Design of Information Systems

Management System for Vehicle-Operation Training Organizations

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1. Introduction

1.1. Purpose of this Report

This report documents a case study written as a practical part of Professor Martin Gogolla's lecture "Design of Information Systems" in summer 2018. The document is written according to the tasks outlined on the lecture's website (Gogolla and Kästner 2018).

1.2. Domain and Developed System

The vast majority of driving schools relies on software programs for scheduling lessons and their student administration. According to this high demand many highly professional standard software solutions are offered for organizations in driver's education. In contrast, for related domains like flight schools and boating schools, there are not as many tools available.

As the market for information systems for aviation academies, for example, is rather small, so is the number of suitable tools. Often the offered programs started as 'hobby projects' originating from aviation clubs that expanded to the developers' side jobs over the years.

However, most requirements of all training organizations like driving schools, flight schools or boating schools are the same. On the one hand, the data of students aiming for certain licences have to be administrated. Practical lessons on vehicles (maybe aircraft or watercraft) and their maintenance have to be coordinated, on the other hand. In addition, especially flight and boating schools offer to charter their craft for former students or other trained customers in order to maximize the vehicles' operating grades.

As in most cases, it does not matter whether a training is for cars, aeroplanes or sailing yachts, this project aims for a system that—prescinding from the individual vehicles' details—unifies the requirements of all those organizations performing training related to any vehicle operation. In fact, it should be possible to model the individual business based on a common data model. As a result, the economically less interesting domains could benefit from the popular ones and also be provided with a professional software system.

2. Class Structure

As this project aims for a generic model covering the requirements of any kind of training organization related to vehicle operation training, it is assumed the modelled organization performs training on multiple vehicle types. This might not represent the reality but ensures a universal model. Actually, there are driving schools that offer training for road vehicles and boats and at least one German company offers training for all common road vehicles, for boats and even for aircraft, which is very unusual (Fahrschule Norbert Klippel 2011).

2.1. Object to Class

For a start, object models of two concrete scenarios were developed. The first object diagram (figure 1) displays parts of an aviation academy. The second object diagram (figure 3) shows parts of a driving school, focussing on the training programme and its units.

Applying the USE *ObjectToClass* plugin's function *Transform to class diagram* these object diagrams were automatically transformed to preliminary class diagrams (figures 2 and 4) which finally helped to design the actual class diagram for the developed system (see section 2.2).

Generalizing examples is a useful method for approaching a universal model. Unfortunately, due to the USE tool's usability, the process took much longer than it should have. In the "Object to Class" mode the diagram's layout is not saved automatically. It has to be saved manually on every change and loaded manually when continuing the design of the model. Now and then USE even crashes, just printing exception stack traces to the console. Presumably, manual modelling of simple object diagrams and a manual transformation would have been much faster.

In contrast, the design of UML class diagrams in USE (like designed for section 2.2) is very comfortable. Editing the textual `.use` file is much more efficient than the interaction with many other UML-based CASE tools.

2.2. Final Class Structure

The class diagrams generated from the object diagrams led to the class structure displayed by the UML diagram in figure 5.

Below the contained classes with their attributes and associations are outlined.

