Domain Conceptual Models

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Motivation

Many confusions in software development are caused by imprecise and inconsistent terminology:

- people use different words for the same thing (synonyms), or the same word for different things (homonyms);
- some words have no clear meaning, or their meaning varies with context;
- people are often not aware of these inconsistencies.

A domain conceptual model and glossary can reduce such confusions and facilitate communication throughout development.

A domain conceptual model also facilitate the software design, implementation and evolution, notably in the context of Domain-Driven Design.

Domain Conceptual Models

What

Names and defines the types of entities that exists in the World, their attributes, and their associations.

Why

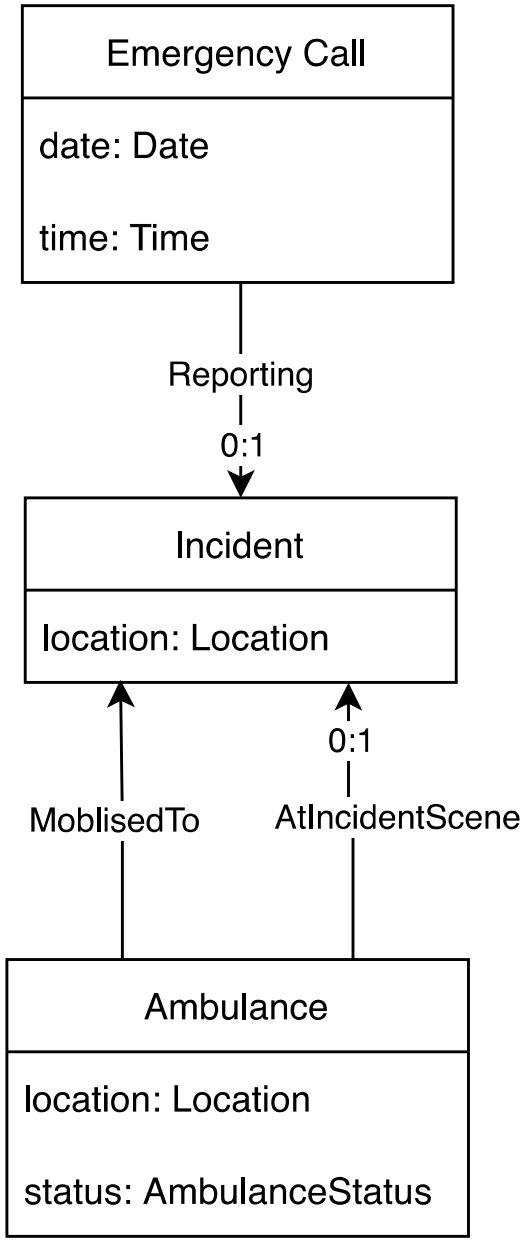
- To understand the stakeholders' concepts and terminology.
- To define a shared language for communication.

Who

Created and used by requirements engineers and software dev teams. Rarely used with other stakeholders.

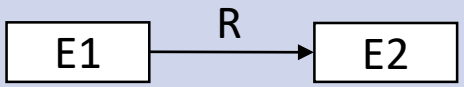
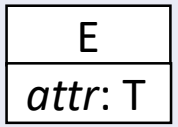
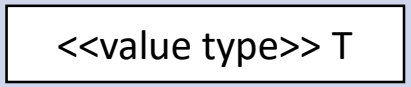
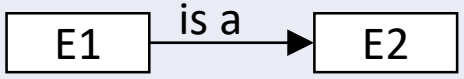
When

All requirements phases, and throughout software development.



Concepts & Notations

Concepts & Notations

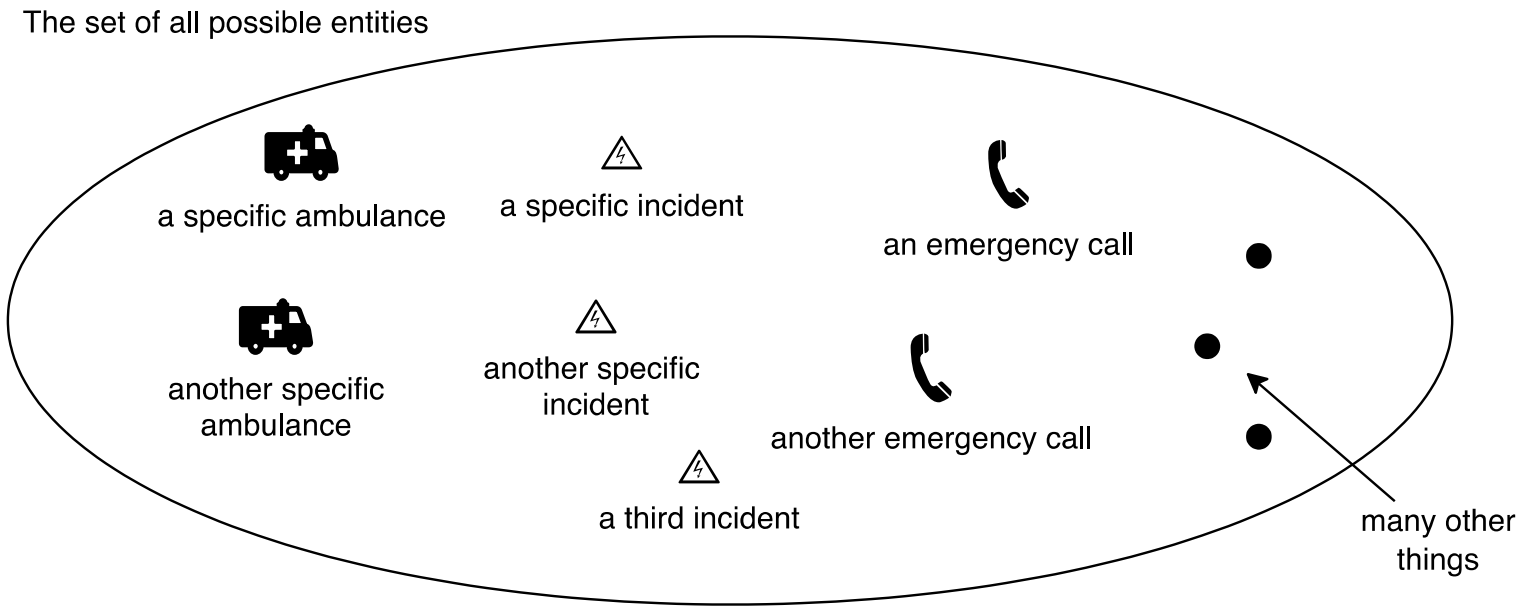
Concept	Graphical Notation	Meaning
Entity		A “thing” with distinct and independent existence.
Entity Type		E is a set of entities {e1, …., en}, called *instances* of E, that share common characteristics.
Association Type		R is a relation between E1 and E2 (R ⊆ E1 X E2).
Attribute		*attr* is a function from E to T (*attr*: E → T), where T is the attribute’s value type.
Value Type		T is a set of possible values. A value *v* is immutable and has no distinct identity.
Specialization		Every instance of E1 is an instance of E2.

A subset of UML class diagram notation.

Entities

An entity is a “thing” with a distinct and independent existence.

- Existence can be a physical (e.g. a student, a classroom) or conceptual (e.g. a class, a university).
- Each entity has a *unique and immutable identity* (amb_1, amb_2, etc.).
- An entity’s characteristics may change over time.



Describing something as an entity is a modelling choice; not a metaphysical claim.

Entity types

An entity type represents a set of entities that share common characteristics.

