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1 On Temporal and Separation Logics

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6 — Abstract —

7 There exist many success stories about the introduction of logics designed for the formal verifica-
8 tion of computer systems. Obviously, the introduction of temporal logics to computer science has
9 been a major step in the development of model-checking techniques. More recently, separation
10 logics extend Hoare logic for reasoning about programs with dynamic data structures, leading
11 to many contributions on theory, tools and applications. In this talk, we illustrate how several
12 features of separation logics, for instance the key concept of separation, are related to similar
13 notions in temporal logics. We provide formal correspondences (when possible) and present an
14 overview of related works from the literature. This is also the opportunity to present bridges
15 between well-known temporal logics and more recent separation logics.

16 **2012 ACM Subject Classification** Theory of Computation, Logic, Modal and Temporal Logics,
17 Separation Logic

18 **Keywords and phrases** separation logics, temporal logics, expressive power

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20 **Category** invited paper

21 **1 Separation Logics**

22 Separation logic has been introduced as an extension of Hoare logic [24] to verify programs
23 with mutable data structures [28, 39, 41]. A major feature is to be able to reason locally
24 in a modular way, which can be performed thanks to the separating conjunction $*$ that
25 allows one to state properties in disjoint parts of the memory. The companion connective -*
26 corresponding to separating implication (a.k.a the magic wand) happens to be also helpful
27 for program verification. So, the study of separation logics is currently very active, with
28 works ranging from foundations to formal verification of programs. For instance, since the
29 evidence that the method is scalable [3, 46], many tools supporting separation logic as an
30 assertion language have been developed [3, 20, 46, 9, 10, 21]. Moreover, many variants
31 of separation logics have been considered, leading to many interesting problems related to
32 decidability/complexity of reasoning tasks, expressive power, relationships with other logical
33 formalisms, proof systems, etc. It is not reasonable to enumerate herein all the existing
34 variants and research directions. By way of example, decidability results about separation
35 logic with general inductive predicates can be found in [27, 7]: notably in [7], the satisfiability
36 problem for the symbolic heap fragment [2] with general inductively defined predicates is
37 shown decidable. Furthermore, as already advocated in [8, 43, 42, 26, 37], dealing with
38 the separating implication -* is a desirable feature for program verification and several
39 semi-automated or automated verification tools support it in some way, see e.g. [43, 42, 37],
40 going beyond separation logics built over the symbolic heap fragment. Nevertheless, the
41 combination of the magic wand -* and the list segment predicate ls (a simple inductive
42 predicate) may lead to undecidability [19]. First-order separation logics have been also been



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43 considered in [2, 6, 16]. So, the first part of the talk is dedicated to basics on separation
 44 logics.

45 **2 Relating Modal/Temporal Logics with Separation Logics.**

46 As the first versions of separation logic can be understood as a concretisation of the logic
 47 of bunched implication BI [38, 28, 40], it is not surprising that separation logics can be
 48 related to other logics, see also [15]. For instance, the concept of separation can be found in
 49 interval temporal logics (see e.g. [44, 45, 25, 35]), in graph logics (see e.g. [14, 1]), or in other
 50 formalisms [23, 22, 4]. Besides, as for temporal logics, the relationships between separation
 51 logic, and first-order or second-order logics have been the source of many characterizations
 52 and works. This is particularly true since the separating connectives are second-order in
 53 nature, see e.g. [32, 29, 11, 6, 17]. Moreover, separation logics can be shown to have close
 54 relationships with hybrid modal logics (see e.g. [8, 18]), with relevance logics (see e.g. [13, 12])
 55 or with logics equipped with associative binary modalities (see e.g. [30, 4]).

56 In this talk, we illustrate how several features of separation logics are related to similar
 57 notions in temporal logics. We provide formal correspondences (when possible) and present
 58 an overview of related works from the literature. It is worth noting that temporal logics and
 59 separation logics can be related in many ways. At the semantical level, memory states from
 60 separation logics can be understood as tree-like models or as linear structures, see e.g. [16, 18]
 61 leading to explicit relationships with temporal logics on similar structures. Nevertheless,
 62 the correspondence is not always immediate. At the level of the operators, separation
 63 is a key concept that has been already introduced in interval temporal logic PITL [36].
 64 Relationships between interval temporal logics and separation logics can be formally stated,
 65 see e.g. [16, 18, 34] and we shall show how complexity results about separation logics can
 66 be concluded. Typically, the TOWER-hardness of the satisfiability problem for first-order
 67 separation logics restricted to the separation conjunction and to two individual variables
 68 with one record field, can be established by reduction the satisfiability problem for PITL [16].

69 Similarly to the links between separation logics and (weak) second-order logics, ongoing
 70 investigations¹ relating separation logics with quantified temporal logics [31] shall be
 71 also evoked. So, apart from the analogies between temporal logics and separation logics
 72 and cross-fertilising results, we also motivate the introduction of formalisms that combine
 73 modal/temporal logics and separation logics, see e.g. [5, 33, 18], in order to reason about
 74 resources in a temporal framework.

75 So, the talk is the opportunity to present bridges between well-known temporal logics
 76 and more recent separation logics.

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¹ Bartosz Bednarczyk's internship at LSV (2018) is dedicated to related issues.

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