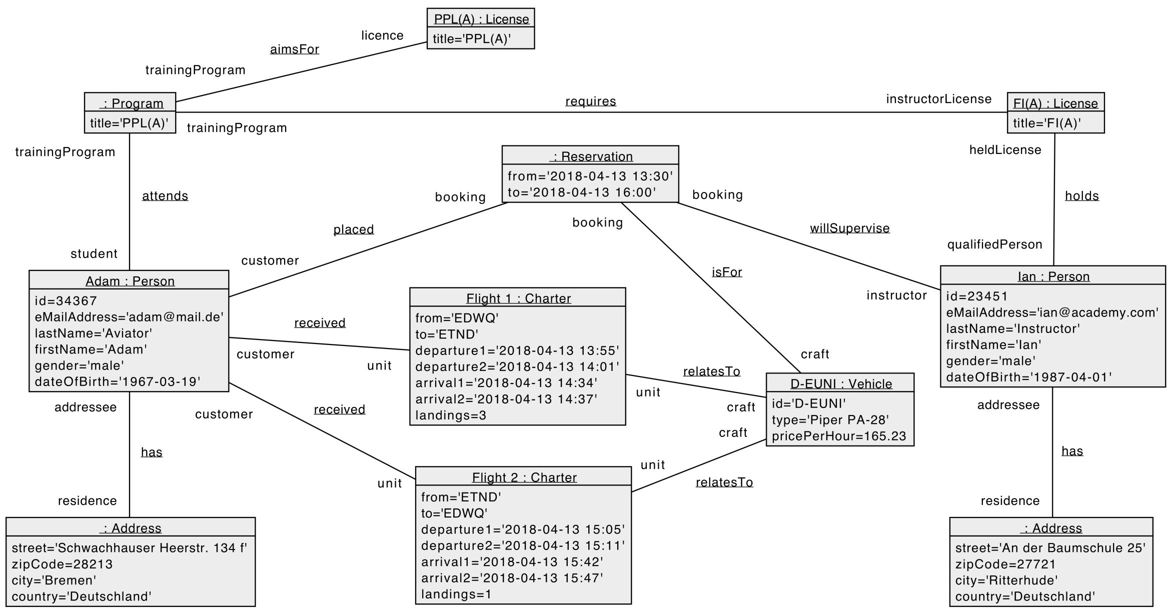


Figure 1: UML Object Diagram modeling parts of an aviation academy

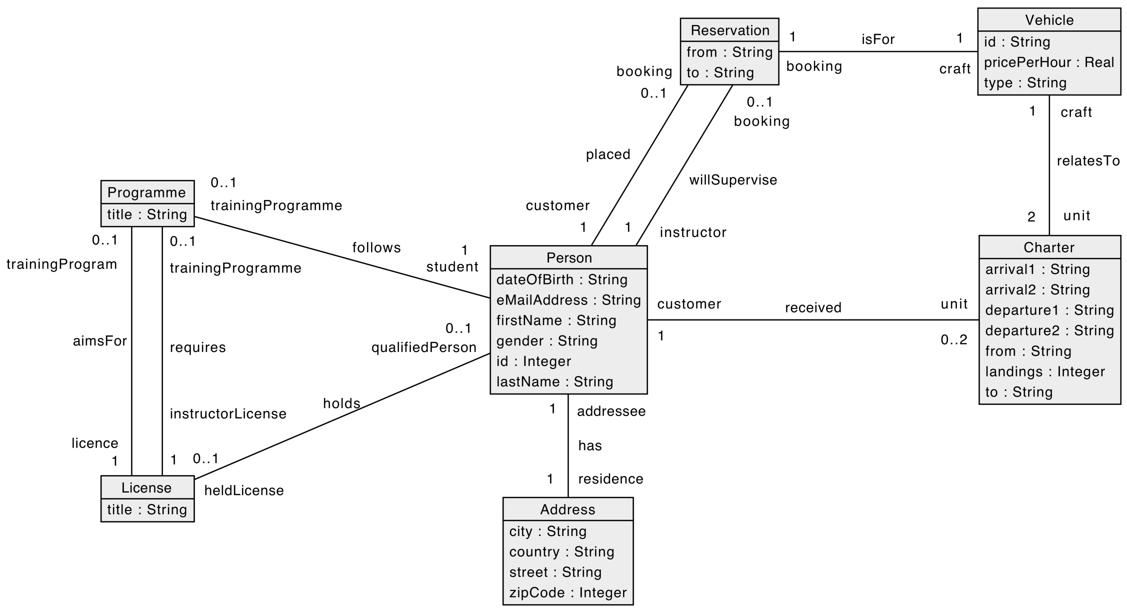


Figure 2: UML class diagram generated from the object diagram displayed in figure 1

