SOFTWARE ENGINEERING 2

EXTENDING AND TESTING A COMPREHENSIVE USE MODEL FOR THE LIBRARY SYSTEM IN USE ASSIGNMENT REPORT

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Collaboration note: This model was created in collaboration with David Byrne C23308943

1. OVERVIEW

For this assignment, I selected the option to extend and test a comprehensive USE model for a Library System using the knowledge from lab sessions. This allowed me to use new real-world case scenarios such as book reservation, borrowing limits, fine payment, and more.

The Library System code is a program that helps to keep track of books, copies, and members in a library system.
Through this project, I expanded the starter code and Created the following:
- Custom enums for tracking borrow/reserve status.
- Refined class structure with new operations and constraints.
- Implemented state machines for Book lifecycle.
- Diagrams (Class, Object, State, Sequence).
- Used SOIL scripts to test multiple scenarios.
- Applied !openter / !opexit for method behavior validation.

2. IMPROVEMENTS MADE TO LIBRARY SYSTEM

Below are the main enhancements made to the initial lab model:

New Enums

- BorrowStatus: Borrowed, NotBorrowed
- ReserveStatus: Reserved, NotReserved

> These Enums ensure the state of individual Copy instances.

New Operations

- createCopy() in Book: Automates copy creation and links them via OfType.
- borrow() / return() in both Book and Copy: Adjust availability counters and update state.

- reserve() / removeReservation() in Copy: Handles copy reservation logic.
- borrow() / return() in Person: Tracks member borrowing and limits.
- viewBorrowed(): Lists all titles a member currently has.
- payFine() in Person: Reduces fine balance after payment.
- applyFine() in Employee: Increases a user's fine (with constraint).

State Machines

- Book: States include newTitle, available, unavailable, transitioned by create, borrow, or return.
- Copy: Tracks reservation and loan status for transitions.

Class and Associations

- Classes: Book, Copy, Person, Member, Employee
- Associations:
  - OfType between Book and Copy
  - HasBorrowed between Person and Copy
  - HasReserved between Copy and Person

Constraints

I Implemented OCL constraints to enforce borrowing/reserving logic, reservation uniqueness, fine limits, and book/copy availability.

SOIL Implementation

A script was created to incorporate Members, Employees, and Books; perform borrowing, reservation, and fine operations; and include invalid and edge case testing.

Testing Enhancements

I Used !openter and !opexit to track method entry/exit and state mutation during payFine.

3. KEY FEATURES ADDED OR CHANGED

Feature	Description
Reservation Logic	Now supports reserving specific copies and canceling them.
Fine Handling	Members (Jay,Dave) can pay fines; employees can apply them (limit: 50). (Tom being the employee in my example)

Borrowing Limits	Enforced constraints based on borrowed amount and copy availability.
Class Expansion	Separated Member and Employee from Person with role-specific behaviors.
SOIL Scenarios	Simulates all operations including edge cases like overpaying a fine.
State Machines	Improves state visibility and system correctness for book availability.

Use code

```
model Library


enum BorrowStatus { Borrowed,
NotBorrowed }

enum ReserveStatus { Reserved,
NotReserved }


class Book

attributes

        title : String

        author : String

        amount : Integer init = 2

        available : Integer init = 2


operations

        createCopy()
```

```
          begin
                    declare c : Copy;
                    for i in
Sequence{1..self.amount} do
                              self.available :=
self.amount;
                              c := new Copy;
                              c.borrowed :=
#NotBorrowed;
                              c.book := self;
                              c.reserved :=
#NotReserved;
                              insert(self, c) into
OfType;
                    end
          end


          borrow()
          begin
                    self.available :=
self.available - 1;
          end


          return()
          begin
```

```
                    self.available :=
self.available + 1;

          end



          statemachines

                    psm States

                    states

                              newTitle : initial

                              available
[available > 0]

                              unavailable
[available = 0]

                    transitions

                              newTitle ->
available { create }

                              available ->
unavailable { [available = 1] borrow() }

                              available ->
available { [available > 1] borrow() }

                              available ->
available { return() }

                              unavailable ->
available { return() }

          end

end
```

```
class Copy

attributes

          book : Book

          borrowed : BorrowStatus init =
#NotBorrowed

          reserved : ReserveStatus init =
#NotReserved

          onLoan : Boolean



operations

          borrow(p : Person)

          begin

                    for p1 in self.reservation
do

                              if p = p1 then


          self.reserved := #NotReserved;

                                        delete(self,
p) from HasReserved;

                              end

                    end;



                    if self.reserved =
#NotReserved then
```

```
                        insert(p, self) into
HasBorrowed;
                        self.borrowed :=
#Borrowed;

        self.book.borrow();

        p.amountBorrowed :=
p.amountBorrowed + 1;
                end
        end

        return(p : Person)
        begin
                delete(p, self) from
HasBorrowed;
                self.borrowed :=
#NotBorrowed;
                self.book.return();
                p.amountBorrowed :=
p.amountBorrowed - 1;
        end

        reserve(p : Person)
        begin
                self.reserved :=
#Reserved;
        insert(self, p) into
HasReserved;
        WriteLine('This copy has
been reserved for you');
    end

    removeReservation(p : Person)
    begin
        if self.reserved =
#NotReserved then
            WriteLine('This
Copy does not have a reservation to
remove');
        else
            self.reserved :=
#NotReserved;
            delete(self, p)
from HasReserved;
        end
    end
end

class Person
attributes
```

```
          name : String

          address : String

          amountBorrowed : Integer init
= 0

          no_onloan : Integer init = 0

          limit : Integer init = 6

          fine : Integer init = 0

          status : String


operations

          borrow(c : Copy)

          begin

                    declare ok : Boolean;

                    ok := self.okToBorrow();

                    c.borrow(self);

          end


          okToBorrow() : Boolean

          begin

                    if self.no_onloan < 2
then

                              result := true

                    else
```

```
                result := false
            end
        end

        return(c : Copy)
        begin
            delete(self, c) from
    HasBorrowed;
            self.no_onloan :=
    self.no_onloan - 1;
            c.return(self);
        end

        viewBorrowed()
        begin
            for c in self.borrowed do

        WriteLine(c.book.title);
            end;
        end

        payFine(amount : Integer)

        reserve(c : Copy)
        begin
                c.reserve(self);
        end

        removeReservation(c : Copy)
        begin

        c.removeReservation(self);
        end
end

class Employee < Person
attributes
        employeeID : Integer
        role : String

operations
        applyFine(p : Person, amount :
Integer)
        begin
                if p.fine + amount <= 50
then
                        p.fine := p.fine +
amount;
```

```
                else
                        WriteLine('Fine
amount exceeds limit of 50');
                end
        end
end

class Member < Person
attributes
        memberID : Integer
end

association OfType between
        Book[1] role book
        Copy[0..*] role type
end

association HasBorrowed between
        Person[0..1] role borrower
        Copy[0..*] role borrowed
end

association HasReserved between
```

```
	Copy[0..1] role copy

	Person[0..*] role reservation

end


constraints


context Person::borrow(c : Copy)

	pre underBorrowLimit :
self.amountBorrowed < self.limit

	pre copyNotYetBorrowed :
self.borrowed -> excludes(c)

	pre notDuplicateBook :
self.borrowed.book ->
excludes(c.book)

	pre loanCapNotExceeded :
self.no_onloan < 2


context Copy::borrow(p : Person)

	pre copyIsAvailable :
self.borrowed = #NotBorrowed


context Book::borrow()

	post availableNotNegative :
self.available >= 0
```

```
context Person::return(c : Copy)

	pre copyIsBorrowedByPerson :
self.borrowed -> includes(c)

	post copyIsReturned :
self.borrowed -> excludes(c)


context Person::payFine(amount :
Integer)

	pre existingFine : self.fine > 0

	post fineIsNonNegative :
self.fine >= 0


context Person::reserve(c : Copy)

	pre copyHasNoReservations :
c.reservation -> isEmpty()


context Copy::reserve(p : Person)

	pre copyNotReserved :
self.reserved = #NotReserved

	pre copyNotBorrowed :
self.borrowed = #NotBorrowed


context Person::removeReservation(c
: Copy)

	pre reservationExists :
c.reservation -> includes(self)
```

```
        post reservationRemoved :
c.reservation -> isEmpty()


context Employee::applyFine(p :
Person, amount : Integer)

        pre withinFineLimit : p.fine < 50

        post stillWithinFineLimit : p.fine
< 50
```

