2. Introduction to UML & Discussion of Related S.E.

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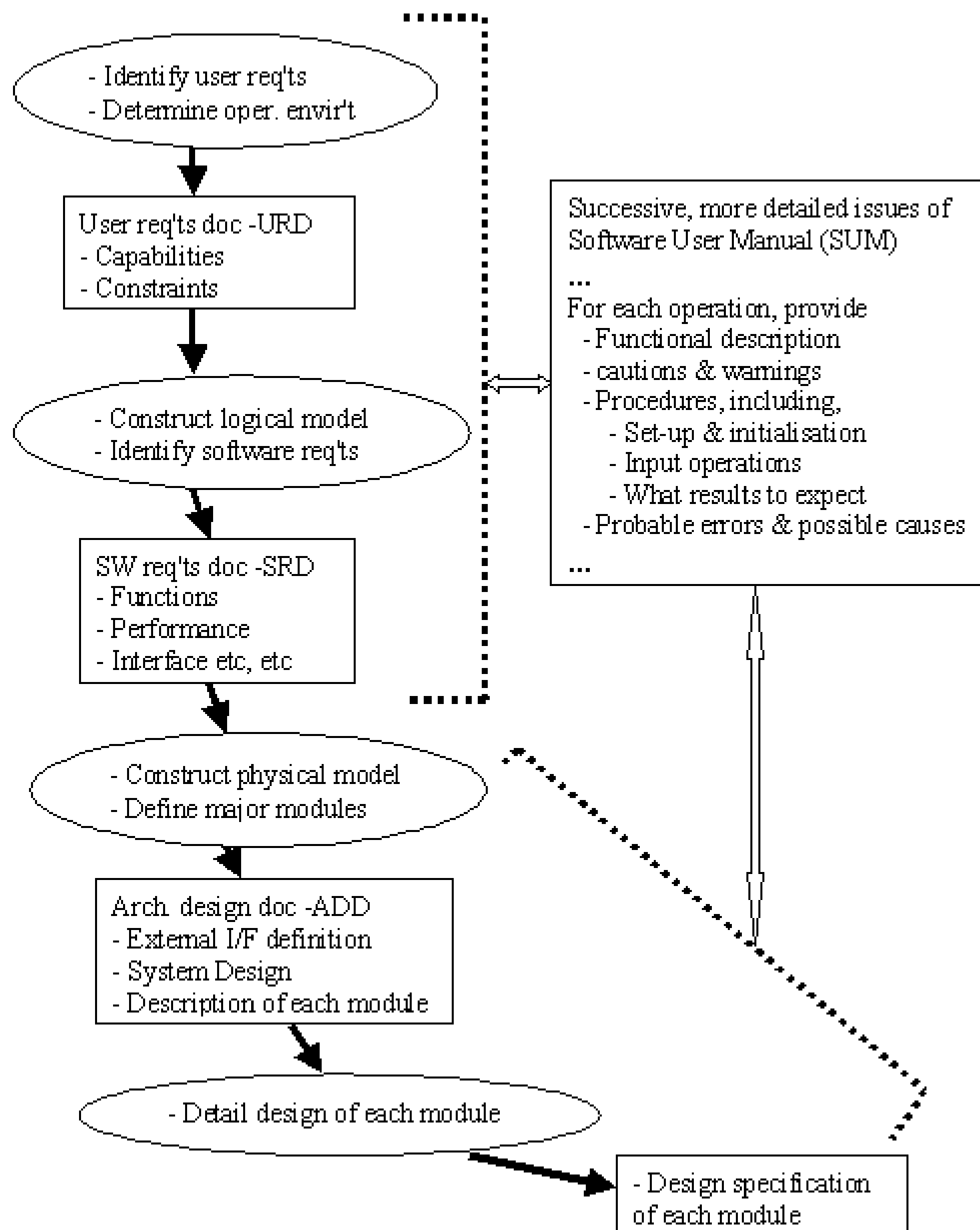
Note: Refer to Chapter 3 of text on Introductory Case Study

2.1 Context of UML

• UML is used for both *specification* and *design* of systems

2.1.1 A "classical" view of specification & design, & how they are related

• It is useful to have a glance at a fairly standard approach to specification and design, in terms of the tasks [*ovals*] done and the outputs [*boxes*] produced. This will provide a context, and a basis for comparison, as we introduce UML.



2.1.2 Examples of requirement specification in an actual project

The following example requirements are **not** in UML. They are taken from the software requirements document (SRD) of an actual project.

It should be noted that

(1) This is not to be taken as the only or best way to document requirements.

(2) The actual project used some specialised terminology, which is irrelevant for us. However, by way of very brief explanation, the abbreviations TM and TC stand for telemetry and telecommand, respectively. Also, the OBDH (*on-board data handling*) is an external system – it can be regarded as a "user" essentially (compare textbook p29, paragraph 2).