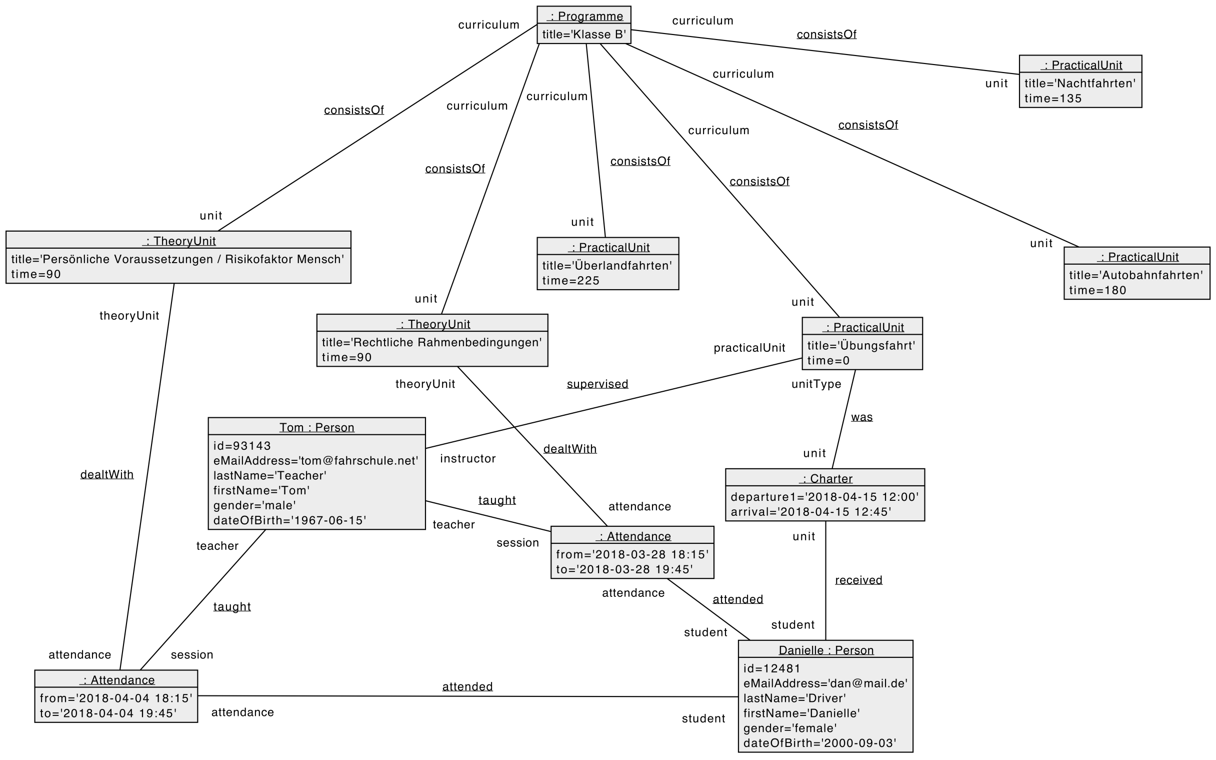


Figure 3: UML object diagram modeling parts of a driving school

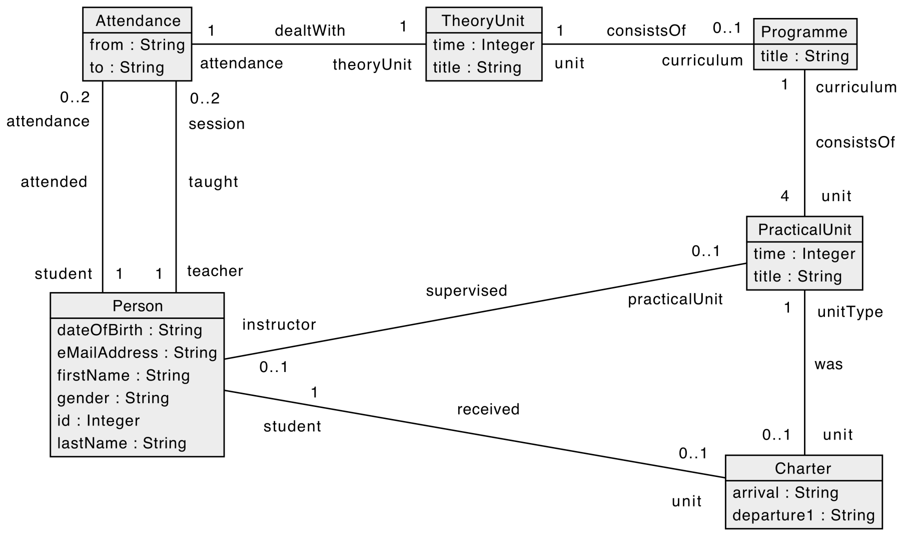


Figure 4: UML class diagram generated from the object diagram displayed in figure 3

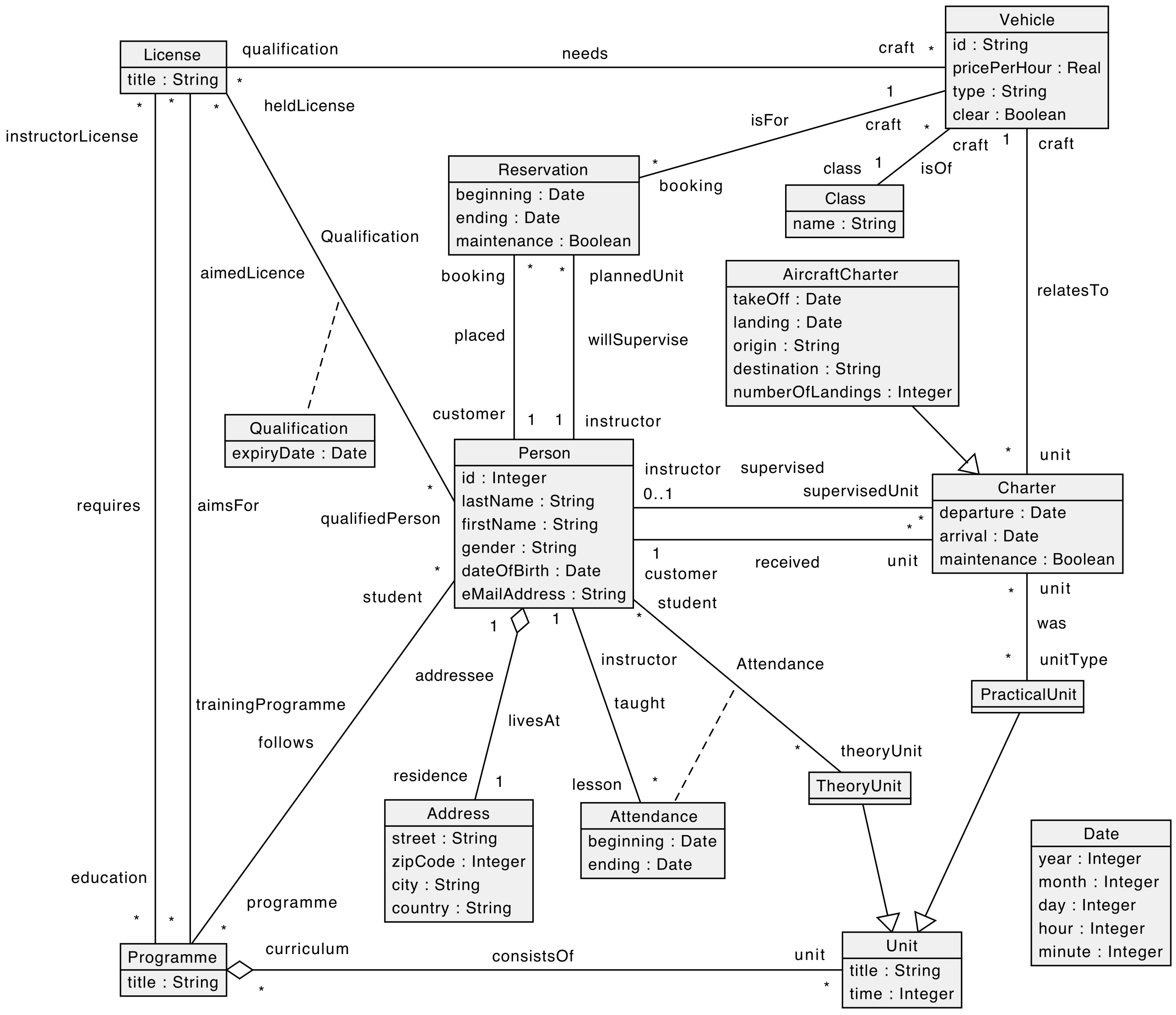


Figure 5: Final UML class diagram

2.2.1. Date

As the system deals a lot with booking, many features are based on date and time information. A *Date* object stores a point in time.

Attributes:

Name	Type	Description
year	Integer	The year.
month	Integer	The month.
day	Integer	The day.
hour	Integer	The hour.
minute	Integer	The minute.

Alternatives:
Date and time could also be encoded in either string or integer attributes in the objects where a date information is required. By default, there are not any compare operations on strings apart from a check on equality and any custom implementation of compares would be more than complicated. In contrast, integer values with a suitable encoding like *yyyymmddHHss* could be compared by using standard compare operations (>, <, >=, etc.). Unfortunately, such a number does not fit into USE's Integer type, which is why *Date* was created.

