

## Chapter 6

# More Theory: Types of Predicates

**Asserting State Predicates** We have accepted that the world state consists of objects which have properties, and relations between them. This suggests that the vocabulary of first-order logic is appropriate for talking about state.

**Types of Objects** We have classified objects into

- System objects
- Environment objects
- Neither (objects belonging to “the world”)

Because objects also have parts, and we allow ourselves the operation of fusion  $\oplus$ , it is possible that we may talk about objects which are part system and part environment: let  $O_s$  be a system object and  $O_e$  belong to the environment. Then  $O_s \oplus O_e$  is part-system, part-environment. However, in the absence of a specific reason for doing so, and in view of the fact that we are mostly concerned with *artifacts*, with systems that we ourselves design and build, it seems wise to attempt to reduce confusion by avoiding talk of such composite objects as far as we can.

**Types of Properties** Relative to the classification of objects, properties of objects that are relevant to system operation thus can have the following types:

- properties that only system objects can have
- properties that only environment objects can have
- properties that both system objects and environment objects can have

**Types of Relations** Relative to the classification of objects, relations amongst objects that are relevant to system operation can have the following types

**System Predicates** relations between system objects alone

**Environment Predicates** relations amongst environment objects alone

**Hybrid Predicates of Type 1** relations that may pertain between system objects and environment objects

**Hybrid Predicates of Type 2** relations that may be between system objects, or between system and environment objects

**Hybrid Predicates of Type 3** relations that may be between environment objects, or between system and environment objects

**We Only Need Hybrid Predicates of Type 1** We may consider hybrid predicates of type 2 to be the union of a hybrid predicates of type 1 with a system predicate, and a hybrid predicate of type 3 to be the union of a hybrid predicate of type 1 with an environment predicate. Their interdefinition is possible in any language which contains the predicates “*Object x belongs to the system*”, that is,  $BelongsToSystem(x)$ , and “*Object x belongs to the environment*”, that is,  $BelongsToEnvironment(x)$ , as follows. Suppose  $A(x, y)$  is a hybrid predicate of type 2. Then

$$BelongsToSystem(x) \ \& \ BelongsToSystem(y) \ \& \ A(x, y)$$

is a system predicate,

$$BelongsToSystem(x) \ \& \ BelongsToEnvironment(y) \ \& \ A(x, y)$$

is a hybrid predicate of type 1, and

$$A(x, y)$$

*if and only if*

$$(BelongsToSystem(x) \ \& \ BelongsToSystem(y) \ \& \ A(x, y))$$

*or*

$$BelongsToSystem(x) \ \& \ BelongsToEnvironment(y) \ \& \ A(x, y))$$

Henceforth, we will consider only hybrid predicates of type 1, and omit the type.

**Limiting the Types of Relations by Fiat** We may assume that if a relation important to the system operation pertains between environment and world objects, that all the objects that can be in the relation to each other (the so-called *domain* of the relation) should be considered to be part of the environment. By this means, we rule out the need to consider relations involving “world” objects.

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**Discrimination of State Predicates** Predicates of the world can have as arguments

- just system parameters, in which case we call them *system predicates*;
- just environment parameters, in which case we call them *environment predicates*; or
- some system parameters and some environment parameters, in which case we call them *hybrid predicates*.

Every predication is precisely one of the three types (a), (b) or (c).

### System State and Environment State

- The *system state* consists of all true system predicates;
- The *environment state* consists of all true environment predicates;
- the collection of all true hybrid predications is the *hybrid state*;
- The *world state* consists of the union of the system state with the environment state with the hybrid state.

**Relations Between the Types of States** Note that a hybrid predication is related to certain system predicates and environment predicates by quantification. For example, let  $x$  be a system parameter,  $t$  be an environment parameter, and  $A$  a hybrid predicate. Then  $A(x, t)$  is a hybrid predication, related to the system predicate ( $\textit{Exists } n.A(x, n)$ ) and the environment predicate ( $\textit{Exists } m.A(m, t)$ ).

**Hybrid Predications Are Essential Information** Although from every hybrid predication one can obtain a system predication, respectively an environment predication, the reverse is not necessarily the case. Suppose

- any state containing  $A(x, t)$  would be an accident state, but that
- there are no such states.

Suppose further that

- $t$  is the only instance of  $n$  in which  $\textit{Exists } n.A(x, n)$  occurs in an accident state;
- that  $x$  is the only instance of  $m$  in which  $\textit{Exists } m.A(m, t)$  occurs in an accident state.

Suppose also that

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- there are plenty of states in which there is an  $n$  such that  $A(x, n)$  and
- plenty in which there is an  $m$  such that  $A(m, t)$ , and
- plenty in which there are both such  $n$  and  $m$ .

Now, observe that

- a predication involving  $A$ ,  $x$  and  $t$  is crucial to determining certain accidents;
- no predication involving  $A$  and  $x$  alone is going to help you to determine a predication involving  $A$ ,  $x$  and  $t$ ;
- no predication involving  $A$  and  $t$  alone is going to help you determine a predication involving  $A$ ,  $x$  and  $t$ .

Therefore, no observation of system states and environment states is going to help you with analysing the chance of this accident. Ergo, hybrid predications are essential information.

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