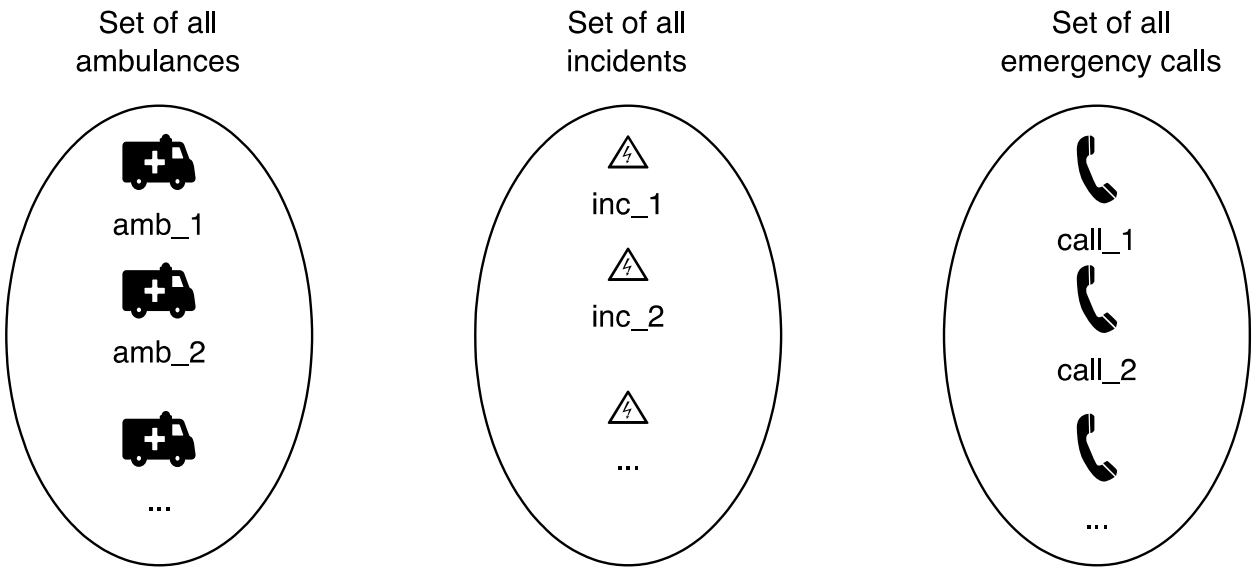
The entities in that set are called *instances of* the entity type.

Ambulance

Incident

Emergency Call

When the context is clear, we say “entity” as a shorthand for entity type.



Naming Guidelines

Entity type name

A **countable noun**, or noun phrase, in singular form.

All words capitalized (with or without space between words).

Examples

Ambulance, Incident Form, Mobilisation Order

Test sentence

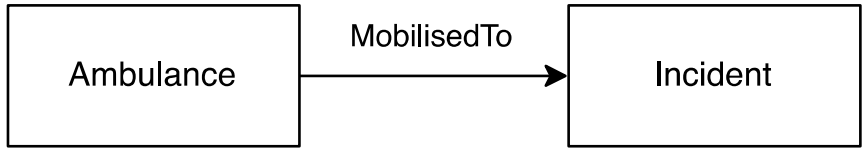
The entity type <E> is the set of all <e>s.

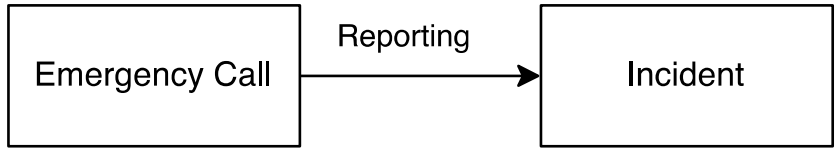
“*The entity type Ambulance is the set of all ambulances*.”

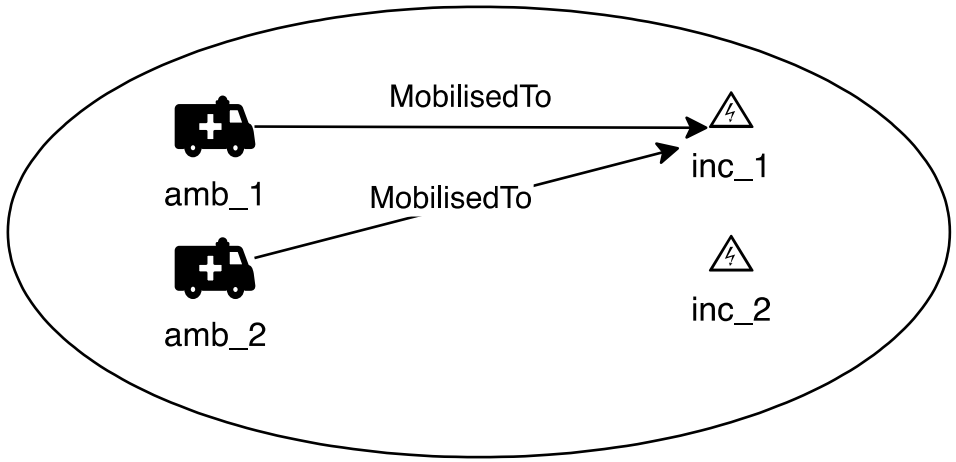
Associations

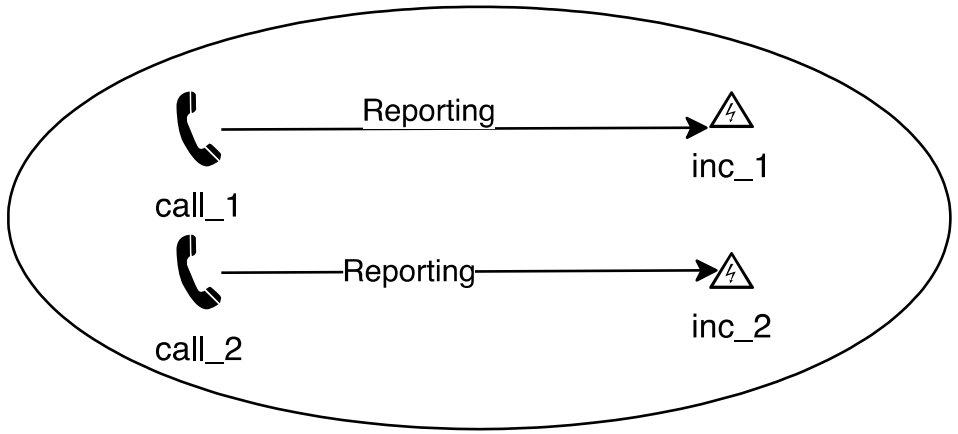
An association link is an ordered list of entities.

An association type represents a set of association links. The set can change over time.