Two functional software requirements**:**

S-1.1.7-2

The SW shall provide either a successful or unsuccessful acknowledgement for receipt of each TC.

A successful acknowledgement shall be indicated by preparation of a **TM Successful TC acceptance** packet entry, while an unsuccessful acknowledgement shall be indicated by preparation of a **TM Unsuccessful TC acceptance** packet entry.

TRACE: CF3-1,MF5.2-2,#

S-1.1.7-3

If a TC is executed unsuccessfully then the SW shall prepare a **TM Unsuccessful TC execution** packet entry.

Remark: Criteria for execution reporting are particular to each TC.

TRACE: CF3-2(UNSUCCESSFUL),MF5.2-3,#

A performance software requirement:

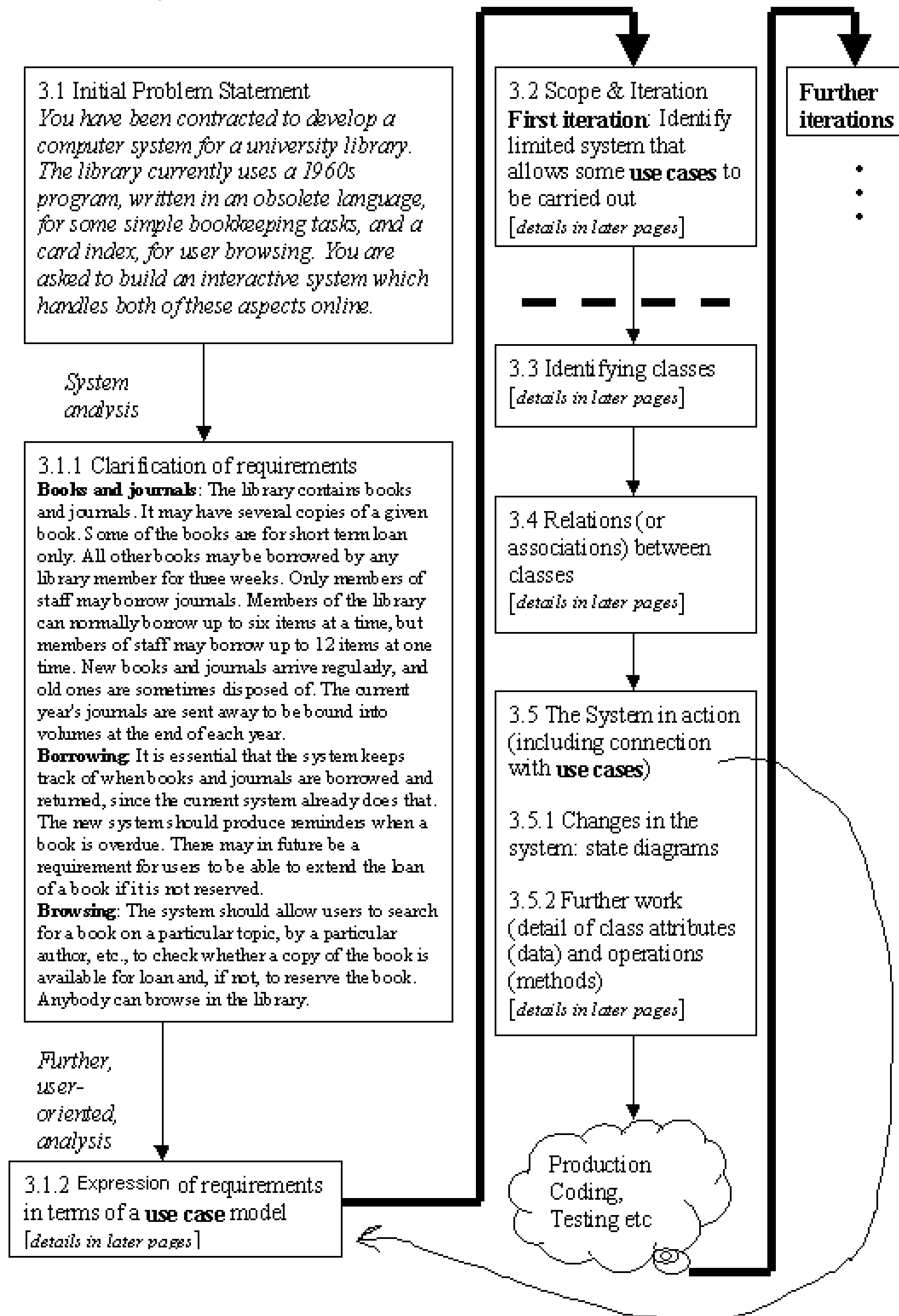
S-2-4
The following time constraints for communicating of TM to the OBDH shall be satisfied,
(1) The ACC SW shall accommodate a maximum transfer rate of 9 complete TM packets per 4 second period.
(2) The next TM buffer, if available, shall be specified to the OBDH within 20mS of the occurrence of **interrupt 10** ...
TRACE:MP6-3(sentence 1), R4.2.2.3-2 of RD.3,#

A maintainability software requirement:

S-13-5
Procedures for building verified releases shall support eventual maintenance of these releases, i.e.:
- (semi)-automated procedures for performing compilation and linking should be developed and configured;
- actual source code used in the release shall be identified;
- copies of delivered files shall be retained.