Soil Code

```
-- SOIL


!new Member('Dave')

!Dave.name := 'David Byrne'

!Dave.address := '7, O' Connell Street,
Dublin'

!Dave.amountBorrowed := 3

!Dave.no_onloan := 0

!Dave.limit := 6

!Dave.fine := 0

!Dave.status := 'Borrowed'

!Dave.memberID := 1234567


!new Member('Jay')
```

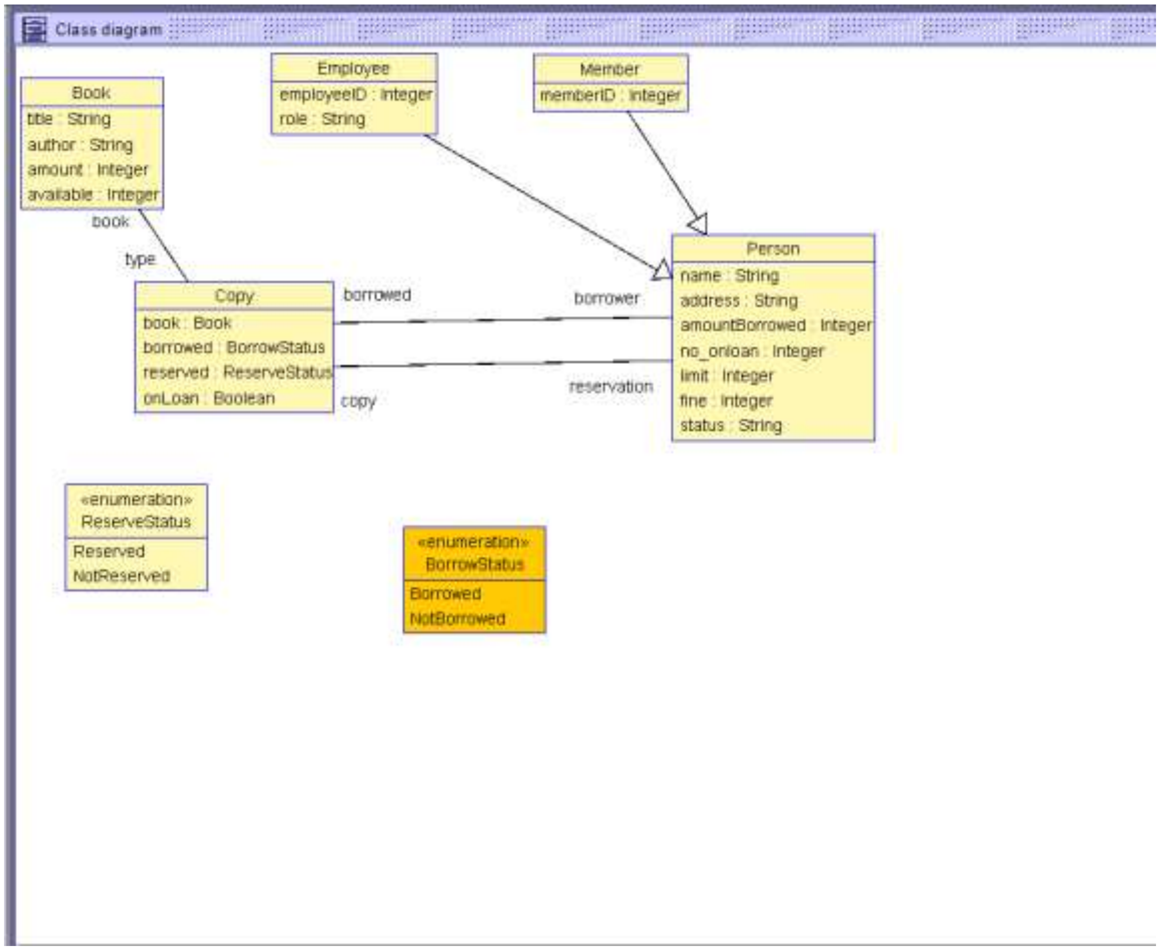
```
!Jay.name := 'Jason Gaynor'

!Jay.address := 'The Shop 133
Galtymore Rd, Drimnagh'

!Jay.amountBorrowed := 1

!Jay.no_onloan := 1

!Jay.limit := 6

!Jay.fine := 0

!Jay.status := 'Borrowed'

!Jay.memberID := 014557324


!new Employee('Tom')

!Tom.name := 'Tommy Mustafa'

!Tom.address := 'The Academy Index,
Dublin 1'

!Tom.amountBorrowed := 0

!Tom.no_onloan := 0

!Tom.limit := 12

!Tom.fine := 0

!Tom.status := 'Reserved'

!Tom.employeeID := 123456789

!Tom.role := 'Librarian'


!new Book('PridePrejudice')

!PridePrejudice.title := 'Pride and
```

```
Prejudice'

!PridePrejudice.author := 'Jane
Austen'

!PridePrejudice.amount := 2

!PridePrejudice.available := 0

!PridePrejudice.createCopy()


!new Book('Dune')

!Dune.title := 'Dune'

!Dune.author := 'Frank Herbert'

!Dune.amount := 2

!Dune.available := 1

!Dune.createCopy()


!new Book('Sapiens')

!Sapiens.title := 'Sapiens: A Brief
History of Humankind'

!Sapiens.author := 'Yuval Noah Harari'

!Sapiens.amount := 2

!Sapiens.available := 1

!Sapiens.createCopy()


!Dave.borrow(Copy1)
```