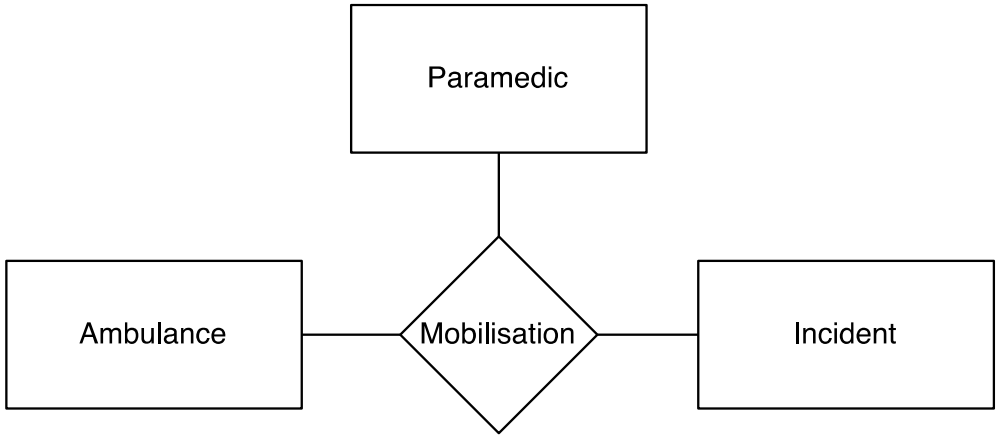


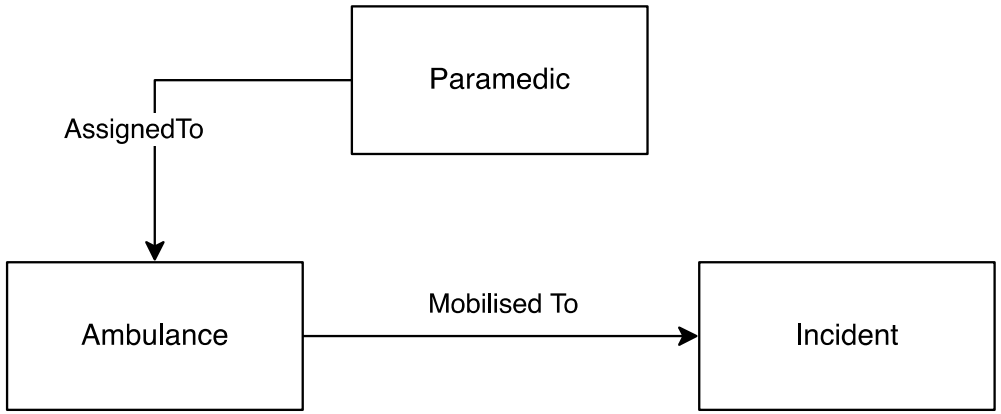




The sets of “MobilisedTo” and “Reporting” links *at a given time*.

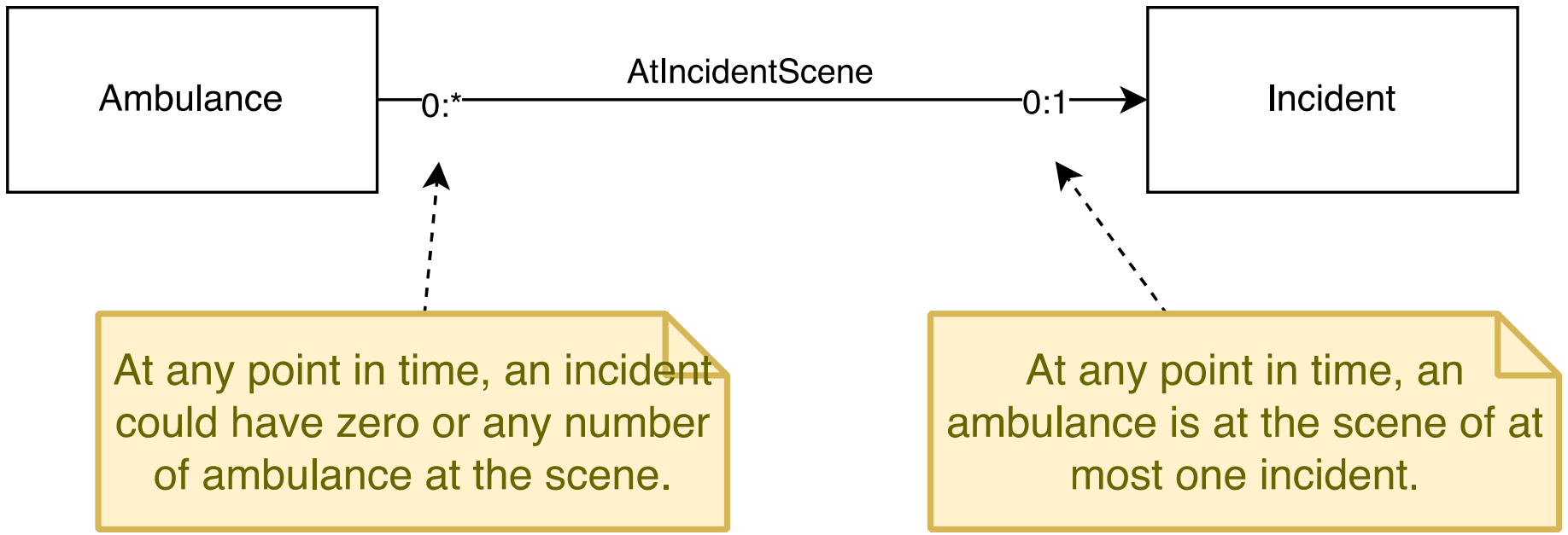
N-ary Associations with N > 2





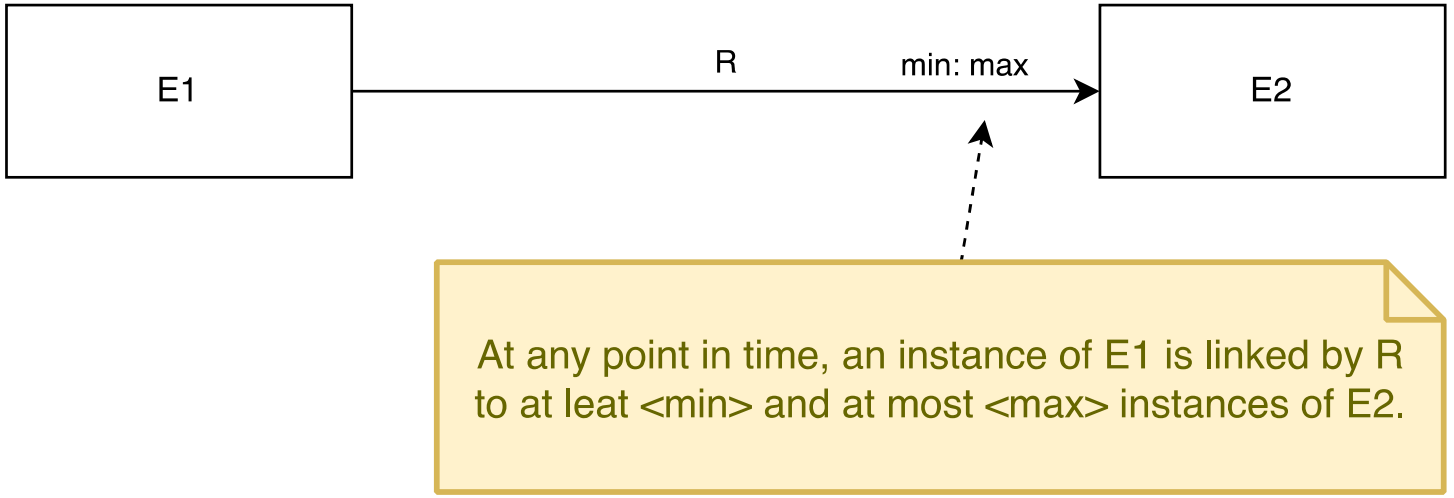
Used rarely because hard to understand and can often be modelled more clearly with binary associations.

Association Multiplicities – An Example



Use multiplicities for domain properties only (laws of nature), not for stakeholder goals (e.g. ”a flight seat should not be assigned to more than one passenger”).

Association Multiplicities - Meaning



Common values

1:*	at least one
0:1	at most one
1:1	exactly one
0:*	any number

default, same as not showing any multiplicity

Naming Guidelines

Binary Association Name

- a **state verb phrase**, in the third person singular. The verb phrase must describe a state, not an action!
- an action verb phrase, in the **present or past participle** (e.g. ending in –ed or –ing).
- any phrase that makes a state verb phrase if prefixed by "**is**" or "**has**".

All words capitalized, with or without space between words.

Examples

- [Emergency Call] Is Reporting [Incident]
- [Ambulance] Mobilized To [Incident]
- [Ambulance] At Scene Of [Incident] – can be prefixed by "is"

Test sentence

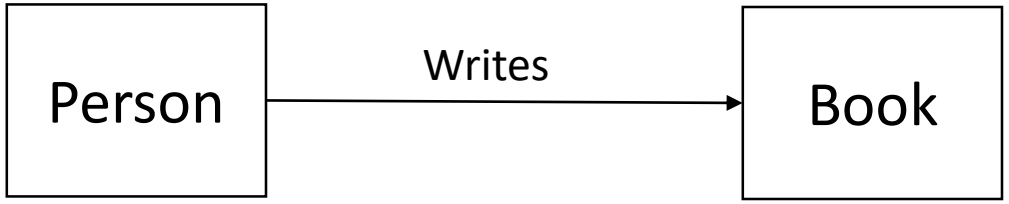
"An <e1> (is | has) R some <e2>".

