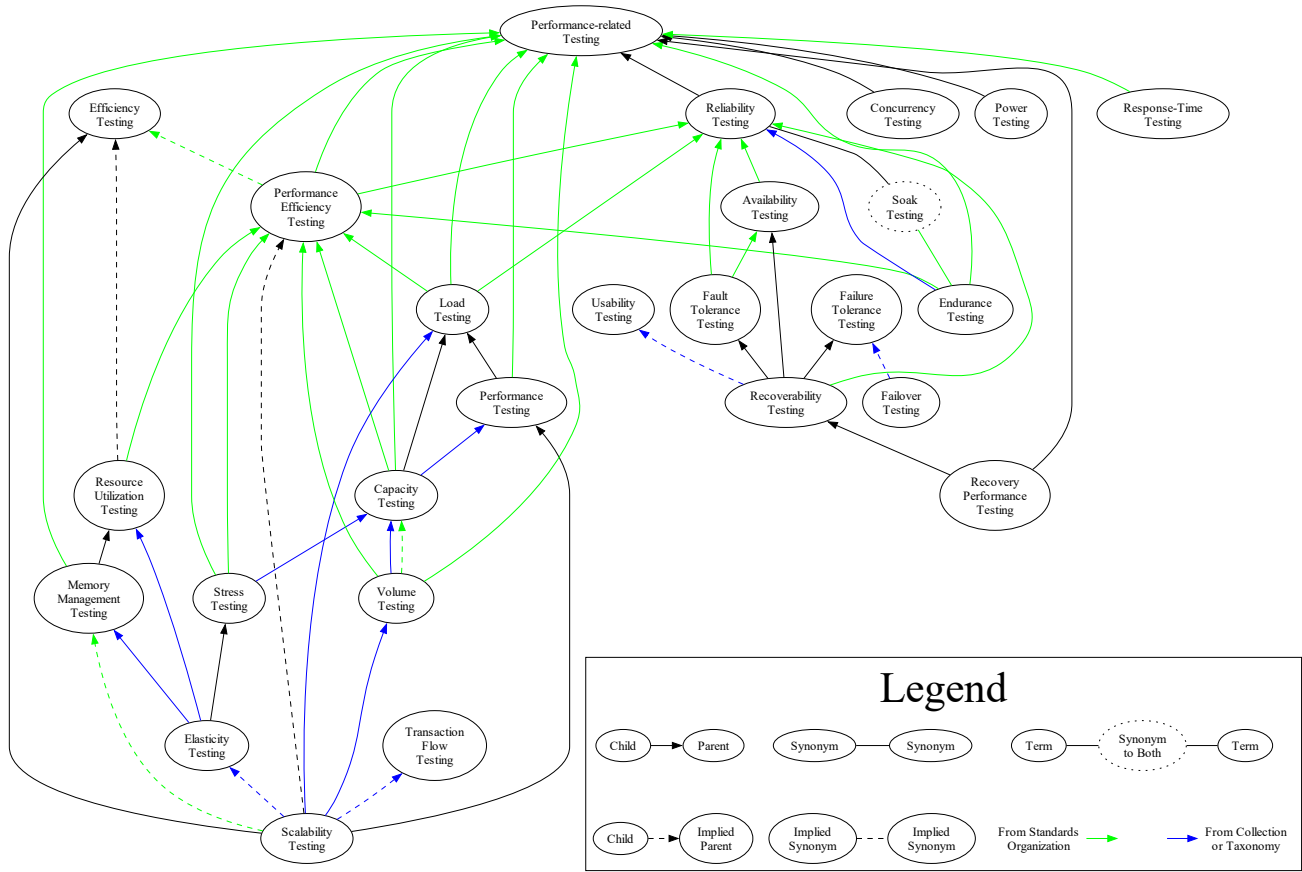


Fig. 5. The proposed relations between “performance-related testing” terms.

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