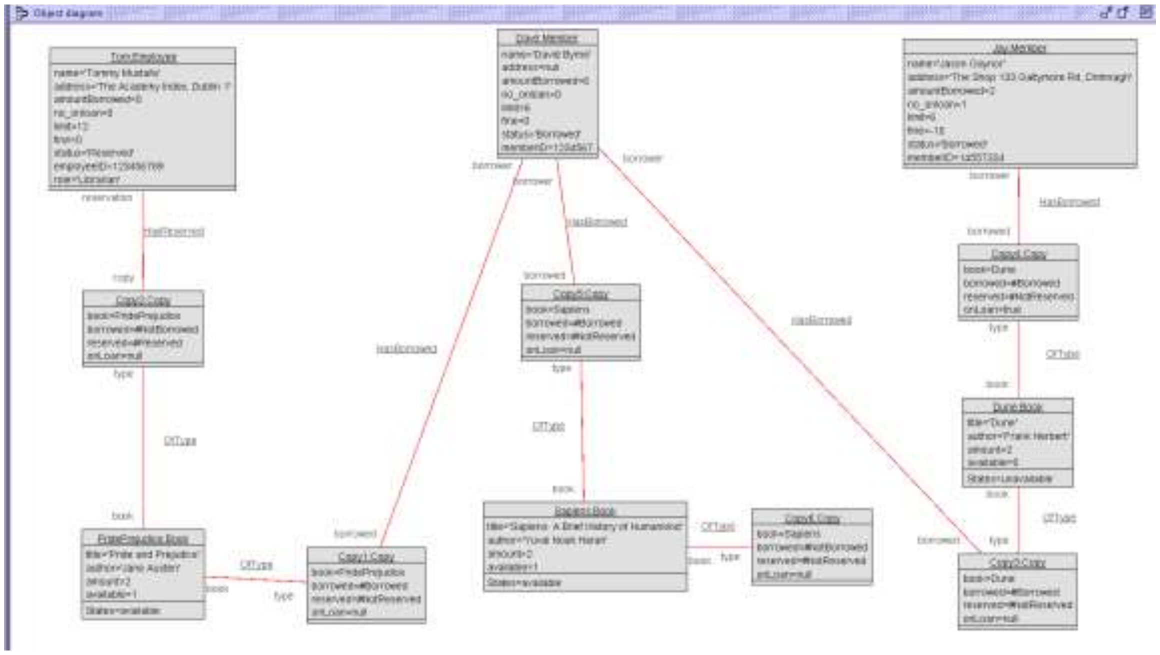
```
!Dave.borrow(Copy5)


!Jay.reserve(Copy4)

!Jay.removeReservation(Copy4)

!Jay.borrow(Copy4)


!Tom.reserve(Copy2)


!Copy4.onLoan := true


!Tom.applyFine(Jay, 30)

!openter Jay payFine(40)

!Jay.fine := (Jay.fine - 40)

!opexit


!Tom.applyFine(Jay, 100)


!Dave.borrow(Copy3)
```

4. DIAGRAMS

- Class Diagram: Relationships between classes, enums, and associations.