2.2.2. Person

A *Person* is any person related to the modelled organization. There is no difference between students and instructors. These characteristics are modelled by associations (an instructor may need a certain license himself in order to act as an instructor, for example).

Attributes:

Name	Type	Description
dateOfBirth	Integer	The person's date of birth.
eMailAddress	String	The person's email address.
firtName	String	The person's first name.
lastName	String	The person's last name.
gender	String	The person's gender.
id	Integer	The person's identification number (personnel / customer number).

Associations:

- A person has an *Address*.
- A person may hold licenses (see *Qualification*).
- A person may follow a (training) *Programme*.
- A person may have placed bookings (see *Reservation*).
- A person may be expected to supervise *Reservations* as an instructor.
- A person may have supervised *Reservations* as an instructor.
- A person may actually have received units (see *Charter*).
- A person may have attended theory units (see *Attendance*).
- A person may have taught theory units (see *TheoryUnit*).

2.2.3. Address

Address is a data class storing the elements of a mailing address. Every *Person* refers to an own *Address* object even if multiple persons happen to have the same address.

Attributes:

Name	Type	Description
street	String	The street and house number.
zipCode	String	The ZIP code (“postcode”)
city	String	The city.
country	String	The country.

2.2.4. License

A *License* authorizes a *Person* to operate a craft or to give lessons for a specific craft.
Attributes:

Name	Type	Description
title	String	The license’s title.

2.2.5. Qualification

As an association class, *Qualification* links *Persons* with *Licenses*.

Attributes:

Name	Type	Description
expiryDate	Date	The day the qualification expires.

2.2.6. Programme

A *Programme* combines all lessons that have to be learned in order to get a specific *License*.

Attributes:

Name	Type	Description
title	String	The programme's title.

Associations:

- A programme aims for a *License*.
- An instructor teaching a programme requires a certain *License*.
- A programme (curriculum) consists of *Units*.

2.2.7. Unit

This class is meant to be abstract. Unfortunately, USE does not export it's abstract status to the PDF.[1] A *Unit* can either be a *TheoryUnit* or a *PracticalUnit*.

Attributes:

Name	Type	Description
title	String	The unit's title.
time	Integer	The time in minutes planned for this unit.

2.2.8. TheoryUnit

A *TheoryUnit* teaches theoretical subjects.

2.2.9. PracticalUnit

A *PracticalUnit* is a lesson taught on a vehicle.

[1]Apparently only on Mac systems.

2.2.10. Reservation

A *Reservation* stores a *Person*'s reservation for a *Vehicle*.

Attributes:

Name	Type	Description
beginning	Date	Start of the booked period.
ending	Date	End of the booked period.
maintenance	Boolean	Whether the booking is for maintenance (e.g. workshop or cleaning) and therefore has not been booked by a student or customer.

Associations:

- A *Reservation* always refers to a *Vehicle*.

Alternatives:
To model a reservation that actually is a planned maintenance—a time the vehicle is in a workshop—it would also be possible to derive another class from *Reservation*.

2.2.11. Vehicle

A *Vehicle* is any kind of land craft, watercraft or aircraft that can be chartered.

Attributes:

Name	Type	Description
id	String	The vehicle's id (most likely taken from number plate for cars or call sign for watercraft and aircraft).
pricePerHour	Real	The vehicle's hourly price.
type	String	The vehicle type (e.g. brand and model).
clear	Boolean	Whether the vehicle can be used or is defective.

Associations:

- A *Vehicle* is of a *Class*.
- To operate a *Vehicle*, *Licenses* might be required.

2.2.12. Class

Each vehicle belongs to a specific *Class*. Some examples are listed below:

- Land craft:
  - Motorcycle
  - Car
  - Heavy Goods Vehicle
  - Bus
  - etc.
- Watercraft:
  - Motorboat
  - Dinghy
  - Sailing Yacht
  - etc.
- Aircraft:
  - Single Engine Piston
  - Touring Motor Glider
  - etc.

Attributes:

Name	**Type**	**Description**
name	String	The name of the class.

2.2.13. Charter

Charter stores the data that is needed to determine a price for a lesson. For domains where not complete lessons but minutes are charged—like in aviation—being able to store start and end is very important. A driving school probably would enter standard times from their timetable regardless of the fact that not all lessons exactly took 45 minutes.

Attributes:

Name	**Type**	**Description**
departure	Date	Time of departure.
arrival	Date	Time of arrival.
maintenance	Boolean	Whether the vehicle has been moved for maintenance or not (the driver or pilot might not have to pay for the “charter” when it was operationally necessary).

Associations:

- A *Charter* always refers to one *Vehicle*.
- During a *Charter* exercises of *Units* might have been trained.

2.2.14. AircraftCharter

As there are some more attributes required to describe aircraft charter, a class *AircraftCharter* has been derived from *Charter*.

Attributes:

Name	Type	Description
takeOff	Date	The take-off time. In contrast, the attribute *departure* in the superclass denotes the time when the aircraft began to taxi.
landing	Date	The landing time. In contrast, the attribute *arrival* in the superclass denotes the time when the aircraft reached its praking position.
origin	String	The flight's origin.
destination	String	The flight's destination.
numberOfLanding	Integer	The number of landings performed during the flight, which might be more than the minimum of one when touch-and-go manoeuvres have been trained.

Associations: Inherited from superclass *Charter*.

Alternatives:
The aircraft specific attributes could belong to the standard class *Charter*. In that case they would be obsolete in cases not involving aircraft.

2.2.15. Attendance

Objects of this association class store when a student (*Person*) attended a *TheoryUnit*.

