

ELEMENTS OF PROGRAMMING EXERCISES AND SOLUTIONS

ASEF AHMED

1. FOUNDATIONS

1.1. **Categories of Ideas: Entity, Species, Genus.** No exercises.

1.2. **Values.**

Lemma 1.1. *If a value type is uniquely represented, equality implies representational equality.*

Solution. Suppose a value type T is uniquely represented. Denote by $v, v' : T$ as equal values of T . By unique representation, v, v' each correspond uniquely to the abstract entities E, E' , and by equality of values, these entities must also be equal. Hence the data D, D' for v, v' are identical, and so v, v' are representationally equal. \square

Lemma 1.2. *If a value type is not ambiguous, representational equality implies equality.*

Solution. Suppose a value type T is not ambiguous. Denote by $v, v' : T$ as representationally equal values of T . As T is not ambiguous, v, v' must each have at most one interpretation, and by representational equality, the data D, D' for the values are identical. Hence the values v, v' must represent the same abstract entity E , and so they are equal. \square

1.3. **Objects.** No exercises.

1.4. **Procedures.** No exercises.

1.5. **Regular Types.**

Lemma 1.3. *A well-formed object is partially formed.*

Solution. Suppose a is an object that is well-formed. Let S_a be the state of a , which by definition is a value $v : T$ of some value type T . By well-formedness of a , S is also well-formed as a value, i.e. WLOG, we may assume that T is **double** as an object type for a . Let b be another object of type **double**. Certainly a may be assigned to b without modifying the state S_b of b , and a may be destructed as well. Therefore a is partially formed. \square

1.6. **Regular Procedures.**

Exercise 1.1. *Extend the notion of regularity to input/output objects of a procedure, that is, to objects that are modified as well as read.*

Solution. A procedure is *regular* if and only if the input objects a_0, \dots, a_r , when replaced by equal objects b_0, \dots, b_r , i.e. for each $i \in \{0, \dots, r\}$, the states $S_{a_i} = S_{b_i}$ are equivalent for the objects a_i, b_i of type T_i , yield equivalent output objects $c_i = d_i$ (where equality of objects means equivalence of the corresponding states). There is a natural equivalence for input/output objects in the following way: an input/output object s is equivalent to t , i.e. $s \equiv t$, if there is a regular procedure F for which t is the output object of the input s under F , or symmetrically if s is the output object of the input t under F . \square