The Modularity of Object Propositions

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Abstract
A significant concern in verification research is the ability to reason modularly about programs with state. Recent work has used substructural logics including separation logic, permissions, and Hoare Type Theory to specify each function in terms of its effect on its footprint. The motivation of our work is the need for formal specifications that allow one to hide shared data between two abstractions. In 2014, we proposed object propositions [1] as an automatable extension to abstract predicates. We allow state to be shared between two objects, by providing fractional permissions to access the common data hidden in a predicate, without revealing this sharing in the objects’ specifications. Unlike conventional object invariant and ownership-based work, our system allows ownership transfer by passing unique permissions (permissions with a project invariant and ownership-based work, our system allows ownership transfer by passing unique permissions (permissions with a fraction of 1) from one reference to another. Unlike separation logic and permission systems, we can modify objects without owning them. This has information-hiding and system-structuring benefits.

Categories and Subject Descriptors D.2.4 [Software/Program verification]

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1. The Theory of Object Propositions
Object propositions combine predicates on objects with aliasing information about the objects, represented by fractional permissions. They are declared by programmers as part of method pre- and post-conditions. An object proposition looks like obj@k Pred(x), where obj is a reference to an object, k is a fraction representing how much of a permission obj has to the abstract predicate Pred(x) that obj satisfies. A critical part of our work is allowing clients to depend on a property of a shared object. To gain read or write access to the fields of an object, we have to unpack it. After a method finishes working with the fields of a shared object, we pack back the shared object to that predicate (or to another predicate if we had a fraction of 1 to it).

2. Using Separation Logic for Verification
We explore the modularity of our system by analyzing an example, where our specifications do not expose the shared information. We consider the example of a spreadsheet in which each cell contains a formula that adds two integer inputs. Each cell may point to two other cells. Whenever the user changes a cell, each of the two cells which transitively depend upon it must be updated (an instance of the observer pattern).

Let us assume we have two cells a1 and a2 at the top of the spreadsheet, a1 points to a4 and a3, while a2 points to a3 and a5. Finally, a3 points to (and uses its additive output as one of the inputs to) a6. Let us say we have a method setInput1(x) that sets the first input of a cell (one of the two inputs of a cell).

In conventional first-order separation logic, the specification of any method has to describe the entire footprint of the method (all heap locations that we read/write to inside the method). The verification using separation logic is as follows. We define the predicate SepOK(cell) to state that the sum of the two inputs of cell is equal to the output, and that the predicate SepOK is verified by all the cells that directly depend on the output of the current cell. In separation logic, the natural pre- and post-conditions of the method setInput1() are both SepOK(this), i.e., the method takes in a cell that is in a consistent state in the spreadsheet and returns a cell with the input changed, but that is still in a consistent state. Before calling setInput1(x) on a2, we have to combine SepOK(a3) * SepOK(a5) into SepOK(a2) (where * is the separating conjunction of separation logic). We observe the following problem: in order to call setInput1() on a2, we have to take out SepOK(a3) and combine it with SepOK(a5), to obtain SepOK(a2). But the specification of the method is not expressive enough to allow it, hence the problem in conventional separation logic. Because the shared cells a3 and a6 have to be mentioned in the specification of all methods that modify the cells a1 and a2, the specification in separation logic exposes some of the shared data.

3. Using Object Propositions for Verification
We verified the same example using object propositions and the predicate OK(), which uses fractions to ensure that all the cells in the spreadsheet are in a consistent state, where the sum of their inputs is equal to their output. Since we only use a fractional permission for the dependency cells (such as a3), it is possible for multiple predicates OK() to talk about the same cell without exposing the sharing in the spreadsheet. More specifically, using object propositions we only need to know a1Ok, OK() before calling a1.setInput1(10) (same for a2) and we can share the cell a3 by using the fractional permissions of object propositions. Here k is an arbitrary fraction in the (0,1] interval meaning that a1 holds a k permission to the predicate OK().

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References