If multiplicity 1:1, 0:1, or 1:0, change "some" to "exactly one", "at most one", and "at least one", respectively.

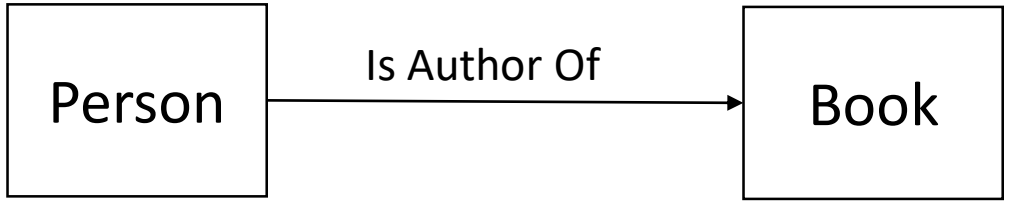
E.g. "*An Emergency call is reporting at most one incident.*"

Avoid action verbs in indicative present

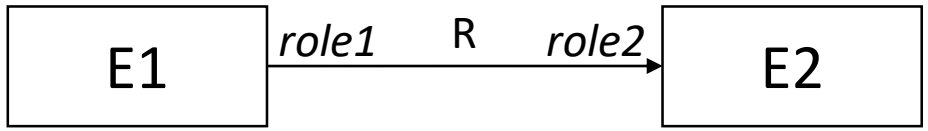
An association does not describe an actor’s action on an object!



An association describes static links between entities.



Association Roles

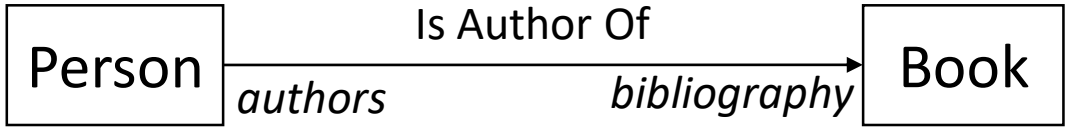


Each role is a **noun phrase**, can be singular or plural.

The roles define two functions derived from R

- *role2*: E1 → ***set*** E2 such that *role2(e1)* is the set of E2s linked to e1 by R.
- *role1: E2* → ***set*** E1 such that *role1(e2)* is the set of E1s linked to e2 by R.

Example



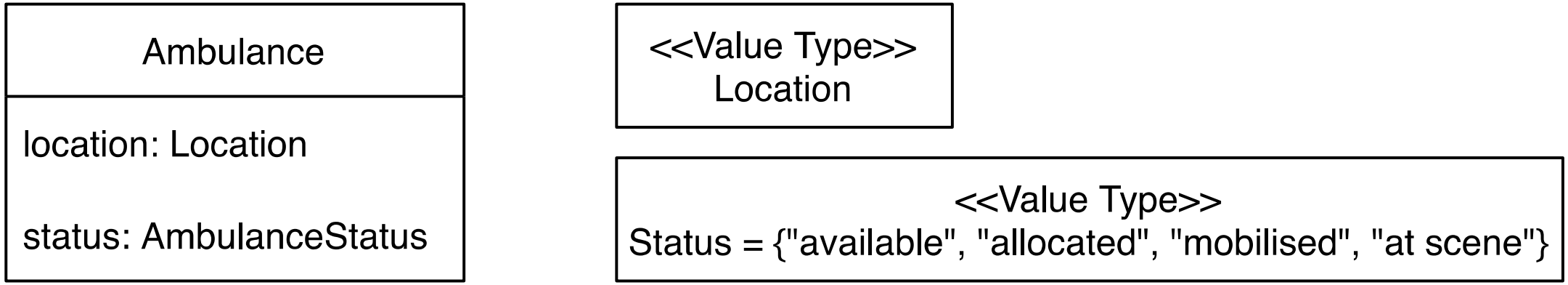
- The *bibliography* of a person is the set of books they authored.
- The *authors* of a book are the set of persons who authored the book.

Each binary relation must have a name ***or*** at least one role name.

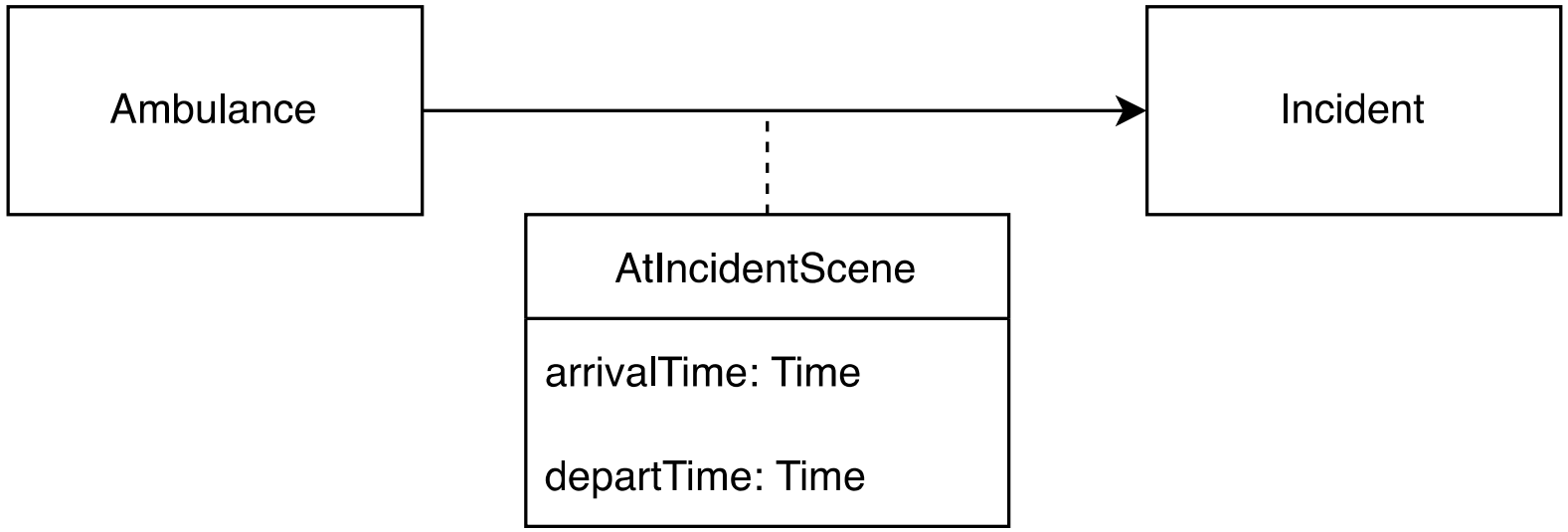
Attributes and Value Types

An attribute *att: T* on entity type *E* is function *att: E* → *T*, where *T* is the attribute value type.

A value type *T* is a set of values {v1, …, vn}. Unlike an entity, a value v has no distinct identity and does not change over time.



Attributes on Associations



The model defines

- a relation *AtIncidentScene* $\subseteq$ *Ambulance X Incident*
- a function *arrivalTime: Ambulance X Incident* $\rightarrow$ *Time*
- a function *departTime*: *Ambulance X Incident* $\rightarrow$ *Time*

Naming Guidelines

Attribute Name

- For non-Boolean attribute, a **noun phrase** in singular or plural form.
- For Boolean (”True/False”) attribute, a phrase of the form *isX* or *hasX*.

starts in lowercase, with following words upper case, with or without space between words.

