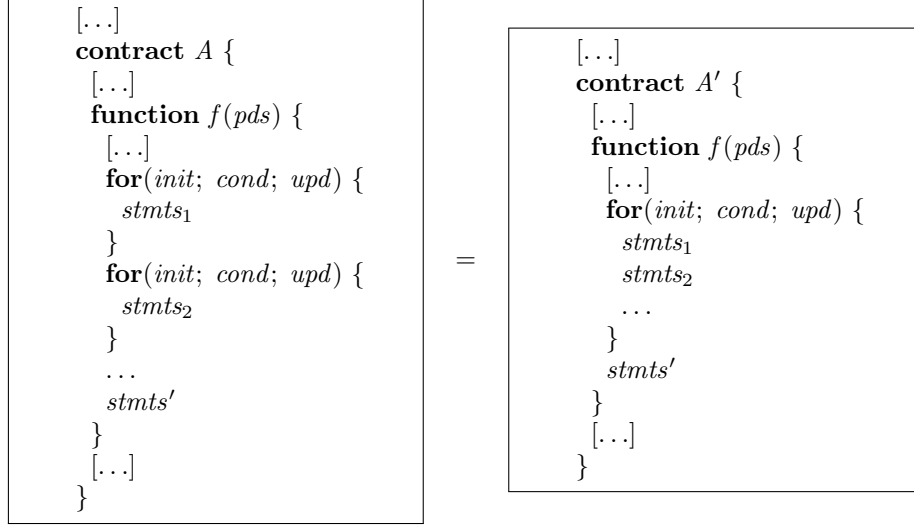


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**Rule 0.22** *⟨Combine Multiple Loops into One⟩*


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**where**

Multiple loops iterate over the same range with identical *init*, *cond*, and *upd*;  
*stmts<sub>1</sub>*, *stmts<sub>2</sub>*, ..., *stmts<sub>n</sub>* represent the bodies of the separate loops;  
*init*, *cond*, and *upd* are the loop initialization, condition, and update expressions;  
*pds* are the parameter declarations of function *f*;  
*stmts'* represents statements following the loops.

**provided**

All loops iterate over the same range or collection;  
 The loop bodies *stmts<sub>1</sub>*, *stmts<sub>2</sub>*, ... do not have dependencies that require sequential execution across iterations;  
 No loop body modifies variables that affect the iteration behavior of other loops;  
 Combining the loops does not introduce race conditions or ordering issues;  
 The statements in each loop body are independent of the execution order relative to other loop bodies within the same iteration.

**Invariant:**

Let  $s_i$  and  $s'_i$  be the initial state of *A* and *A'*, respectively.  
 Let  $s_f$  and  $s'_f$  be the state reached by *A* and *A'*, respectively, after *A.f()* and *A'.f()* are executed from  $s_i$  and  $s'_i$ , respectively.  
 Then, the coupling invariant is

$$\forall s_i, s'_i . (s_i = s'_i) \rightarrow (s_f = s'_f)$$


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