Attributes:

Name	Type	Description
beginning	Date	Start of the lesson.
ending	Date	End of the lesson.

3. Invariants

3.1. Date

There are no invariants checking the correct use of *Date* as a full calendar model would be required for sensible constraints.

3.2. Person

3.2.1. Positive Person ID

A person's ID must be greater than or equal to zero.

```
inv positivePersonId:
  self.id >= 0
```

3.2.2. Unique Person ID

A person's ID must be unique.

```
inv uniquePersonId:
  Person.allInstances->isUnique(id)
```

3.3. License

3.3.1. Unique License

A license must be unique.

```
inv uniqueLicense:
  License.allInstances->isUnique(title)
```

3.4. Programme

3.4.1. Unique Programme

A training programme must be unique.

```
inv uniqueProgramme:
  Programme.allInstances->isUnique(title)
```

3.4.2. TheoryUnit

3.4.3. Student Not Instructor

A student must not be his or her own instructor.

```
inv studentNotInstructorInTheoryUnit:
  not self.theoryUnit.instructor->asSet()->includes(self)
```

3.5. PracticalUnit

3.5.1. Student Not Instructor

A student must not be his or her own instructor.

```
inv studentNotInstructorInPracticalUnit:
  not self.unit.unitType.instructor->asSet()->includes(self)
```

3.6. Reservation

3.6.1. Student Not Instructor

A student must not be his or her own instructor.

```
inv studentNotInstructorInReservation:
  not self.booking.instructor->asSet()->includes(self)
```

3.6.2. Valid Beginning and Ending

```
inv validBeginningAndEnding:
  self.beginning <= self.ending
```

3.6.3. No Chronological Overlapping

```
inv noChronologicalOverlappingOfReservations:
  self.craft.booking->excluding(self)->forAll(
    r|r.ending < self.beginning
      or r.beginning > self.ending
  )
```

3.7. Vehicle

3.7.1. Unique Vehicle

A vehicle ID must be unique.

```
inv uniqueVehicle:
  Vehicle.allInstances->isUnique(id)
```

3.7.2. Non-negative Price

A vehicle’s price must not be negative.

```
inv nonNegativePrice:
  self.pricePerHour >= 0
```

3.8. Class

3.8.1. Unique Class

A (vehicle) class must be unique.

```
inv uniqueClass:
  Class.allInstances->isUnique(name)
```

3.9. Charter

3.9.1. No Chronological Overlapping

```
inv noChronologicalOverlappingOfCharters:
  self.craft.unit->excluding(self)->forAll(
    c|c.arrival < self.departure
    or c.departure > self.arrival
  )
```

3.9.2. Valid Departure and Arrival

```
inv validDepartureAndArrival:
  self.departure <= self.arrival
```

3.10. AircraftCharter

3.10.1. Positive Number of Landings

The number of landings during an aircraft charter must be greater than zero.

```
inv positiveLandings:
  self.numberOfLandings > 0
```

3.10.2. Valid Take-off and Landing

```
inv validTakeOffAndLanding:
  self.takeOff <= self.landing
  and self.takeOff >= self.departure
  and self.landing <= self.arrival
```

3.11. Further Ideas

- Checking whether a *Person* either holds the required license for a booked *Vehicle* or planned a supervised unit with an instructor.
- An instructor must have the required license to teach a programme's units. This constraint may be problematic as an instructor might somehow lose his or her license (due to age or medical issues, for example). Then instantly all

lessons taught in the past become invalid. This is why an operation *isQualifiedForProgramme* has been defined. It can be used as a precondition for the operation entering a unit.

4. Operations

4.1. Date

4.1.1. equals

The operation checks whether a *Date* equals another *Date*.

Parameters:

- d : Date – The other date.

Returns:
Boolean: `true`, if the instance equals `d`; `false` else.

Code:

```
equals(d : Date) : Boolean
  = self.year = d.year and
    self.month = d.month and
    self.day = d.day and
    self.hour = d.hour and
    self.minute = d.minute
```

4.1.2. before

The operation checks whether a *Date* represents a date prior to another *Date*.

Parameters:

- d : Date – The other date.

Returns:
Boolean: `true`, if the instance represents a date prior to `d`; `false` else.

Code:

```
before(d : Date) : Boolean
  = if not (self.year = d.year) then
      self.year < d.year
    else
```

```
      if not (self.month = d.month) then
        self.month < d.month
      else
        if not (self.day = d.day) then
          self.day < d.day
        else
          if not (self.hour = d.hour) then
            self.hour < d.hour
          else
            self.minute < d.minute
          endif
        endif
      endif
    endif
```

Preconditions

```
pre initialized:
  not self.year.isUndefined() and
  not self.month.isUndefined() and
  not self.day.isUndefined() and
  not self.hour.isUndefined() and
  not self.minute.isUndefined()
```

4.1.3. after

The operation checks whether a *Date* represents a date later than another *Date*.

Parameters:

- d : Date – The other date.

Returns:
Boolean: `true`, if the instance represents a date later than `d`; `false` else.

Code:

```
after(d : Date): Boolean = not self.before(d)
```

Preconditions

```
pre initialized:
  not self.year.isUndefined() and
  not self.month.isUndefined() and
  not self.day.isUndefined() and
  not self.hour.isUndefined() and
  not self.minute.isUndefined()
```

4.1.4. duration

The operation calculates the period's time between a *Date* and another *Date*. The operation only works for dates of the same day.

Parameters:

- d : Date – The other date.

Returns:
Integer: The time between the two dates in minutes.