Examples

Incident
location: Location isPending: True/False

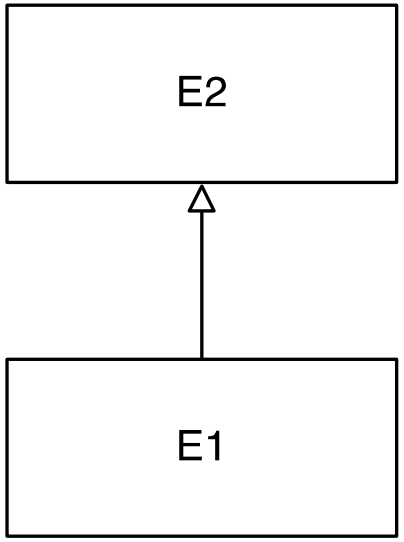
Test sentences

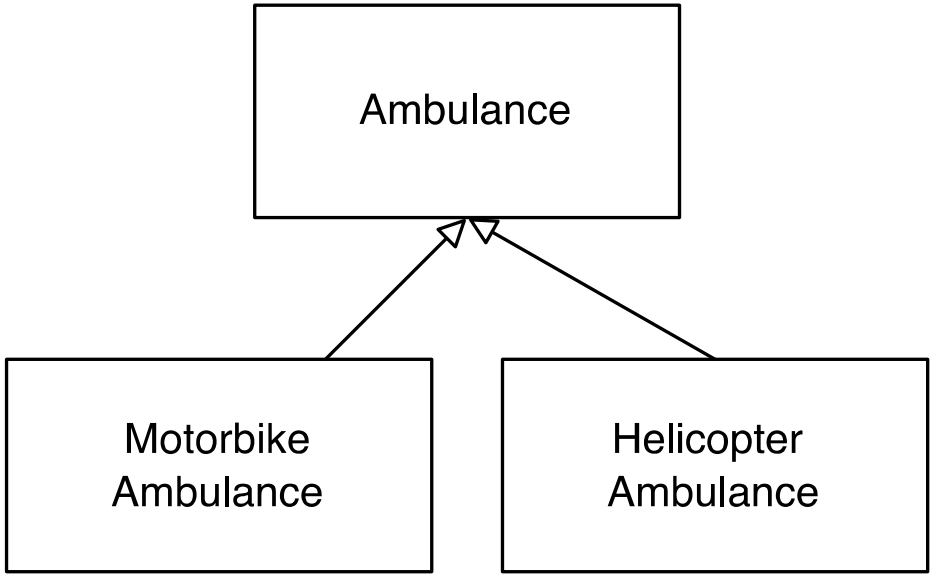
For non-boolean attribute *att*: “an <e> has some *att*” or “may have some att” if *att* is optional.

For Boolean attribute: “an <e> is X or not”, “an <e> has X or does not have X”.

Specialization

E1 is a specialization of E2 means that every instance of E1 is an instance of E2.

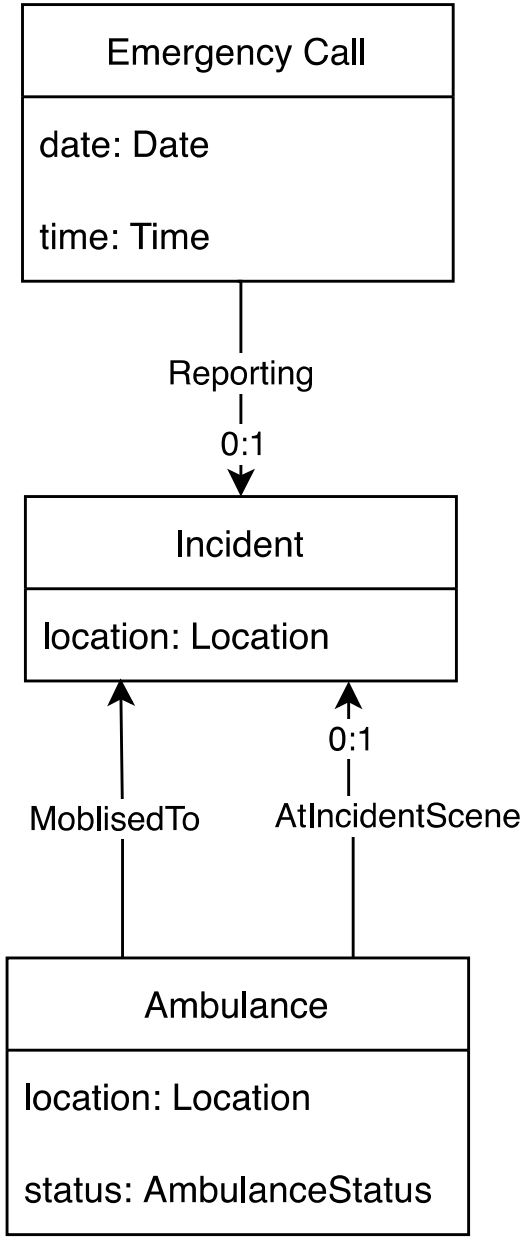




Glossary

Provides definition for all domain concepts.

Terms	Meaning
Emergency Call	*Any call to the emergency service numbers (999 and 112).*
• date	*the call date (e.g. 2 October 2023).*
• time	*the time at which the call is answered.*
Incident	*Any event that may require an emergency ambulance response.*
• location	*the incident's location.*
Reporting	*Link between an emergency call and the reported incident.*
Ambulance	*Any emergency vehicle managed by the ambulance service – this includes ambulance vans, cars, helicopters, motorbikes, bicycles.*
• location	*the ambulance's current location.*
• status	*the ambulance's status (available, mobilized, etc.).*



Relations to Other Models

Domain conceptual models are related to

Domain scenarios

- scenario world objects = entities, associations and attributes

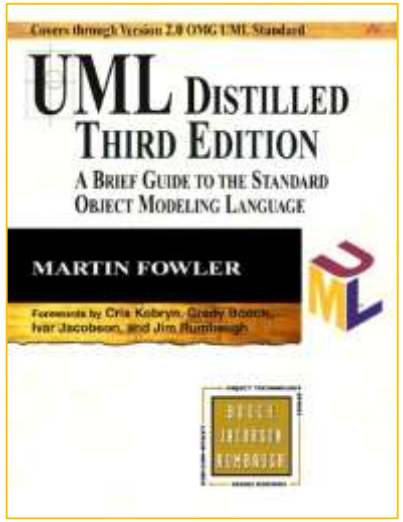
Context diagram

- interface phenomena are subset of entities, attributes and associations.

Goal models

- world phenomena in goal descriptions = entities, associations and attributes.

Modelling Guidelines



"I've found conceptual class diagrams very useful in exploring the language of a business. For this to work, you have to work hard on keeping software out of the discussion and keeping the notation very simple"

-- Martin Fowler in UML Distilled (3rd edition)

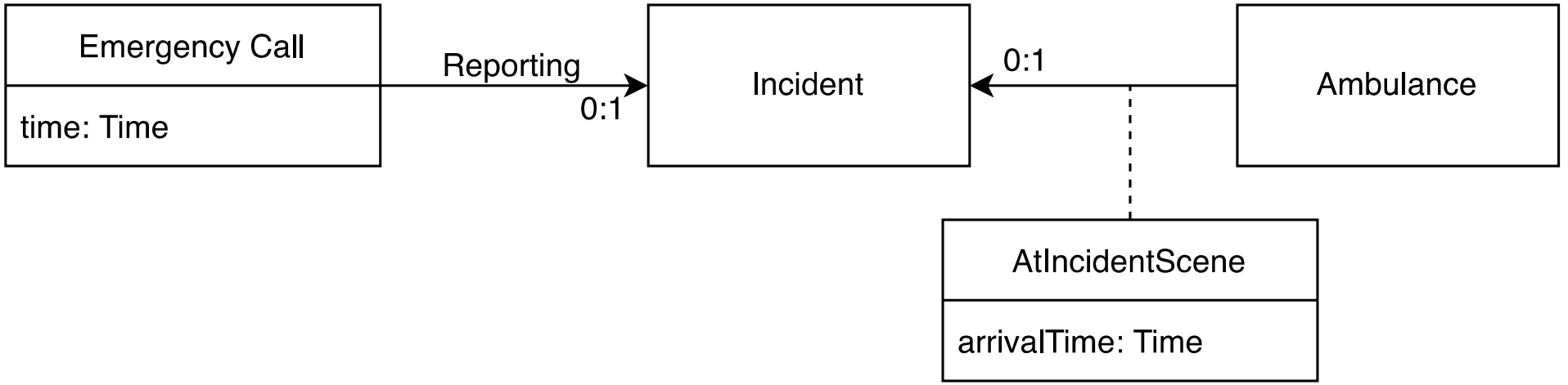
General Guidelines

1. The purpose is to explore and clarify the domain concepts.
   - to facilitate discussions with stakeholders and
   - to help the development team understand the application domain
2. Keep the model free of implementation concerns.
   - We model the World, not an Object-Oriented design of the Machine.
   - Model concepts as if you were modelling a world without computers.
3. Keep the notation simple.
   - We don’t need to full complexity of UML class diagrams.

