Requirements Specification: Hamster Marking System

Final Version

Fritz Solms
Dept Computer Science, University of Pretoria

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Contents

1 Project background

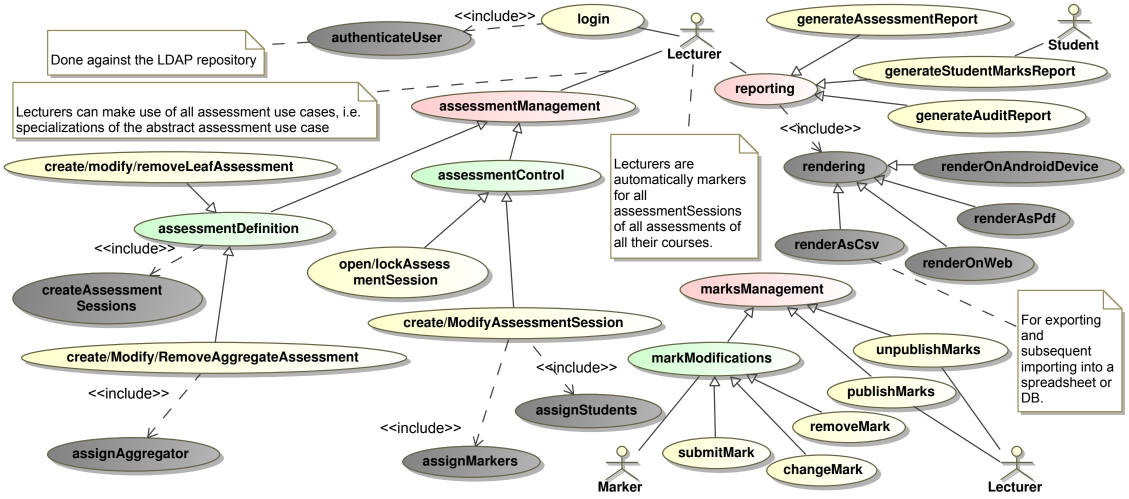
Lecturers make use of assistant lecturers and higher-level students to mark assessments like practicals, assignments, tests and exams. The management of marking sheets, collection, aggregation and publication of marks results currently in a lot of manual labour. This is not only very inefficient, but may also result in integrity issues with lost marks and in errors being introduced during the collection and importing of marks as well as privacy issues with marks being, at times, visible to fellow students.

The above inefficiencies and other problems have led Jan Kroeze to propose a marks management system which can be accessed from mobile devices and web browsers.

2 Project vision and scope

The proposed system is a mark collection, aggregation and publication system which will allow lecturers to

- maintain course information,
- manage assessments,
- manage marks, and
- reporting.



Done against the LDAP repository

Lecturers can make use of all assessment use cases, i.e. specializations of the abstract assessment use case

Lecturers are automatically markers for all assessmentSessions of all assessments of all their courses.

For exporting and subsequent importing into a spreadsheet or DB.

Figure 1: The scope of the system.

In particular, the system will allow

- **administrators** to

  - downloading and updating of information around courses from the CS systems
    - including the lecturers, teaching assistants and students for a course,

- **lecturers** to
  - specify atomic leaf assessments (assessments which are given a single, atomic mark, like a question for a test or a practical which is assigned a single atomic mark in the assessment system) and how these assessments are to be aggregated into higher level assessments (e.g. how the questions are aggregated into a test mark and how the test and practical marks are aggregated into a semester mark),
  - create assessment sessions with students and markers assigned to these sessions,
  - publish leaf and aggregated marks,
  - and generate assessment reports at any level of aggregation as well as audit reports and have these rendered either onto the screen, onto a PDF document or onto a CSV file for subsequent importing into a spreadsheet or a database.
- **markers** who have been assigned to mark leaf assessments of certain students[1]
  - to submit, modify or remove marks[2],
- and **students**
  - retrieve their marks for an assessment at any level of aggregation and have these rendered either onto the screen, onto a PDF document or onto a CSV file for subsequent importing into a spreadsheet or a database.

3 Stakeholders

The stakeholders of the system include the following

The Client is7 Jan Kroeze who originated the idea for the mini-project and who is the main source of the requirements information. Vreda Pieterse, who has been involved with teaching in the department for some time and has also significantly contributed to the requirements and requirements validation.

Lecturers use the system to define assessments and aggregations of assessments and to retrieve marks.

Teaching asssistants use the system to capture marks.

Students use the system to retrieve their marks.

TechTeam is responsible with assisting with the CS system integration and has to deploy the system into production and maintain the system.

WebTeam will be responsible for integrating the system into the web front end of the CS systems and for maintaining the web front end.

[1] If a marker is assigned to an aggregate assessment, the marker may mark all components of that aggregate assessment,

[2] A full audit trail will be maintained by the system,

4 Architecture requirements

This section discusses the software architecture requirements — that is the requirements around the software infrastructure within which the application functionality is to be developed. The purpose of this infrastructure is to address the non-functional requirements. In particular, the architecture requirements specify

- the architectural responsibilities which need to be addressed,
- the access and integration requirements for the system,
- the quality requirements, and
- the architecture constraints specified by the client.

4.1 Access and integration requirements

This section discusses

1. the requirements for the different channels through which the system can be accessed by people and systems, and
2. the integration channels which must be supported by this system.

4.1.1 Access channels

The system will be accessible by human users through the following channels:

1. From a web browser through a rich web interface. The system must be accessible from any of the widely used web browsers including all recent versions of *Mozilla Firefox*, *Google Chrome*, *Apple Safari* and *Microsoft Internet Explorer*.
2. From mobile *Android* devices.