Code:

```
duration(d : Date) : Integer
    = (self.hour - d.hour).abs() * 60
    + (self.minute - d.minute).abs()
```

Preconditions

```
pre initialized:
  not self.year.isUndefined() and
  not self.month.isUndefined() and
  not self.day.isUndefined() and
  not self.hour.isUndefined() and
  not self.minute.isUndefined()
```

4.2. Person

4.2.1. init

Initializes a *Person* object ("constructor").

Parameters:

- id : Integer – The person's id.
- lastName : String – The person's last name.
- firstName : String – The person's first name.
- gender : String – The person's gender.

- dateOfBirth : Date – The person's date of birth.
- eMailAddress : String – The person's email address.
- residence : Address – The person's (post) address.

Code:

```
init(id : Integer,
     lastName : String,
     firstName : String,
     gender : String,
     dateOfBirth : Date,
     eMailAddress : String,
     residence : Address)
  begin
    self.id := id;
    self.lastName := lastName;
    self.firstName := firstName;
    self.dateOfBirth := dateOfBirth;
    self.eMailAddress := eMailAddress;
    insert (self, residence) into livesAt
  end
```

Preconditions:

```
pre notInitialized:
  self.id.isUndefined() and
  self.lastName.isUndefined() and
  self.firstName.isUndefined() and
  self.gender.isUndefined() and
  self.dateOfBirth.isUndefined() and
  self.residence.isUndefined()
```

Postconditions:

```
post initialized:
  self.id = id and
  self.lastName = lastName and
  self.firstName = firstName and
  self.dateOfBirth = dateOfBirth and
  self.eMailAddress = eMailAddress and
  self.residence = residence
```

4.2.2. isQualifiedForProgramme

Checks whether a *Person* is qualified for teaching a specified *Programme*.

Parameters:

- prog : Programme – The programme that shall be checked.

Returns:
Boolean: `true` if the person is qualified for teaching the programme; `false` else.

Code:

```
isQualifiedForProgramme(prog : Programme) : Boolean
    = let heldLicenses = self.heldLicense in
      heldLicenses->union(prog.instructorLicense->asSet())
      = heldLicenses
```

4.2.3. isQualifiedForVehicle

Checks whether a *Person* is qualified for operating specified *Vehicle*, i.e. if the person holds the required *License(s)*.

Parameters:

- vhcl : Vehicle – The vehicle that shall be checked.

Returns:
Boolean: `true` if the person is qualified for operating the vehicle; `false` else.

Code:

```
isQualifiedForVehicle(vhcl : Vehicle) : Boolean
  = let heldLicenses = self.heldLicense in
    heldLicenses->union(vhcl.qualification->asSet())
    = heldLicenses
```

4.2.4. addCharter

Adds a *Charter*.

Parameters:

- charter : Charter – The charter.

Code:

```
addCharter(charter: Charter)
  begin
    insert (self, charter) into received;
  end
```

4.2.5. addSupervisedCharter

Adds a *Charter* that has been supervised by an instructor.

Parameters:

- charter : Charter – The charter.
- instructor : Person – The instructor.
- unit : PracticalUnit – The unit the performed exercises were taken from.

Code:

```
addSupervisedCharter(charter : Charter,
                     instructor : Person,
                     unit : PracticalUnit)
  begin
    self.addCharter(charter);
    insert (charter, unit) into was;
    insert (instructor, charter) into supervised;
  end
```

Preconditions:

```
pre validInstructor:
  instructor.heldLicense->union(unit.curriculum.
     instructorLicense)->asSet()
  = instructor.heldLicense
```

4.2.6. sumOfHours

Sums up the total duration of all units a *Person* has received.

'Hours', in the operation's title, should not be taken literally as the function —with the *Date's* class present implementation—returns minutes.

Returns:
Integer: Total duration in minutes.

Code:

```
sumOfHours() : Integer = self.unit.duration()->sum()
```

4.3. Programme

4.3.1. qualifiedInstructors

Returns all *Persons* who are qualified to teach lessons in the *Programme*.

Returns:
Set(Person): All persons who are qualified to teach lessons in the programme.

Code:

```
qualifiedInstructors() : Set(Person) =
  Person.allInstances()->select(p : Person |
  p.heldLicense->intersection(self.instructorLicense)
  = self.instructorLicense
)
```

4.4. Charter

4.4.1. duration

Returns a *Charter's* duration.

Returns:
Integer: The charter's duration.

Code:

```
duration() : Integer = arrival.duration(departure)
```

5. Test Cases

Two positive scenario and one negative scenario have been designed in order to test the system. All scenarios require an initial state (see section A.2.1). Figure 6 shows an object diagram of the initial state.