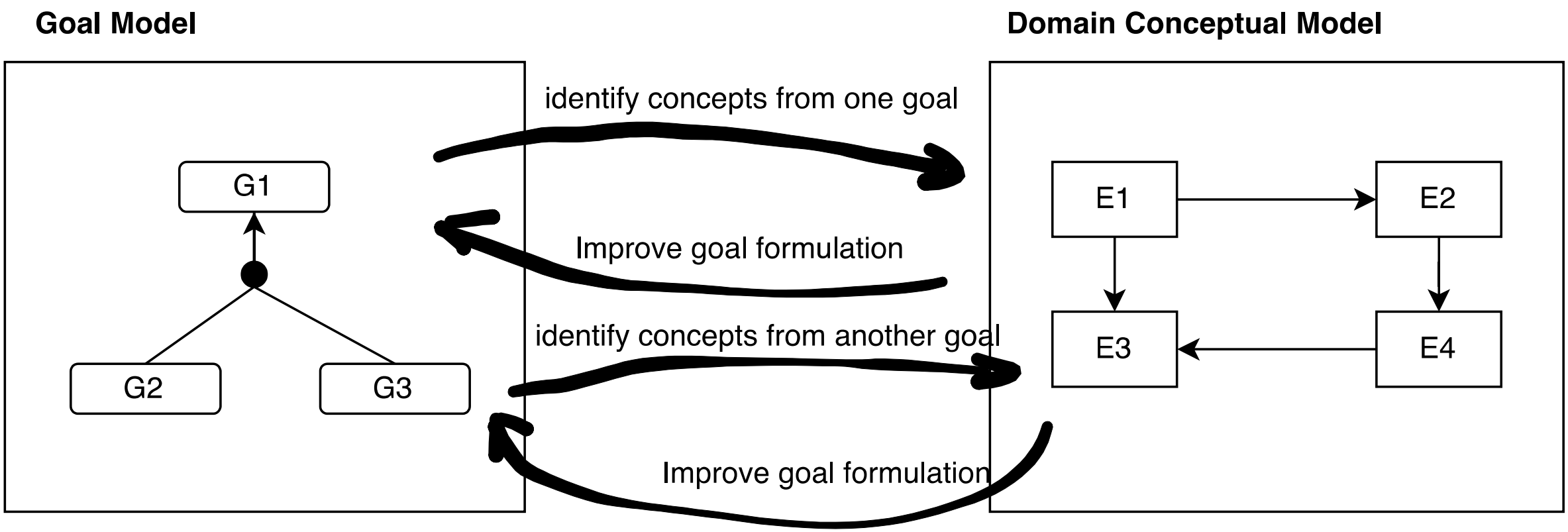
Scope: what concepts to include and exclude?

- Include all domain concepts referenced in stakeholder goals and domain scenarios.
- Exclude concepts that are irrelevant to describing stakeholder goals and domain scenarios.

Example: "*An ambulance must arrive at the incident scene within 14 minutes after the first call reporting the incident*."



An Iterative Process

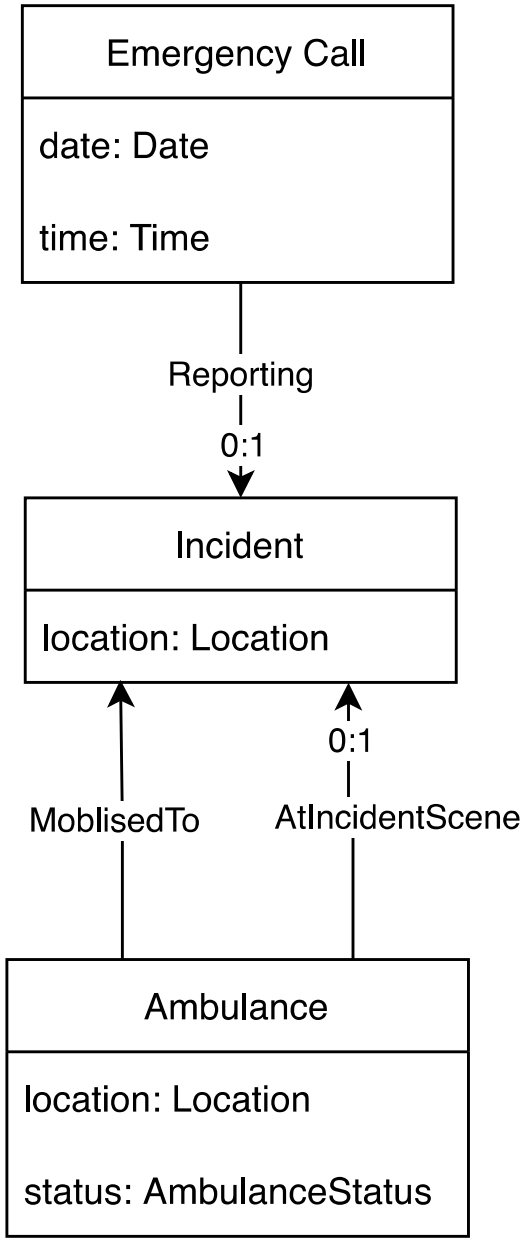


Use concrete examples to create and validate the model

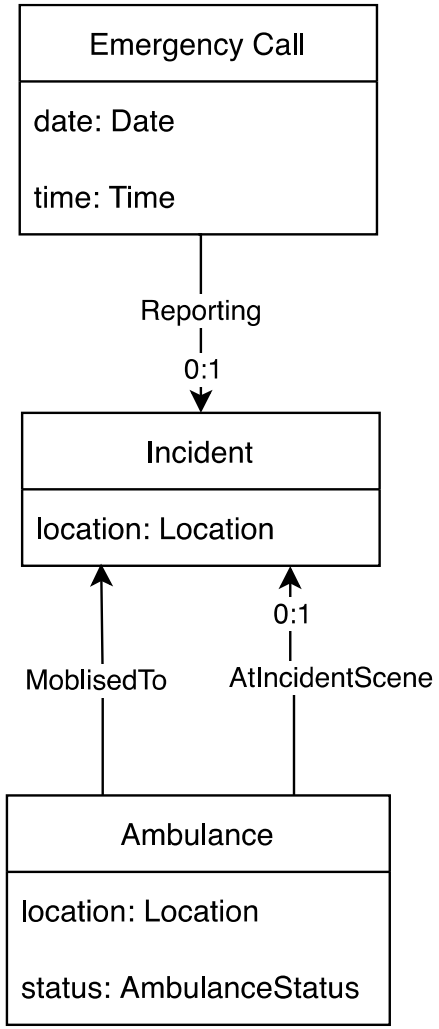
- An incident occurs at 10 Downing street.
- A first emergency call reports that incident at 9:00.
- A second emergency call reports that incident at 9:03.
- A third emergency call asks for progress about the incident at 9:10.
- An ambulance arrives at the incident scene at 9:12.
- A second ambulance arrives at the incident at 9:15.