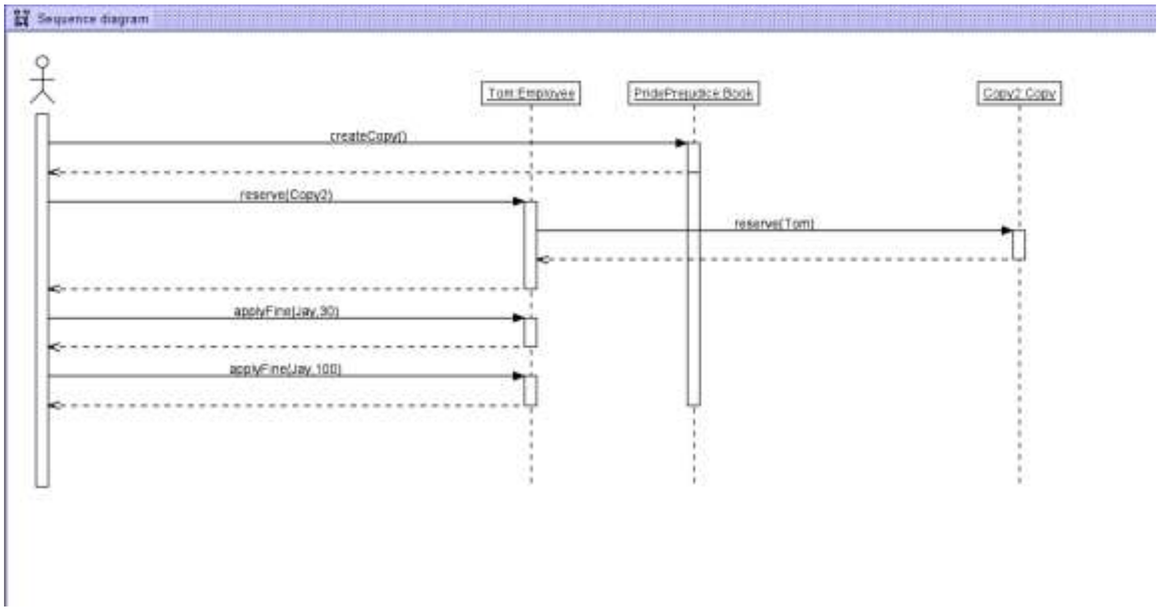


- Object Diagram: Snapshot of system state after running a scenario.

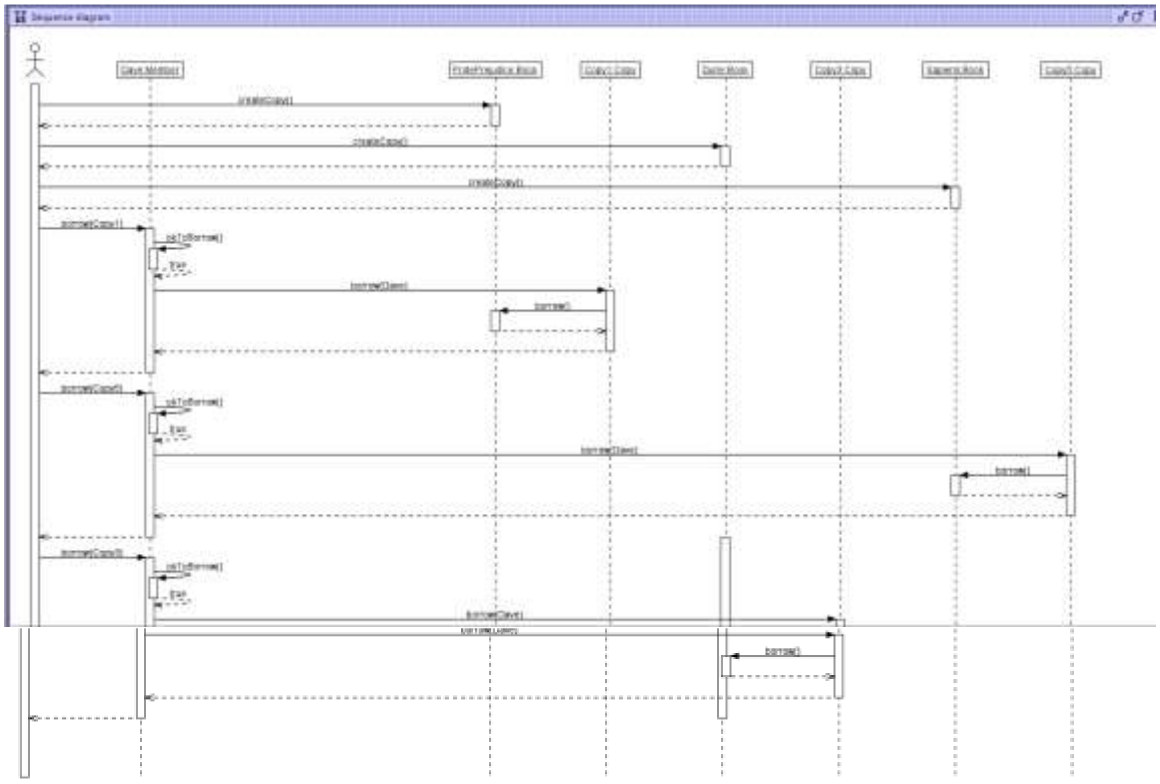


Sequence diagrams

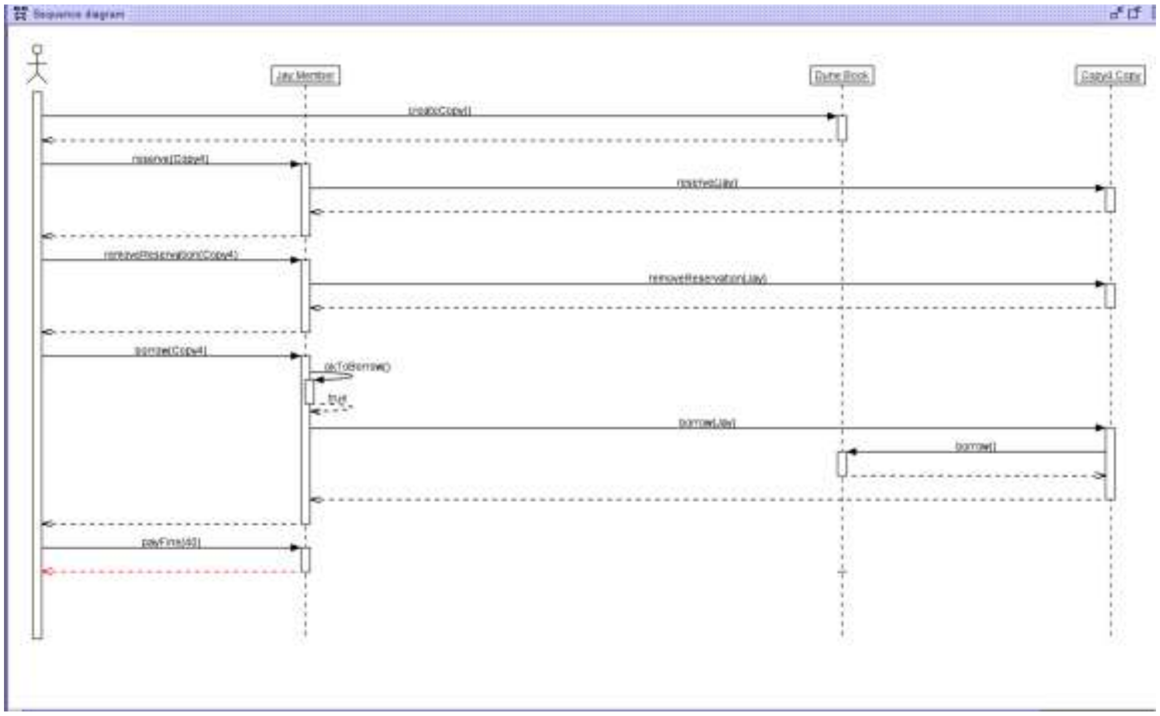
Sequence diagram for Tom employee reserving and applying fee