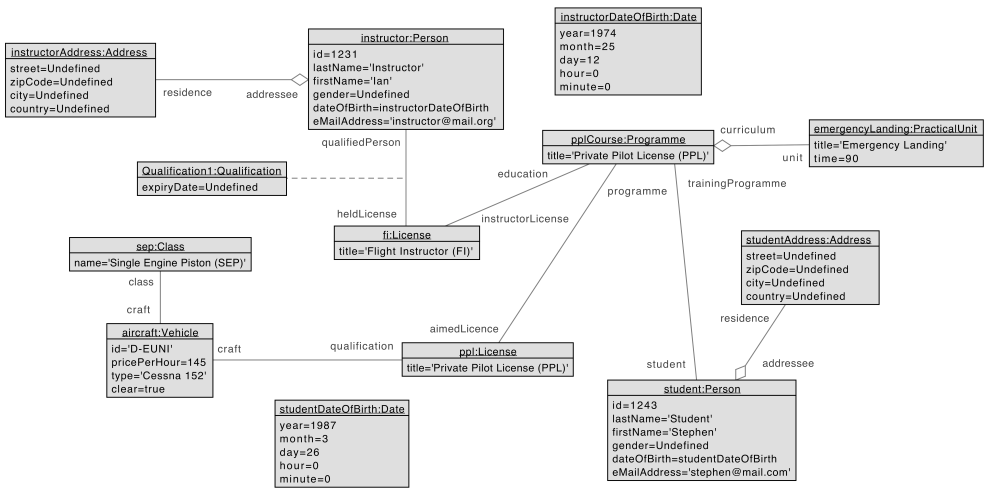
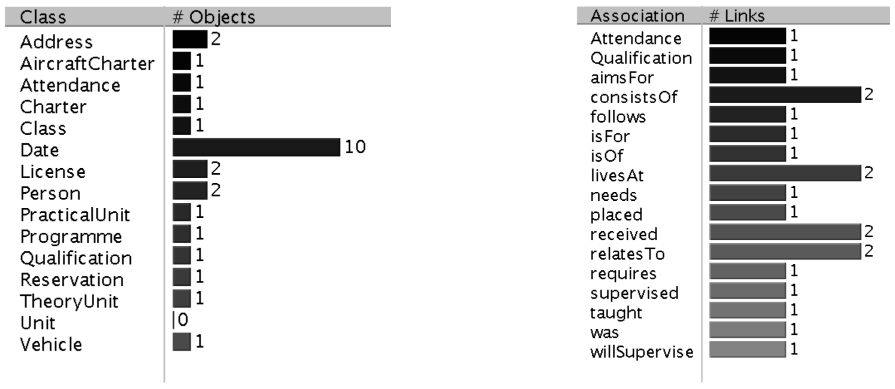


Figure 6: Initial state

5.1. Positive Scenarios

In the positive scenarios, all invariants, pre- and postconditions and inherent constraints are fulfilled.

The positive scenarios together cover all objects and all links as shown in figure 7. Only *Unit* is never instantiated because it is an abstract class.



(a) Object Count (b) Link Count

Figure 7: Object and link coverage

5.1.1. Positive 1

The scenario is given by the listing in section A.2.2. Figure 8 shows the scenario as UML object diagram. As shown in figure 9, all invariants are fulfilled.

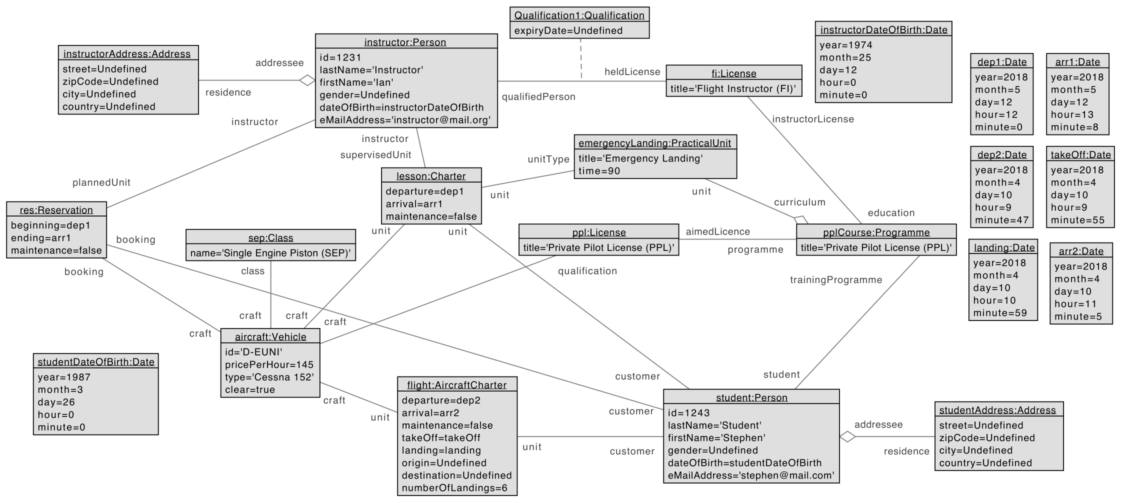
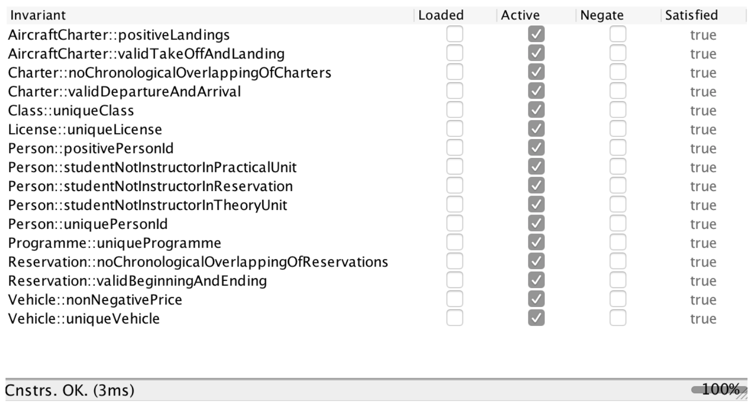


Figure 8: Positive 1



Invariant	Loaded	Active	Negate	Satisfied
AircraftCharter::positiveLandings		✓		true
AircraftCharter::validTakeOffAndLanding		✓		true
Charter::noChronologicalOverlappingOfCharters		✓		true
Charter::validDepartureAndArrival		✓		true
Class::uniqueClass		✓		true
License::uniqueLicense		✓		true
Person::positivePersonId		✓		true
Person::studentNotInstructorInPracticalUnit		✓		true
Person::studentNotInstructorInReservation		✓		true
Person::studentNotInstructorInTheoryUnit		✓		true
Person::uniquePersonId		✓		true
Programme::uniqueProgramme		✓		true
Reservation::noChronologicalOverlappingOfReservations		✓		true
Reservation::validBeginningAndEnding		✓		true
Vehicle::nonNegativePrice		✓		true
Vehicle::uniqueVehicle		✓		true

```
Cnstrs. OK. (3ms)                                          100%
```

Figure 9: Invariants in Positive 1

5.1.2. Positive 2

The scenario is given by the listing in section A.2.3. Figure 10 shows the scenario as UML object diagram. As shown in figure 11, all invariants are fulfilled.