Other systems should be able to access the services offered by the system through either RESTful or SOAP-based web services.

4.1.2 Integration channels

This system will be able to access

- the CS LDAP server in order to retrieve person details and class lists.
- the CS MySQL database to access course/module information.

Details of the respective data structures are given in appendix A.1. Further details regarding the integration to these databases and the use of the mock databases created for this project can be obtained from the *TechTeam*.

In addition, the system will allow manual integration through importing and exporting of CSV files. In particular, the system will support

- Importing of assessment entries from CSV files.
- Exporting of mark sheets to CSV files.

4.1.3 Quality requirements for access and integration channels

All communication of sensitive data must be done securely using HTTPS.

4.2 Architectural responsibilities

The architectural responsibilities include the responsibilities of providing an infrastructure for

1. a web access channel,
2. a mobile access channel,
3. hosting and providing the execution environment for the services/business logic of the system,
4. persisting and providing access to domain objects,
5. providing an infrastructure for specifying and executing reports, and
6. integrating with an LDAP repository.

4.3 Quality requirements

The quality requirements are the requirements around the quality attributes of the systems and the services it provides. This includes requirements like performance, scalability, security, auditabilty, usability, and testability requirements.

4.3.1 Security

General security considerations:

1. All system functionality is only accessible to users who can be authenticated through the LDAP system used by the department of Computer Science.
2. The system must make certain that any operation on any data is only allowed if the user may use the requested operation on the requested data object. Some services only require role based authorization for the service itself. However, the system must be able to constrain who is allowed to do what with which entity. For example, a student may see his or her results, but not those of any other students.

In particular

1. One or more persons may be assigned as marker for any assessment at any level of granularity. If the assessment is a leaf assessment, the marker may assign a mark to that assessment. If the assessment is an aggregate assessment, the marker may assign a mark to any leaf assessment of the aggregate assessment. Only markers and assessment owners may change the marks for an assessment.
2. The person creating an assessment is the assessment owner. Only the assessment owner may modify any aspects of the assessment itself including adding, changing or removing assessment components or the marks assigned to assessment components.

4.3.2 Auditability

One should be able to query for any entity, any changes made to that entity or any of its components. The information provided must include

- by whom the change was made,
- when the change was made, and
- the new and old value of the field(s) which were changed.

The system will provide only services to extract information from the audit log and will not allow the audit log to be modified.

4.3.3 Testability

All services offered by the system must be testable through unit tests which test

- that the service is provided if all pre-conditions are met (i.e. that no exception is raised except if one of the pre-conditions for the service is not met), and
- that all post-conditions hold true once the service has been provided.

4.3.4 Usability

1. 98% of users (e.g. students or lecturers) should be able to use the system without prior training.
2. The system must be developed using internationalization in order to support multiple languages. Initially only English needs to be supported, but it must allow for translations to the other official languages of the University to be added at a later stage.

4.3.5 Scalability

1. The deployed system must be able to scale to handle all assessments of all modules of the department of Computer Science.
2. The deployed system must be able to operate effectively under the load of 500 concurrent users.
3. The software architecture should be such that it can, in future, be easily modified to scale to *Massive Open Online Courses* (MOOC) by porting the system onto clustered and cloud-computing based architectures.

4.3.6 Performance requirements

The system does not have particularly stringent performance requirements.

1. All non-reporting operations should respond within less than 1 second.
2. Report queries should be processed in no more than 10 seconds.

4.4 Architecture constraints

The following architecture constraints have been introduced largely for maintainability reasons:

1. The system must be developed using the following technologies
   - The system must be developed using the *Django web framework*.
   - Persistence to a relational database must be done using the *Object-Relational Mapper* bundled with *Django*.
   - The unit tests should be developed using the *Django unittest module*.
2. The system must ultimately be deployed onto a *Django application server* running within the `cs.up.ac.za` *Apache* web server.
3. The mobile client must be running on an *Android* application
4. The system must be decoupled from the choice of database. The system will use the *MySQL* database.
5. The system must expose all system functionality as restful web services and hence may not have any application functionality within the presentation layer.
6. Web services must be published as either SOAP-based or RESTful web services.

5 Requirements for the development process used

- All changes to produced artifacts must be made through the `git` repositories assigned to the project.
- All functionality must be unit-tested.

6 Application (functional) requirements

This section discusses the functional requirements for the *Hamster Marking System*. Section 6.1 which discusses the domain objects introduces the core domain concepts and relationships between this concepts.

This is followed by the functional requirements specification for the concrete use cases of the system.

6.1 Domain objects

This section introduces core domain concepts and aspects of the requirements which cross-cut across different use cases. these concepts. These concepts are relevant for the understanding of the detailed use case requirements.

6.1.1 Overview

The main domain objects are

- **persons** which may be assigned lecturer, marker or student roles with respect to different courses and assessments,
- **assessments** which can be aggregated which are aggregated into higher level assessments (meaning marks are aggregated into higher level marks), and for which different assessment sessions may be created, and
- mark allocations.