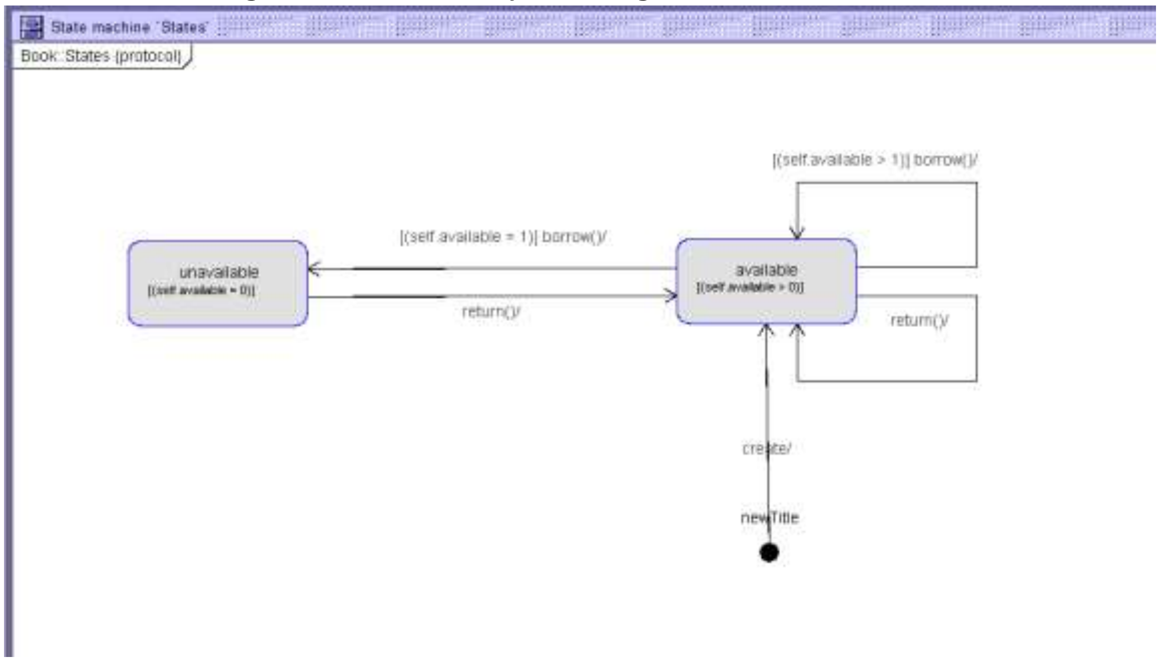
Sequence diagram, Dave borrowing



Sequence diagram for jay reserving, removing reservation ,borrowing and paying a fine



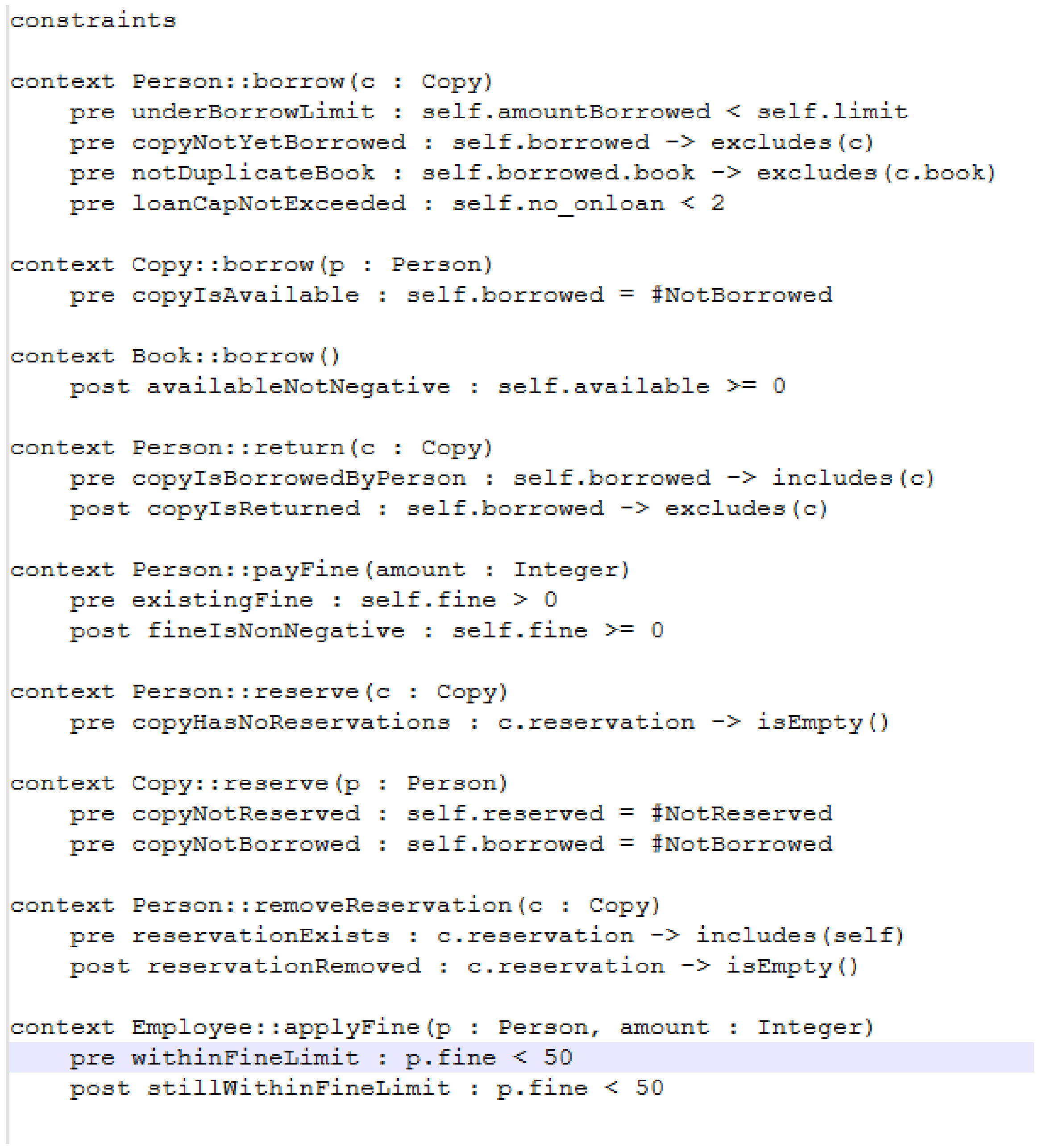
- State Machine Diagrams: For Book lifecycle management.