Do we need a new association between Emergency Call and Incident?

Does our model include the ambulance's arrival time?



Test your model by reading it

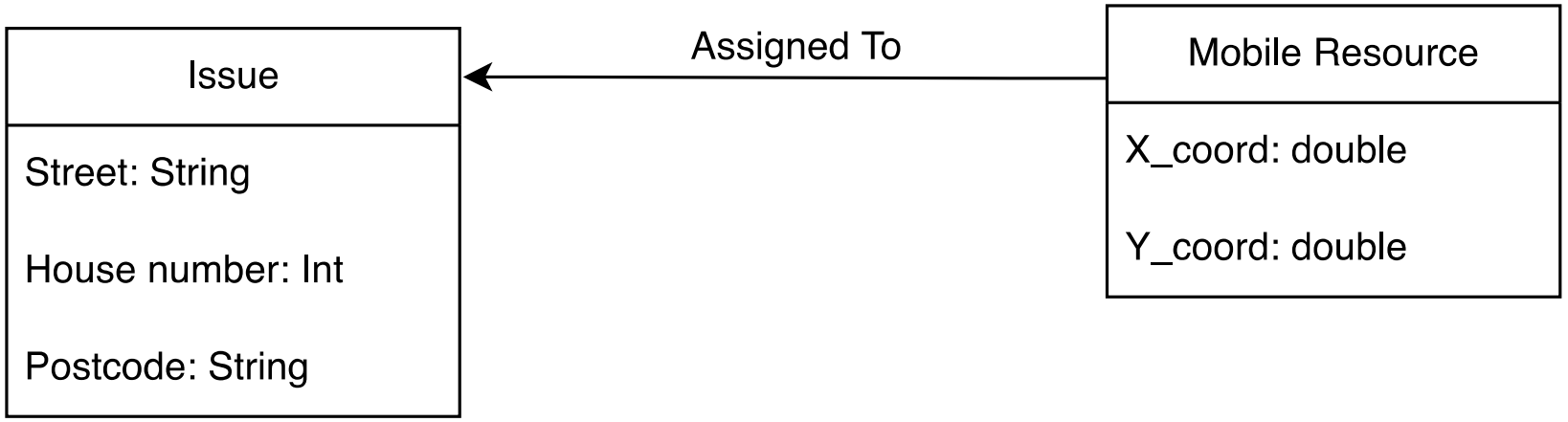


- The entity type Emergency Call is the set of all emergency calls.
- An emergency call has a date and time.
- An emergency call is reporting at most one incident.
- The entity type Incident is the set of all incidents.
- An incident has a location.
- …

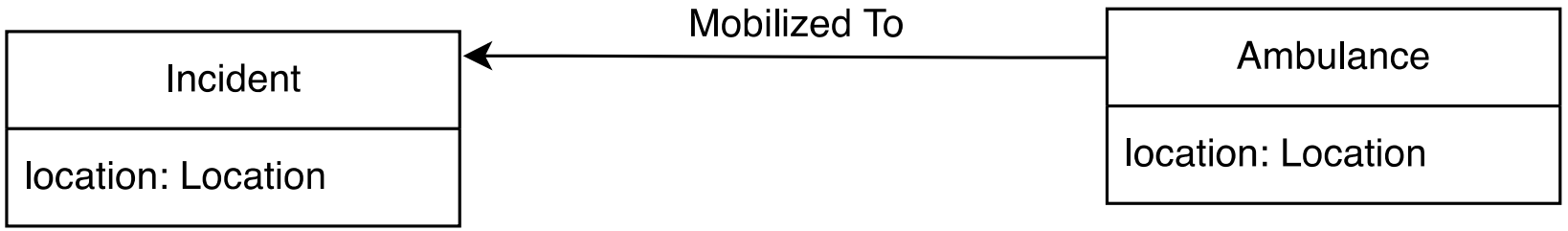
Common Mistakes

Mistake 1: Using computer science jargon and making up your own domain terminology

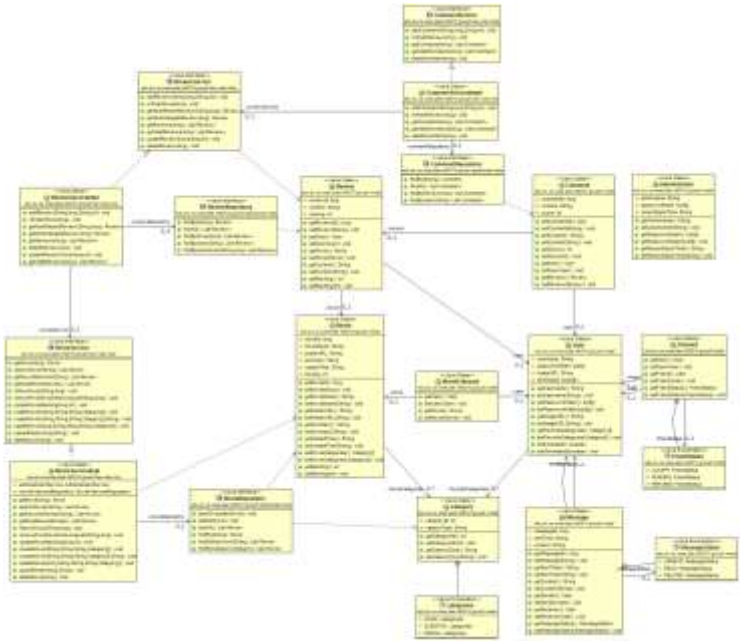
Computer science jargon and made-up terminology



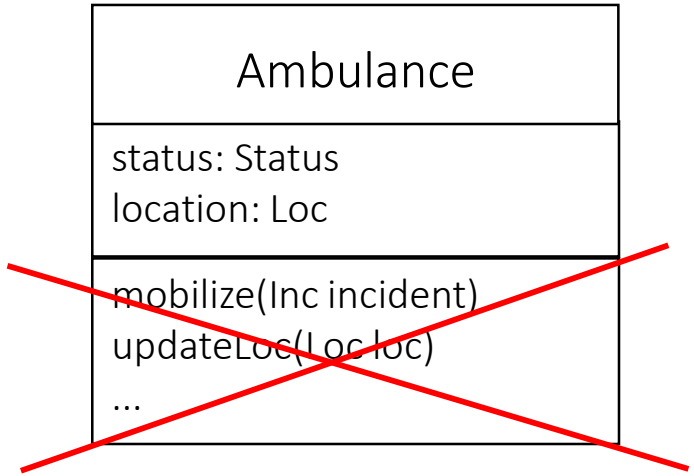
Same concepts in stakeholder language



Mistake 2: Modelling implementation design



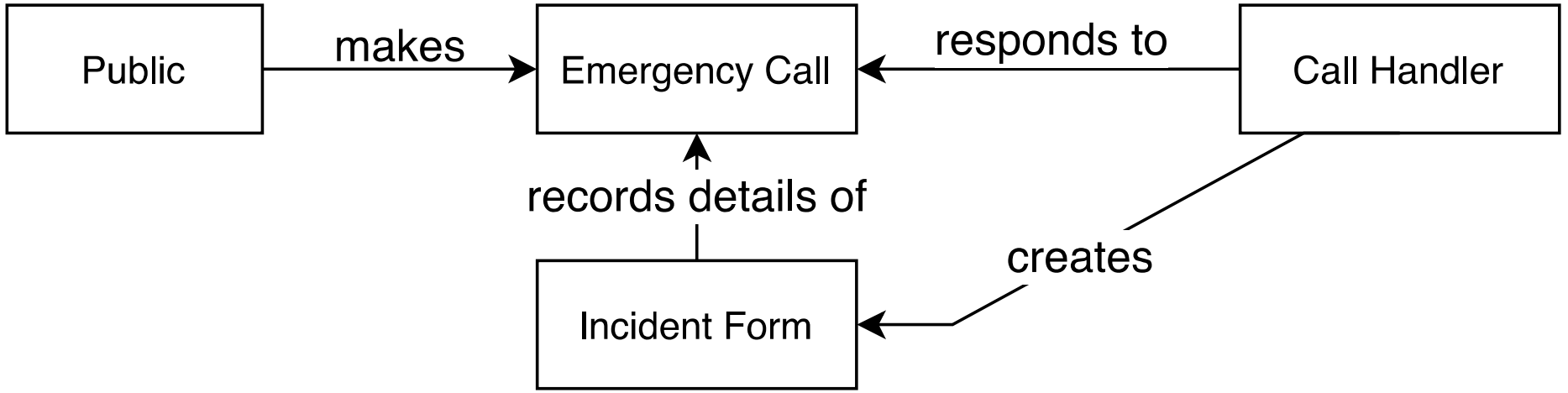
Do not include any OO design classes
(Event publishers, event handlers, adapters, thread controllers, exceptions, etc.)