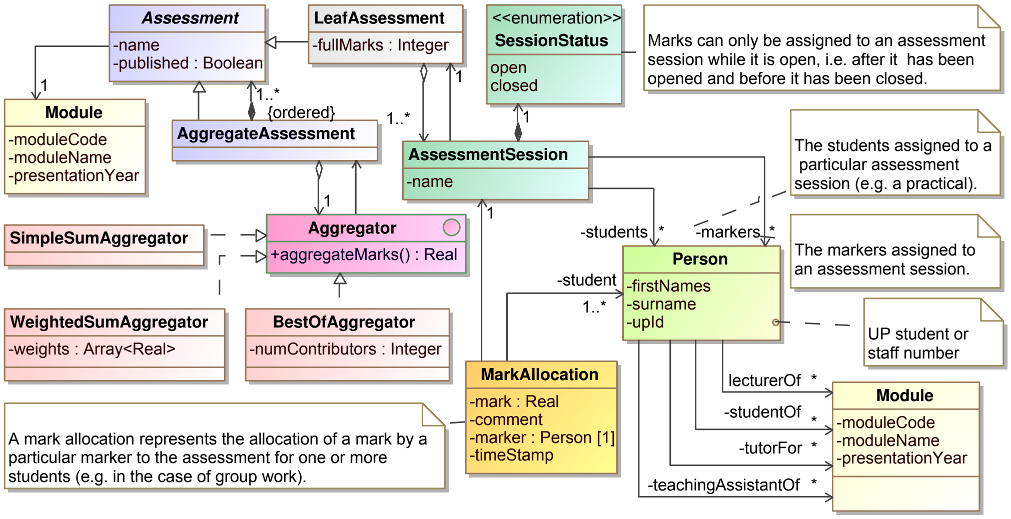


Figure 2: Overview of the data structures and relationships for the core domain objects of the system.

6.1.2 Persons

All persons known to the system must be persons which are registered users of the Computer Science LDAP registry and will have to be authenticated against this registry. The person information their demographic details (name, student/personal no, . . .) including the courses assigned to lecturers and students is obtained from the CS-LDAP repository.

The system should not have separate classes for students, markers and lecturers, but these are simply different roles people could play in the context of a course or an assessment session. A person who is a lecturer of one course could be assigned to be a marker of an assessment for another course and could register to be a student of a third course.

6.1.3 Assessment, assessment sessions and markers

Assessments are either leaf assessments or aggregate assessments. a leaf assessment is an assessment for which an atomic mark is allocated to and for which the full marks have been specified. Examples include a question in a test or exam and a mark for a practical component or for the entire practical (if only the full practical marks captured by the system). An aggregate assessment is an aggregation of lower level assessments which can themselves be aggregate assessments or leaf assessments. For example,

- the marks of the questions for a test are aggregated into a test mark,
- the marks across the tests and practicals could be aggregated into a semester mark, and
- the semester and exam marks could be aggregated into a course mark.

The default aggregator is the simple sum aggregation (i.e. the marks for the lower level assessment components are simply added up). But the lecturer may assign a different aggregator to an aggregate assessment. For now, the aggregators which need to be supported are

- a `WeightedSumAggregator` which assigns different weights to the components of the aggregate component, and
- a `BestOfAggregator` which selects only the best n components of the aggregate component and returns the sum of their allocated marks.

A leaf assessment (i.e. an assessment for which a mark is allocated by markers) has one or more assessment sessions. Each assessment session is assigned a number of markers and a subset of the students enrolled for the module. The associated markers may mark the assessment (including all its assessment components recursively) of those students allocated to that particular assessment session.

6.1.4 Assessment sessions, markers and mark allocations

By default any assessment associated with a module may only be marked by the persons who are assigned lecturers for that module. Thus by default an assessment has a single assessment session which contains all registered students for the course and only the lecturers as markers.

A lecturer can assign any person within the CS-LDAP system as an additional marker. Alternatively, a lecturer may create multiple assessments, each with a subset of the students and each with its assigned markers.

Markers may be assigned to be able to mark an assessment for a set of students. The marker will be able to supply marks for the allocated students for all the leaf assessments contained within any of the assessments assigned to him or her.

Assessment sessions can be opened and closed for markling. By default, assessment sessions are closed and need to be opened for marking by one of the lecturers of the course. Marks can only be allocated by assigned markers and only whilst the assessment session is open.

Any marker assigned to an assessment session for an aggregate assessment may mark all its components. Any markers assigned to additional assessment session for specific components are in addition to the markers assigned at the higher level of aggregation.

6.2 Login

All system functionalities are only accessible to users who have been able to log into the system.

6.2.1 Service contract

The service request for the `login` use case contains the authentication credentials (username and password). If the LDAP system is available and if the user could be authenticated, the response contains the user's name and uid (student or staff number) as well as the information of the different roles the user has been assigned on different modules.

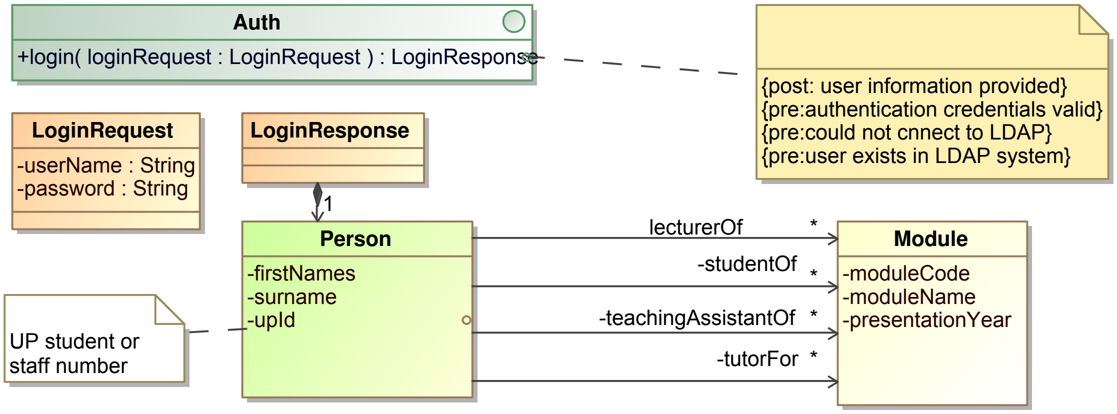


Figure 3: The service contract for the login use case.