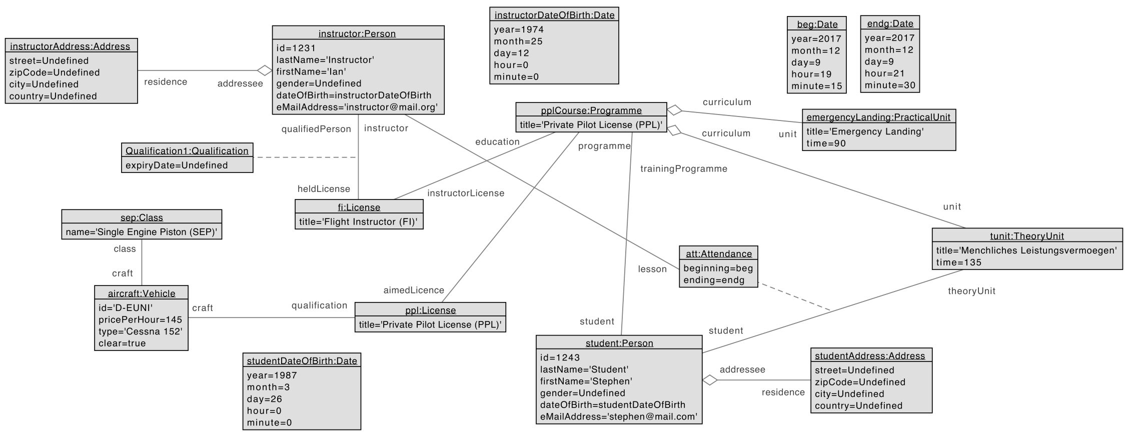
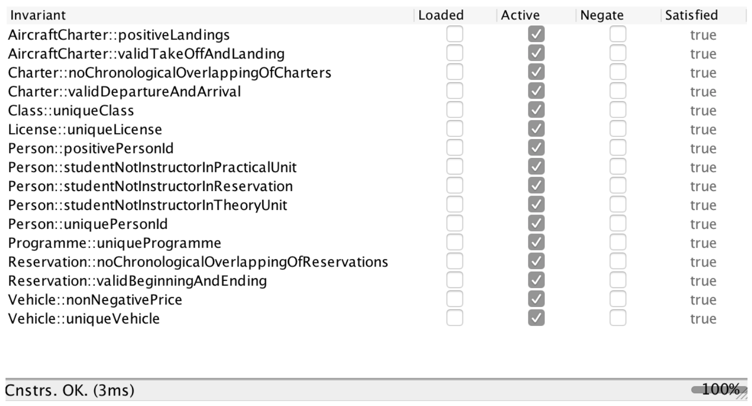


Figure 10: Positive 2



Invariant	Loaded	Active	Negate	Satisfied
AircraftCharter::positiveLandings	☐	✓	☐	true
AircraftCharter::validTakeOffAndLanding	☐	✓	☐	true
Charter::noChronologicalOverlappingOfCharters	☐	✓	☐	true
Charter::validDepartureAndArrival	☐	✓	☐	true
Class::uniqueClass	☐	✓	☐	true
License::uniqueLicense	☐	✓	☐	true
Person::positivePersonId	☐	✓	☐	true
Person::studentNotInstructorInPracticalUnit	☐	✓	☐	true
Person::studentNotInstructorInReservation	☐	✓	☐	true
Person::studentNotInstructorInTheoryUnit	☐	✓	☐	true
Person::uniquePersonId	☐	✓	☐	true
Programme::uniqueProgramme	☐	✓	☐	true
Reservation::noChronologicalOverlappingOfReservations	☐	✓	☐	true
Reservation::validBeginningAndEnding	☐	✓	☐	true
Vehicle::nonNegativePrice	☐	✓	☐	true
Vehicle::uniqueVehicle	☐	✓	☐	true

Cnstrs. OK. (3ms) 100%

Figure 11: Invariants in Positive 2

5.2. Negative Scenarios

In negative scenarios at least one condition (invariant, pre- or postcondition) fails.

5.2.1. Negative 1

This scenario tries to add a supervised charter with the student himself as an instructor. As expected, this is not possible:

```
[Error] 1 precondition in operation call ‘Person::
    addSupervisedCharter(self:student, charter:lesson,
    instructor:student, unit:emergencyLanding)’ does not hold:
  validInstructor: ...
```

6. Queries

Queries—in contrast to operations—do not deal with individual objects. They rather provide information on the entire record.

6.1. Qualified Instructors

This query returns all persons in the organization who are qualified to instruct in any training programme.

Requires:
`init.soil`

Query:

```
Programme.allInstances().qualifiedInstructors()->asSet()
```

Result:

```
Set{instructor} : Set(Person)
```

References

[Fahrschule Norbert Klippel 2011] Fahrschule Norbert Klippel (2011): *Drive & Fly*. Unternehmenswebsite. URL: http://www.fahrschule-klippel.de (visited on 23/04/2018).

[Gogolla and Kästner 2018] Gogolla, Martin and Andreas Kästner (2018): Design of Information Systems (Entwurf von Informationssystemen) (SoSe 2018, VAK 03-MB-703.02, 6 SWS / 8 ECTS). Lecture website. URL: http://www.db.informatik.uni-bremen.de/teaching/courses/ss2018_eis/ (visited on 13/04/2018).