Do not add methods to entity types: deciding what class will perform what function is an implementation concern.

Mistake 3: Modelling actors' actions

A domain conceptual model in notation only; not in content.



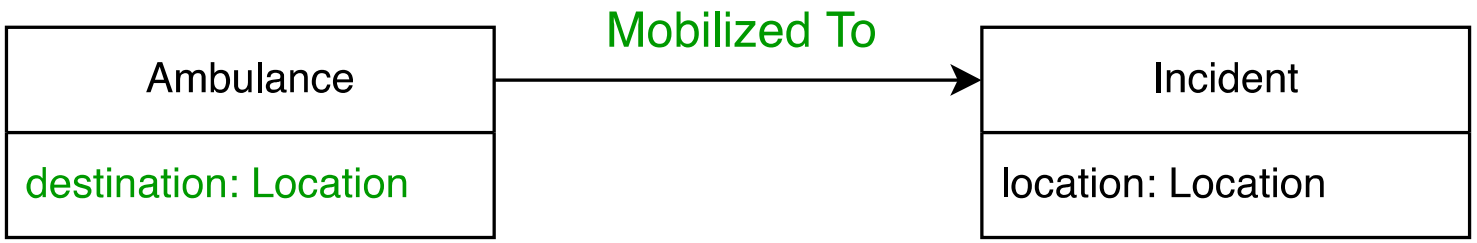
Use each model for its right purpose:

- domain scenario for describing sequences of actors' action.
- context diagram for showing actors and their interfaces.
- domain conceptual model for presenting domain concepts.

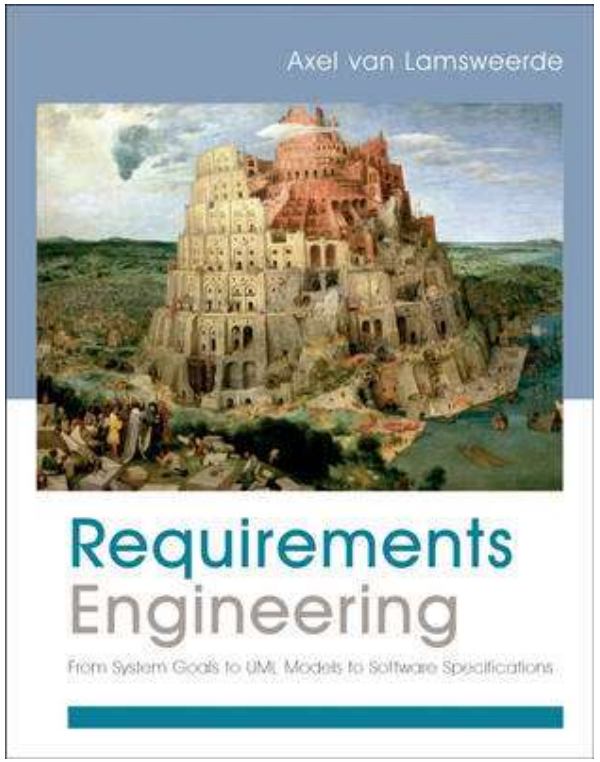
Mistake 4: Entity type as attribute value type

Do not use attribute as pointer to another entity type.

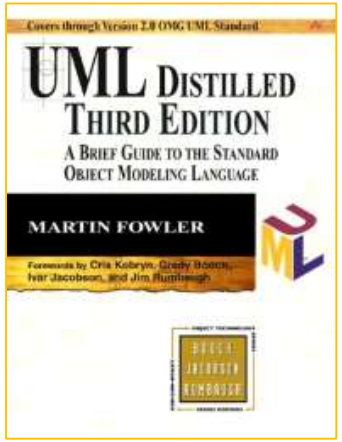
Use association to entity type, use attribute to value type.



References and further reading



Chapter 10. Modelling Conceptual Objects with Class Diagrams



Naming guidelines adapted from Aguilera, Gomez and Olivé, “A complete set of guidelines for naming UML conceptual schema elements”, 2013

Exercises

File System

Sketch a domain conceptual model for a computer file system with the following characteristics.

A file system is composed of File System Objects, which can be either files or folders. There is one special folder called “Root”. Each folder contains a set of file system objects. Every file system object except the root is contained in exactly one folder.

Course Timetable

Sketch a domain conceptual model for a system that displays the personal timetable of students enrolled at UCL. The personal timetable should display the time and locations of all modules the student is enrolled in.

Use your personal timetable as an example from which to identify concepts.

Exercise – From goals to concepts

Sketch a domain conceptual model representing the concepts referenced in the following goals for a radiation therapy controller.

G1. Achieve [Radiation Session Delivered]

When a patient attends a radiation session, they will eventually leave the session having received the radiation treatment described in their doctor's prescription.

G2. Avoid [Radiation Session Not Conforming to Prescription]

When a patient attends a radiation session, they should not receive radiation that does not conform to their doctor's prescription.

Exercise – From scenario to concepts

Sketch a domain conceptual model related to this scenario

Scenario: Redirect user to originally requested page after logging in

Given I am an unauthenticated user

When I attempt to view some restricted content

Then I am shown a login form

When I authenticate with valid credentials

Then I should be shown the restricted content

Flood Warning System

Sketch a domain conceptual from the following partial description of an automated flood warning system.

The region in which the system is to be deployed is composed of two river basins with a major city at the intersection. Each river basin is partitioned into separate zones, and each zone is partitioned into one or more areas. Each area is covered by at least one emergency service unit. The main purpose of the system is to mitigate the consequences of imminent flooding by ensuring that flood alerts are transmitted to emergency services and citizens of the affected areas at least two hours before a flooding occurs

...

The system will use two types of measurement stations: precipitation sensors capable of measuring in real-time the amount of rain falling at a given location, and stream sensors capable of measuring in real-time water height and velocity of the river at that location. Each sensor has a specific location and is used to predict flooding for at least one of the two river basins.

Acute Kidney Injuries Alerts

```
Feature: Send AKI Alerts to Clinician's Phone

As a member of the AKI clinical response team
I want to receive AKI alerts on my Streams-enabled
phone
So that I can treat AKI as soon as possible

Rules:

* Streams evaluates a patient's AKI risks every time it
receives a message reporting a patient's creatinine's
level

* Streams uses the risk assessment algorithm mandated
by the National Patient Safety Agency (NPSA) to assess
AKI risks.

* When an AKI risk is detected, an alert is sent to all
members of the AKI clinical response team.

* To avoid false alarms, no alert is sent for patients
undergoing dialysis.

* An AKI alert should display the patient's name and
location in the hospital (e.g. "bed 12 in Oncology
Ward").
```

Example HL7 message reporting a patient's creatinine level

```
Resource Type: Observation

Code: Creatinine (Serum)

Subject: { Name: John Doe

Medical Record Number:12345678

birthDate: 1 December 1955

                }

value: 1.0 mg/dL

date: 5 May 2018
```