Note that its is the service's responsibility to construct the required response object.

6.2.2 Functional requirements

The functional requirements for the `login` use case include the authentication against LDAP and the sourcing of required information from the LDAP repository as well as the ultimate construction of the result object.

6.2.3 Process specification

The provided user authentication credentials are used to authenticate the user against the LDAP repository. If this is unsuccessful, a corresponding exception is raised. Otherwise the person's demographics as well as the designated lecturer, teaching-assistant, tutor and student roles with respect of different modules is sourced from the LDAP repository and the person details are constructed as required by the services contract specified in section 6.2.1.

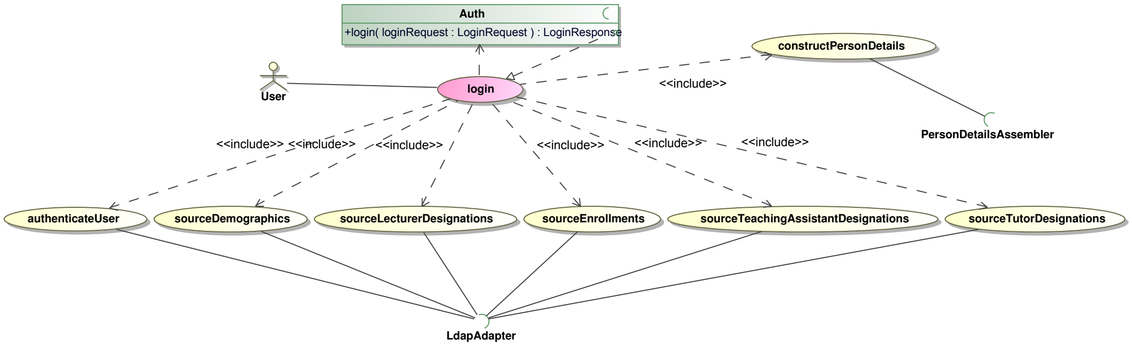


Figure 4: The functional for the login use case.

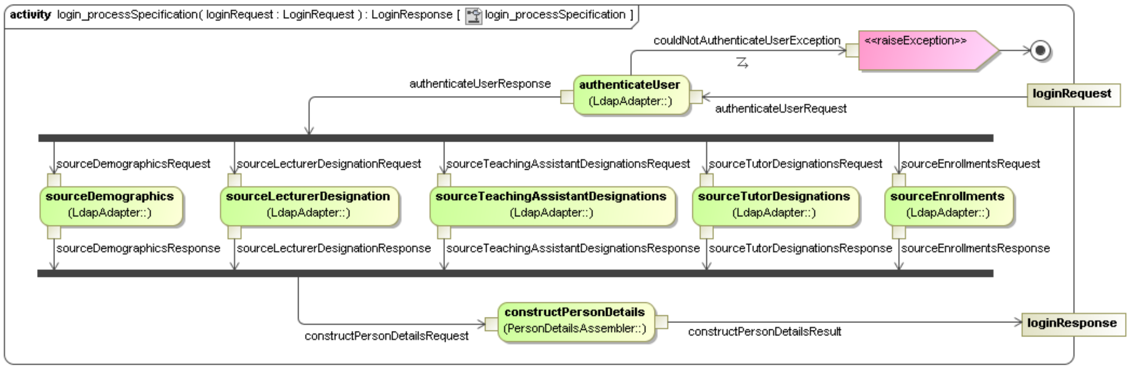

activity login_processSpecification(loginRequest : LoginRequest) : LoginResponse [login_processSpecification]
couldNotAuthenticateUserException
<<raiseException>>
authenticateUserResponse
authenticateUser
(LdapAdapter::)
loginRequest
authenticateUserRequest
sourceDemographicsRequest
sourceLecturerDesignationRequest
sourceTeachingAssistantDesignationsRequest
sourceTutorDesignationsRequest
sourceEnrollmentsRequest
sourceDemographics
(LdapAdapter::)
sourceLecturerDesignation
(LdapAdapter::)
sourceTeachingAssistantDesignations
(LdapAdapter::)
sourceTutorDesignations
(LdapAdapter::)
sourceEnrollments
(LdapAdapter::)
sourceDemographicsResponse
sourceLecturerDesignationResponse
sourceTeachingAssistantDesignationsResponse
sourceTutorDesignationsResponse
sourceEnrollmentsResponse
constructPersonDetails
(PersonDetailsAssembler::)
constructPersonDetailsRequest
constructPersonDetailsResult
loginResponse

Figure 5: The process specification for the login use case.

6.3 Assessment use cases

The system will allow lecturers to create, modify and remove aggregate and leaf assessments. An assessment is by default not published implying that students cannot, by default, query their marks for an assessment. Once a lecturer has published an assessment, students can query marks for that assessment or any of its components.

Leaf assessments are assessments to which an atomic, floating point mark is assigned. Aggregate assessments are not assigned marks. Instead the mark is calculated by aggregating the marks of the component assessments. How these are aggregated depends on the type of aggregator assigned to the aggregate assessment. Examples are simple summation aggregators, weighted sum aggregators or best-of aggregators.