Use code for state machine

```
statemachines
    psm States
    states
        newTitle : initial
        available [available > 0]
        unavailable [available = 0]
    transitions
        newTitle -> available { create }
        available -> unavailable { [available = 1] borrow() }
        available -> available { [available > 1] borrow() }
        available -> available { return() }
        unavailable -> available { return() }
end
```

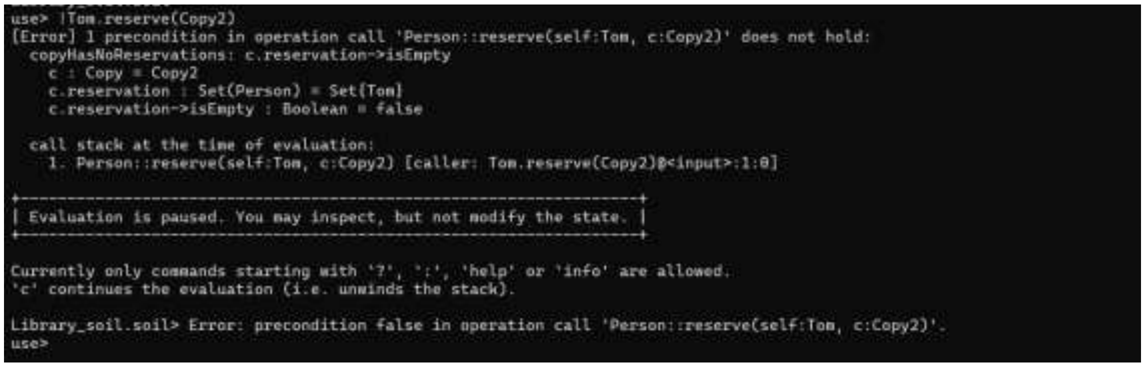
Constraints



```
constraints

context Person::borrow(c : Copy)
    pre underBorrowLimit : self.amountBorrowed < self.limit
    pre copyNotYetBorrowed : self.borrowed -> excludes(c)
    pre notDuplicateBook : self.borrowed.book -> excludes(c.book)
    pre loanCapNotExceeded : self.no_onloan < 2

context Copy::borrow(p : Person)
    pre copyIsAvailable : self.borrowed = #NotBorrowed

context Book::borrow()
    post availableNotNegative : self.available >= 0

context Person::return(c : Copy)
    pre copyIsBorrowedByPerson : self.borrowed -> includes(c)
    post copyIsReturned : self.borrowed -> excludes(c)

context Person::payFine(amount : Integer)
    pre existingFine : self.fine > 0
    post fineIsNonNegative : self.fine >= 0

context Person::reserve(c : Copy)
    pre copyHasNoReservations : c.reservation -> isEmpty()

context Copy::reserve(p : Person)
    pre copyNotReserved : self.reserved = #NotReserved
    pre copyNotBorrowed : self.borrowed = #NotBorrowed

context Person::removeReservation(c : Copy)
    pre reservationExists : c.reservation -> includes(self)
    post reservationRemoved : c.reservation -> isEmpty()

context Employee::applyFine(p : Person, amount : Integer)
    pre withinFineLimit : p.fine < 50
    post stillWithinFineLimit : p.fine < 50
```

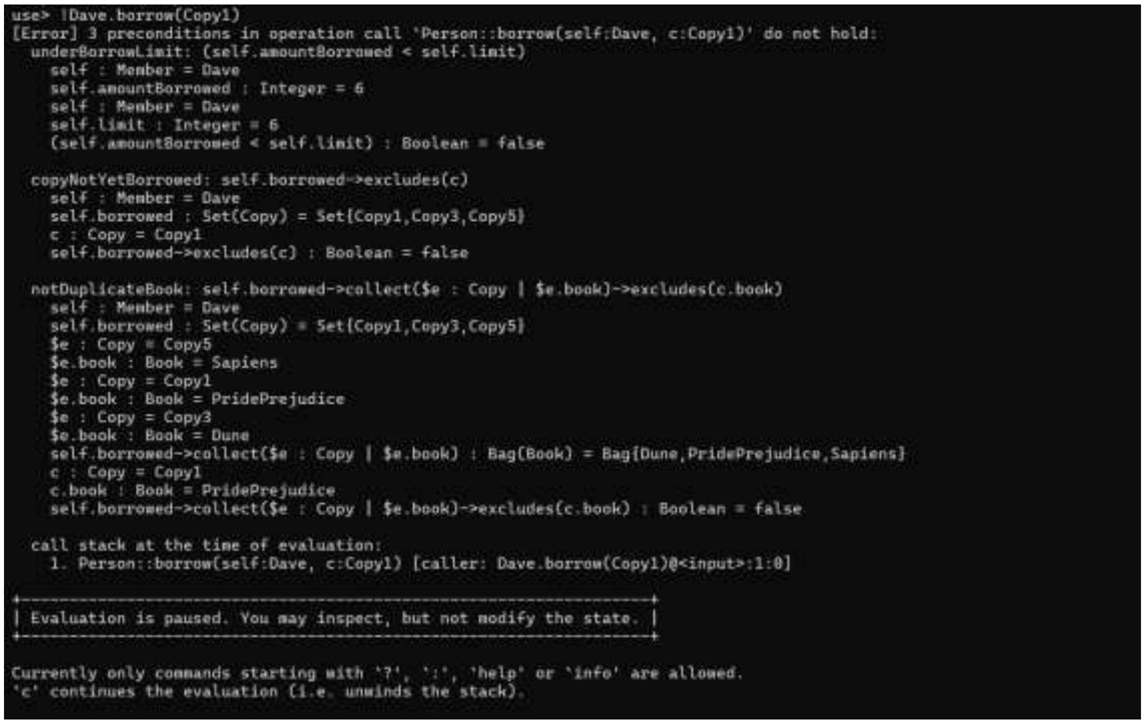
5. CONSTRAINTS TESTING (HIGHLIGHTS)

TC1 - Book copy already reserved 1



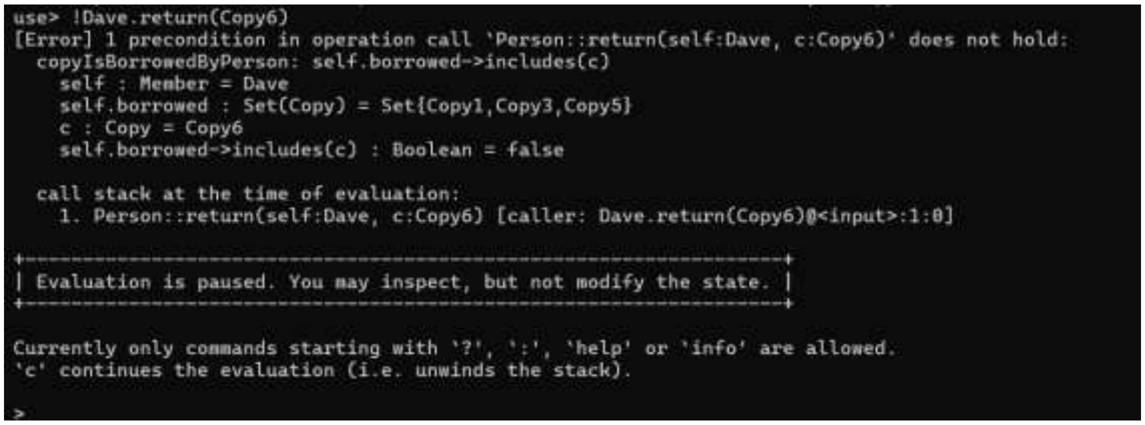
```
use> !Tom.reserve(Copy2)
[Error] 1 precondition in operation call 'Person::reserve(self:Tom, c:Copy2)' does not hold:
  copyHasNoReservations: c.reservation->isEmpty
    c : Copy = Copy2
    c.reservation : Set(Person) = Set{Tom}
    c.reservation->isEmpty : Boolean = false

  call stack at the time of evaluation:
    1. Person::reserve(self:Tom, c:Copy2) [caller: Tom.reserve(Copy2)@<input>:1:0]

+---------------------------------------------------------------+
| Evaluation is paused. You may inspect, but not modify the state. |
+---------------------------------------------------------------+

Currently only commands starting with '?', ':', 'help' or 'info' are allowed.
'c' continues the evaluation (i.e. unwinds the stack).

Library_soil.soil> Error: precondition false in operation call 'Person::reserve(self:Tom, c:Copy2)'.
use>
```

TC2 Copy of book already borrowed (4)



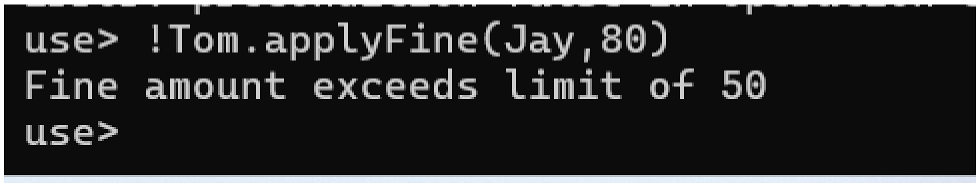
```
use> !Dave.borrow(Copy1)
[Error] 3 preconditions in operation call 'Person::borrow(self:Dave, c:Copy1)' do not hold:
  underBorrowLimit: (self.amountBorrowed < self.limit)
    self : Member = Dave
    self.amountBorrowed : Integer = 6
    self : Member = Dave
    self.limit : Integer = 6
    (self.amountBorrowed < self.limit) : Boolean = false

  copyNotYetBorrowed: self.borrowed->excludes(c)
    self : Member = Dave
    self.borrowed : Set(Copy) = Set{Copy1,Copy3,Copy5}
    c : Copy = Copy1
    self.borrowed->excludes(c) : Boolean = false

  notDuplicateBook: self.borrowed->collect($e : Copy | $e.book)->excludes(c.book)
    self : Member = Dave
    self.borrowed : Set(Copy) = Set{Copy1,Copy3,Copy5}
    $e : Copy = Copy5
    $e.book : Book = Sapiens
    $e : Copy = Copy1
    $e.book : Book = PridePrejudice
    $e : Copy = Copy3
    $e.book : Book = Dune
    self.borrowed->collect($e : Copy | $e.book) : Bag(Book) = Bag{Dune,PridePrejudice,Sapiens}
    c : Copy = Copy1
    c.book : Book = PridePrejudice
    self.borrowed->collect($e : Copy | $e.book)->excludes(c.book) : Boolean = false

  call stack at the time of evaluation:
    1. Person::borrow(self:Dave, c:Copy1) [caller: Dave.borrow(Copy1)@<input>:1:0]

+---------------------------------------------------------------+
| Evaluation is paused. You may inspect, but not modify the state. |
+---------------------------------------------------------------+

Currently only commands starting with '?', ':', 'help' or 'info' are allowed.
'c' continues the evaluation (i.e. unwinds the stack).
```