6.3.1 Create leaf assessment

Creating a leaf assessment requires the lecturer to specify

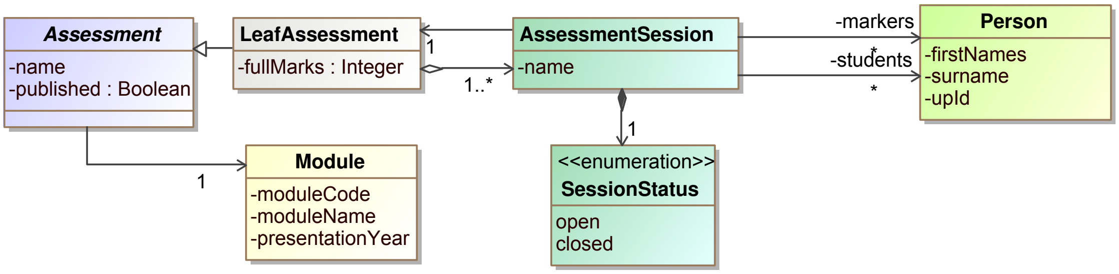


Figure 6: The structure of a leaf assessment.

- the course for which this is an assessment,
- a name for the assessment,
- and the full marks for the assessment (e.g. a practical which counts out of 20), and
- one or more assessment sessions which have a name and is either open or closed for marking and which have a subset of the enrolled students as well as potentially a set of markers assigned for the assessment session[3].

The data structure created by the use case is shown in figure 6.

6.3.2 Create aggregate assessment

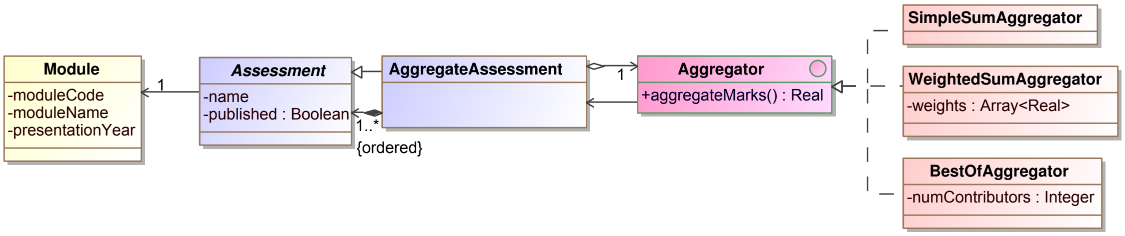


Figure 7: The structure of a aggregate assessment.

When creating aggregate assessments, lecturers need to specify

1. the course for which this is an assessment,
2. the assessment name,

[3] By default there is a single assessment session for all enrolled students with only the course lecturers being assigned as markers and assessment sessions are, by default closed.

3. the asssessments which are to be the components of the aggregate assessment, and
4. an aggregator which determines how the marks of the component assessments are aggregated into a mark for the aggregate assessment.

The data structure created by the use case is shown in figure 7.

6.4 Marks management

Lecturers can open and close assessment sessions for marking. A person may only assign a mark for a leaf assessment for a specific student if

- the assessment session for that student is open,
- the person is assigned by one of the lecturers of the course as a marker for the assessment session for that assessment and student, or
- if the person is assigned as marker for one of the aggegate assessments containing the leaf assessment with such an assessment session.

The system will prevent a marker from assigning a mark which is either negative or exceeds the fullMarks for the leaf assessment.

6.5 Reporting

The reporting use cases purely provide raw and processed information from the system without altering any information within the system (except adding some audit log entries for the report generation itself). This includes the generation of assessment reports, student marks reports and audit reports. All reports can be rendered either onto an Android device, a web interface, a PDF document or a CSV file for later importing into a database or spreadsheet.

6.5.1 Generate assessment report

Assessment reports can be generated at any level of aggregation. All marks are aggregated to the level at which the assessment report is requested. In addition a statistical analysis of the marks is done which includes the calculation of the class average as well as a frequency analysis.

The assessment report request has the information required to identify the asessment for which an assessment report is requested as well as the details for the frequency analysis required.

The response object contains the information of the report rendered in the required format (e.g. on a web page, a PDF document or a CSV file). It contains information about which assessment this is an assessment report, a date/time stamp, the mark allocations for the different students of the module and the results of the simple statistical analysis which includes the class average (arithmetic mean), the standard deviation, and the results of the frequency analysis and a normal distribution analysis.

The functional requirements for the `generateAssessmentReport` use case include the sourcing and aggregation of all assessment components, the calculation of statistics, the construction of the report data object and ultimately the rendering of the report onto either a user interface, a PDF document or a CSV file. The latter is done by appropriate report renderers.

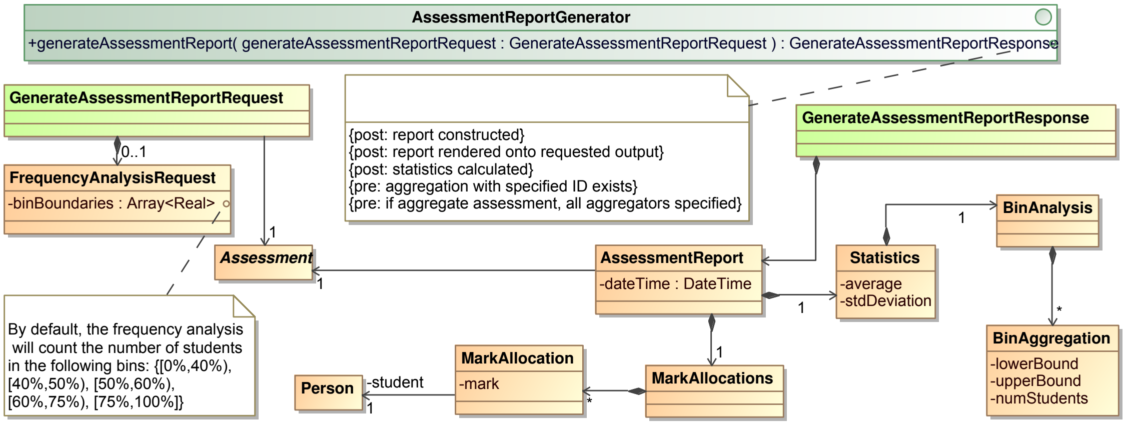

AssessmentReportGenerator
+generateAssessmentReport(generateAssessmentReportRequest : GenerateAssessmentReportRequest) : GenerateAssessmentReportResponse
GenerateAssessmentReportRequest
0..1
FrequencyAnalysisRequest
-binBoundaries : Array<Real>
{post: report constructed}
{post: report rendered onto requested output}
{post: statistics calculated}
{pre: aggregation with specified ID exists}
{pre: if aggregate assessment, all aggregators specified}
GenerateAssessmentReportResponse
1
Assessment
1
AssessmentReport
-dateTime : DateTime
Statistics
-average
-stdDeviation
1
BinAnalysis
1
*
BinAggregation
-lowerBound
-upperBound
-numStudents
By default, the frequency analysis will count the number of students in the following bins: {[0%,40%), [40%,50%), [50%,60%), [60%,75%), [75%,100%]}
Person
-student
1
MarkAllocation
-mark
*
MarkAllocations
1

Figure 8: The service contract for the login use case.

6.5.2 Generate student marks report

Students can use the system to generate themselves marks reports at any level of granularity. The marks report will contain, in a tree structure, all leaf and aggregated marks up to the level of aggregation for which the report was requested.

Like all other reports, the student marks report can also be rendered onto web and Android based UIs as well as PDF and CSV files.

The student marks report request has sufficient information to identify both, the student and the assessment for which a marks report is required.

The response object has a date/time stamp and the marks tree which contains the assessment name and allocated mark as well as all published contributing (aggregated) assessments and their marks.

6.5.3 Generate audit report

Lecturers may request audit reports for any assessment which will contain for any audit event

- A date/time stamp.
- The userId for the session within which the event occured.
- The action which was performed by the user.

The audit events will include

- all assessment creations, modifications and removals,
- all assessment session creations, modifications and removals,
- all mark submissions, modifications and removals,
- any requests to open/close assessment sessions,

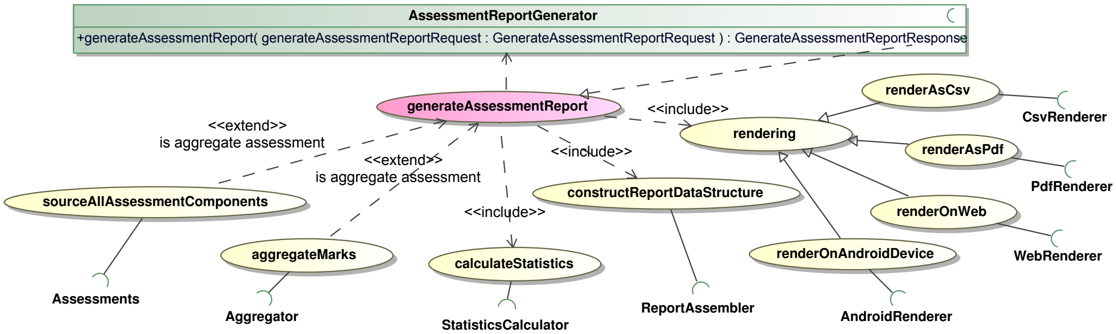


Figure 9: The functional for the generate assessment-report use case.

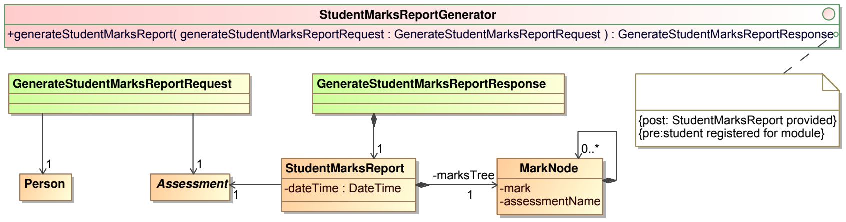

StudentMarksReportGenerator
+generateStudentMarksReport(generateStudentMarksReportRequest : GenerateStudentMarksReportRequest) : GenerateStudentMarksReportResponse
GenerateStudentMarksReportRequest
GenerateStudentMarksReportResponse
{post: StudentMarksReport provided}
{pre:student registered for module}
1
1
1
Person
Assessment
1
StudentMarksReport
-dateTime : DateTime
-marksTree
1
MarkNode
-mark
-assessmentName
0..*

Figure 10: The service contract for the generate student marks report use case.

- any requests to publish marks,
- any requests for any reports including assessment reports, students marks reports and audit reports.

7 Architecture design

7.1 Overview

layered architecture: - presentation layer - access layer - services layer - domain objects layer - infrastructure layer (ORM, integration channels, ...)

presentation layer - django web app - android app - restful web services access for other systems

layers: presentation business logic domain objects infrastructure backend

7.2 Layers

The architectural pattern used at the high-level will be layering. This results in good high-level responsibility separation and allows the reuse of lower level layer components across components in higher level layers (e.g. the business logic layer components are reused across the web front-end, Android client application and web services portal).