TC3 Cant return a book if it wasn’t borrowed before 3



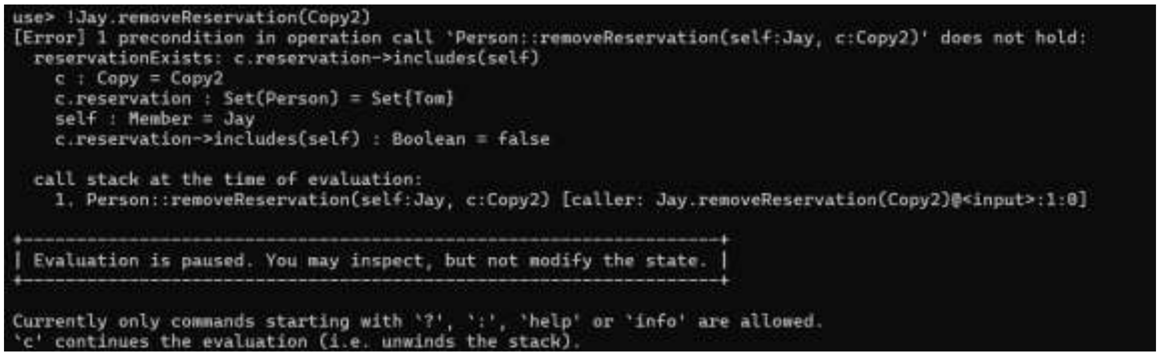
```
use> !Dave.return(Copy6)
[Error] 1 precondition in operation call 'Person::return(self:Dave, c:Copy6)' does not hold:
  copyIsBorrowedByPerson: self.borrowed->includes(c)
    self : Member = Dave
    self.borrowed : Set(Copy) = Set{Copy1,Copy3,Copy5}
    c : Copy = Copy6
    self.borrowed->includes(c) : Boolean = false

  call stack at the time of evaluation:
    1. Person::return(self:Dave, c:Copy6) [caller: Dave.return(Copy6)@<input>:1:0]

+---------------------------------------------------------------+
| Evaluation is paused. You may inspect, but not modify the state. |
+---------------------------------------------------------------+

Currently only commands starting with '?', ':', 'help' or 'info' are allowed.
'c' continues the evaluation (i.e. unwinds the stack).

>
```

TC4 - Can’t apply fine over limit 6



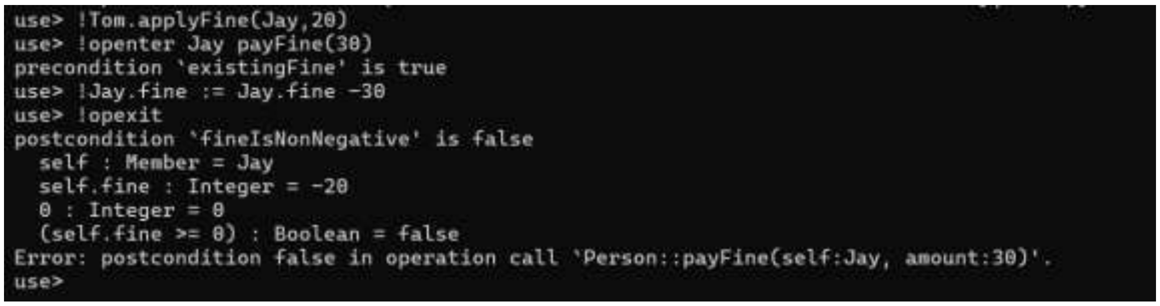
```
use> !Tom.applyFine(Jay,80)
Fine amount exceeds limit of 50
use>
```

TC5 – no reservation to be removed



```
use> !Jay.removeReservation(Copy2)
[Error] 1 precondition in operation call 'Person::removeReservation(self:Jay, c:Copy2)' does not hold:
  reservationExists: c.reservation->includes(self)
    c : Copy = Copy2
    c.reservation : Set(Person) = Set{Tom}
    self : Member = Jay
    c.reservation->includes(self) : Boolean = false

  call stack at the time of evaluation:
    1. Person::removeReservation(self:Jay, c:Copy2) [caller: Jay.removeReservation(Copy2)@<input>:1:0]

+---------------------------------------------------------------+
| Evaluation is paused. You may inspect, but not modify the state. |
+---------------------------------------------------------------+

Currently only commands starting with '?', ':', 'help' or 'info' are allowed.
'c' continues the evaluation (i.e. unwinds the stack).
```

TC6 – cant over pay fine



```
use> !Tom.applyFine(Jay,20)
use> !openter Jay payFine(30)
precondition `existingFine' is true
use> !Jay.fine := Jay.fine -30
use> !opexit
postcondition `fineIsNonNegative' is false
  self : Member = Jay
  self.fine : Integer = -20
  0 : Integer = 0
  (self.fine >= 0) : Boolean = false
Error: postcondition false in operation call `Person::payFine(self:Jay, amount:30)'.
use>
```

6. CONCLUSION

The extended Library System model showcases an implementation of a real-world scenario using the USE tool. It integrates borrowing logic, fine management, and reservation workflows with enforcement through OCL constraints and state machines. This model supports consistent, testable behavior and ensures reliability in a multi-user environment. The project has deepened my understanding of modeling systems with precision and correctness.