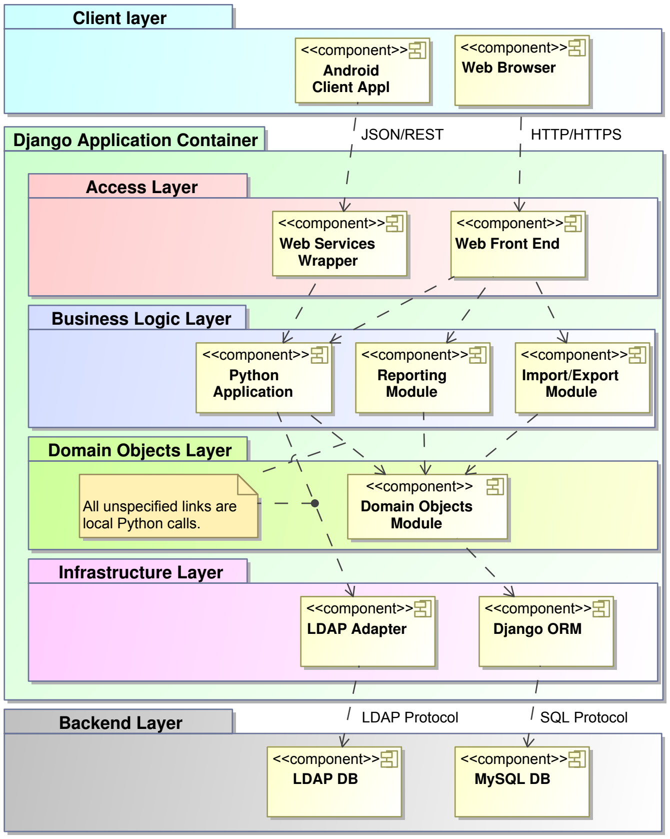

Client layer
<<component>> Android Client Appl
<<component>> Web Browser
JSON/REST
HTTP/HTTPS
Django Application Container
Access Layer
<<component>> Web Services Wrapper
<<component>> Web Front End
Business Logic Layer
<<component>> Python Application
<<component>> Reporting Module
<<component>> Import/Export Module
Domain Objects Layer
All unspecified links are local Python calls.
<<component>> Domain Objects Module
Infrastructure Layer
<<component>> LDAP Adapter
<<component>> Django ORM
LDAP Protocol
SQL Protocol
Backend Layer
<<component>> LDAP DB
<<component>> MySQL DB

Figure 11:

The layers and the main components they include are shown in figure **??**. The responsibility allocation across the layers is as follows:

1. Provide access to humans → *Client Layer*
2. Provide access to system functionality to human access layer and other systems (including decoding of client messaghes) → *Access Layer*
3. Encapsulate business logic → *Business Processes Layer*
4. Provide domain objects → *Domain Objects Layer*
5. Provide accessibility to backend components → *Infrastructure Layer*
6. Host databases → *Backend Layer*

All system components except for the components in the client and backend layers are deployed within the Django application container.

The communication protocols are also shown. They include

1. HTTP/HTTPS from the browser to the web module
2. JSON/REST/HTTP/HTTPS for the web services between the Android application and the Django-based web services wrapper[4]. JSON is used for the data encoding and teh REST protocol for the light-weight web services.
3. The LDAP protocol is used by the LDAP adapter to communicate with the LDAP database, and
4. SQL is used by the Django Object-Relational mapper to communicate with the relational databse.
5. All other communication is in the form of local Python calls.

7.3 Frameworks and technologies

This section lists the various frameworks used by the system.

7.3.1 Persistence

Persistence will be done using *Oobject-Relational mapping* django ORM (db.models) with caching for persistence

7.3.2 Web framework

The *Django AngularJS* web framework will be used to implement the web application for the marking system. This is a powerful framework which enables one to implement rich dynamic web front-ends.

7.3.3 LDAP integration

Django python-ldap from `python-ldap.org` will be used to query LDAP DB.

7.3.4 Reporting

For the reporting the application uses *Django-report* — a simple reporting framework which is able to generate both, HTML and PDF reports.

7.3.5 REST frameworks

For the *Django REST Framework* together with the *Django JSON Serializer* will be used for developing a RESTful seb services wrapper around the server API in order for the Android application to make use of the backend services and in order to provide general integarbility.

[4] The web services wrapper is also available to allow the system to be integrated with other systems — e.g. for other systems to retrieve marks from the marking system.

7.3.6 Data import and export

Data import and export is available through the web interface. The requirements are that the system must support importing from and exporting to CSV (Comma-Separated-Values) file. This will be done using the *Python CSV library.*

7.3.7 Logging

Django logging provides a simple, flexible logging framework. It will be used to log all requests and all responses as well as all changes to any of the entities.

7.3.8 Testing

Unit testing is done across levels of granularity using Python's `unittest` and mocking (wth mock objects) using `unittest.mock`.

Integration testing is done using `unittest` without mocking (i.e. using the real lower level objects instead of mock objects).

7.3.9 Extract, build and deploy

The *Django fabric* framework will be used to extract the sources from the git repositories, construct the deployable artifacts and deploy the application.

7.4 Architectural tactics addressing quality requirements

This section discusses the architectural tactics which are used to concretely address the quality requirements for the application. Most of these are provided be the selected frameworks.

7.4.1 Security

Security is very important. At the business logic layert, the application will make use of

- *authentication* against the CS LDAP repository using **Django-Auth-LDAP**. and
- *role based authorization* at services level using **RBAC** (Django Role Based Access Control).

At the web-access layer the application will make use of *role based views*, publishing only the fucntionality accessible to users through the user interface using the **Django Groups and Permissions**.

Finally, at the communications side, the application will make use of secure (encrypted) communication over *SSL/HTTPS*, following the security vulnerability guidelines in `https://docs.djangoproject.com/en/dev/`

7.4.2 Auditability

The application will provide flexible/maintainable logging using the *Django logging framework* with *formatters*, *filters* and *handlers*.

7.4.3 Usability

Usability is addressed through

- user workflow design for efficient processes,
- *multi-language support* using the *Django internationalization framework*, and
- providing a table interface for entering marks.

7.4.4 Maintainability

The following architectural decisions have been made in order to improve maintainability:

- Separating the application into access, business logic, domain objects and infrastructure layers.
- Using JSON and REST for web services.
- Using an Object-Relational Mapper (ORM) instead of directly using SQL.
- API documnentation will be done using **pdoc** makes the source code maintainable for the maintenance team. It supports flexible and easy code documentation and allows for the generation of API documentation in HTML or plain text.

7.4.5 Integrability

In order to make the system integrable so that the functionality can be accessed by other software systems, all services are published as RESTful web services with the request and result objects encoded in JSON. This will enable other systems to extract marks from the system, provide marks to the system and even submit assessments to the system[5].

7.4.6 Scalability and Performance

Scalability and performance are improved by using

- Django's page caching (instead of everytime re-rendering dynamically generated pages,
- Django's thread pooling,
- Django's persistent database connections in order to avoid the overheads of continuously creating and destroying connections (i.e. in order to reuse connections),
- the caching done by the ORM which can be further improved by using **QuerySet**, and
- performing computation intensive tasks in the background using the **Celery** framework, and
- database indexes.

In future scalability can be further improved by adding support for

- *clustering* with *load balancing* using **Celery**, and
- setting up a **memcache** which is shared across the cluster.

[5] Since the web services are over HTTPS, the system will still have to authenticate itself and communicate securely.

7.4.7 Reliability

Reliability will initially be improved by using transactions around services which should be comleted either in their entirity or not at all (e.g. the service of creating an assessment with the various database additions made for the assessment). To this end transaction boundaries will be on service/methd boundaries.

The application will use the *Django Transaction Framework* with **transaction decorators**. The latter are applied to Python functions.

In future the reliability of the application can be further improved by using clustering.

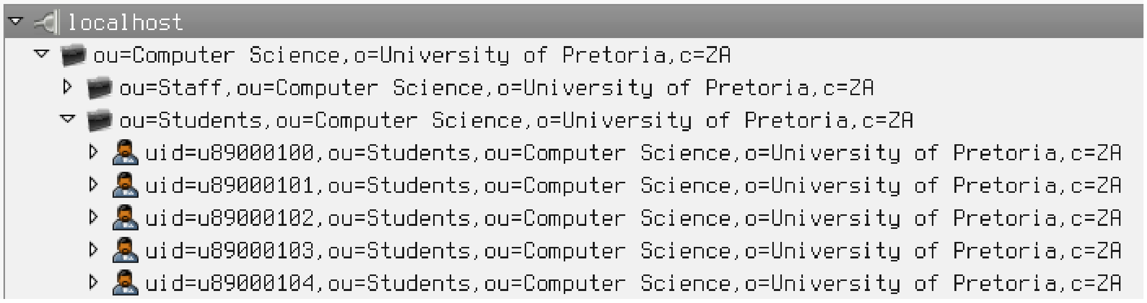
A Appendices

A.1 External database structures

The relational database structure containing the courses/module information has the following structure:

Field	Type	Null	Key	Default	Extra
id	int(11)	NO	PRI	NULL	auto_increment
code	varchar(20)	YES		NULL	
name	varchar(255)	NO			
lecturer	varchar(255)	NO		0	
description	text	YES		NULL	
semester	smallint(6)	NO		0	
has_webct	tinyint(4)	YES		NULL	
year_group	int(11)	YES		NULL	
hidden	tinyint(3) unsigned	NO		0	
last_updated	datetime	NO		0000-00-00 00:00:00	
discussion_board	tinyint(4)	YES		NULL	
tutors_allowed	tinyint(2)	YES		NULL	

The structure of the LDAP repository is shown in the following figure



```
localhost
  ou=Computer Science,o=University of Pretoria,c=ZA
    ou=Staff,ou=Computer Science,o=University of Pretoria,c=ZA
    ou=Students,ou=Computer Science,o=University of Pretoria,c=ZA
      uid=u89000100,ou=Students,ou=Computer Science,o=University of Pretoria,c=ZA
      uid=u89000101,ou=Students,ou=Computer Science,o=University of Pretoria,c=ZA
      uid=u89000102,ou=Students,ou=Computer Science,o=University of Pretoria,c=ZA
      uid=u89000103,ou=Students,ou=Computer Science,o=University of Pretoria,c=ZA
      uid=u89000104,ou=Students,ou=Computer Science,o=University of Pretoria,c=ZA
```

For example, an LDAP search for stud_COS301 returns:

```
dn:            cn=stud_COS301,ou=Modules,ou=Groups,ou=Computer Science,o=University of Pretoria,c=ZA
objectClass:   top
objectClass:   posixGroup
cn:            stud_COS301
gidNumber:     10093
memberUid:     u11061015
memberUid:     u12214834
memberUid:     u11063612
memberUid:     u11002566
memberUid:     u12019837
memberUid:     u11371910
memberUid:     u12148858
memberUid:     u29557373
memberUid:     u11247143
```

and an LDAP search for u29052735 returns:

```
dn:               uid=u29052735,ou=students,ou=Computer Science,o=University of Pretoria,c=ZA
objectClass:      inetOrgPerson
objectClass:      posixAccount
objectClass:      top
uidNumber:        26526
gidNumber:        10001
loginShell:       /bin/bash
title:            Mr
initials:         CJ
st:               8911085042083
sn:               van Rooyen
homeDirectory:    /home/cs/students/u29052735
employeeNumber:   29052735
uid:              u29052735
mail:             nexusdk@gmail.com
cn:               Neels
```

and an LDAP search for memberuid=u29052735 returns:

```
cn:   stud_COS333
cn:   stud_COS301
cn:   stud_COS326
cn:   stud_COS216
cn:   stud_COS330
```