TRACE: Untraced,#

2.2 Outline of how our text book presents its introductory case study



2.3 Notes on different stages of introductory case study (see text for section numbering)

2.3.1 Initial Problem Statement

An initial, general statement of this kind is essential to set out the broad nature of the system desired. However, it is much too general and vague, and so must be analysed and refined in a dialogue between prospective users and software developers.

The points noted in the text (pp27, 28) are important:

a) Different users have different priorities

b) Users may not have clearly expressed views of what they want (& so should be engaged with to elucidate these views)

c) A description alone of the system may miss vital aspects (in addition it may help to mock up some aspects, to look at similar systems, etc)

d) Make sure that real users not just managers are included

The following extract on "Capture of user requirements" from ESA SW engineering standards is a good summary of the process:

"*While user requirements originate in the spontaneous perception of need, user requirements should be clarified through the criticism and experience of existing software and prototypes. The widest possible agreement about the user requirements should be established through interviews and surveys. The knowledge and experience of the potential development organisations should be used to advise on implementation feasibility, and, perhaps, to build prototypes. User requirements definition is an iterative process, and requirements capture activities may have to be repeated a number of times before the URD is ready for review*."

Remark: Notice that there are different "voices" in the above extract. It is mainly written perhaps from the point of view of the "acquirer" or customer. Other distinct "stakeholders" are the "users" and "developers".

Note: There are various software engineering glossaries on the internet, such as "A Compilation of Software Engineering Terms from Existing Sources", which may be found helpful.

2.3.1.1 Clarification of requirements

In this first phase of analysis, emphasis is on understanding what the user problem is, in teasing out terminology, in making statements as unambiguous as possible, in defining terms clearly, in trying to make sure terms are used consistently, etc.

The outcome of the analysis, that is,

> **Books and journals**: The library contains books and journals. ...
> **Borrowing**: It is essential that the system keeps track of ...
> **Browsing**: The system should allow users to

is not yet a clear statement of requirements but several salient facts and constraints have been established. Also, functions that the system must provide have been defined and key "objects" that the system is concerned with have been identified. The problem now is to produce a clear ***synthesis*** of these "findings".

Often with UML, a "user-oriented" approach is used to produce this synthesis, identifying

- the users of the system
- the tasks these users must undertake with the system

Remark: This focus of UML is consistent with ESA SW engineering standard regarding "Determination of operational environment":
"*Determining the operational environment should be the first step in defining the user requirements. A clear account should be developed of the real world in which the software is to operate. This narrative description may be supported by context diagrams, to summarise the interfaces with external systems (often called 'external interfaces'), and system block diagrams, to show the role of the software in a larger system.*
The nature of exchanges with external systems should be specified and controlled from the start of the project. ... If the external system already exists, then the exchanges may already be defined in some detail, and constrain the design. ...."

2.3.1.2 Expression of [some] requirements in a use case model

	UML terminology	
users of the system	**actors**	*persons or things external to the system, but which interact with it*
tasks users must undertake with the system	**use cases**	*tasks which an actor needs to perform with the help of the system*

• ***Use case descriptions – an example in "formal" English***

Borrow copy of book	*use case name*
A `Bookborrower` presents a book. The system checks that the potential borrower is a member of the library, and that s/he does not already have the maximum permitted number of books on loan. This maximum is 6 unless the member is a staff member, in which case it is 12. If both checks succeed, the system records that this library member has this copy of the book on loan. Otherwise it refuses the loan.	*use of third person and active voice is recommended*

Note: Of course, one needs a description for each use case.

Note: See text (page 29) for some remarks on "user interfaces" - not for this module.

Remarks:

(1) Compare the above style of use case description with the style used in the illustrative software requirements (from an actual project) presented earlier.

(2) When writing down software requirements, one should attempt to make sure that they are **consistent**, **complete** and **verifiable**. Use case descriptions should also have these three properties.

Question: Is the above use case verifiable? How would you verify it in the implemented system?

(3) CASE tools can be a big help in ensuring **consistency** and **completeness** of use cases (and of requirements). Such tools can range from fairly simple, in-house tools to large-scale tools from commercial suppliers.

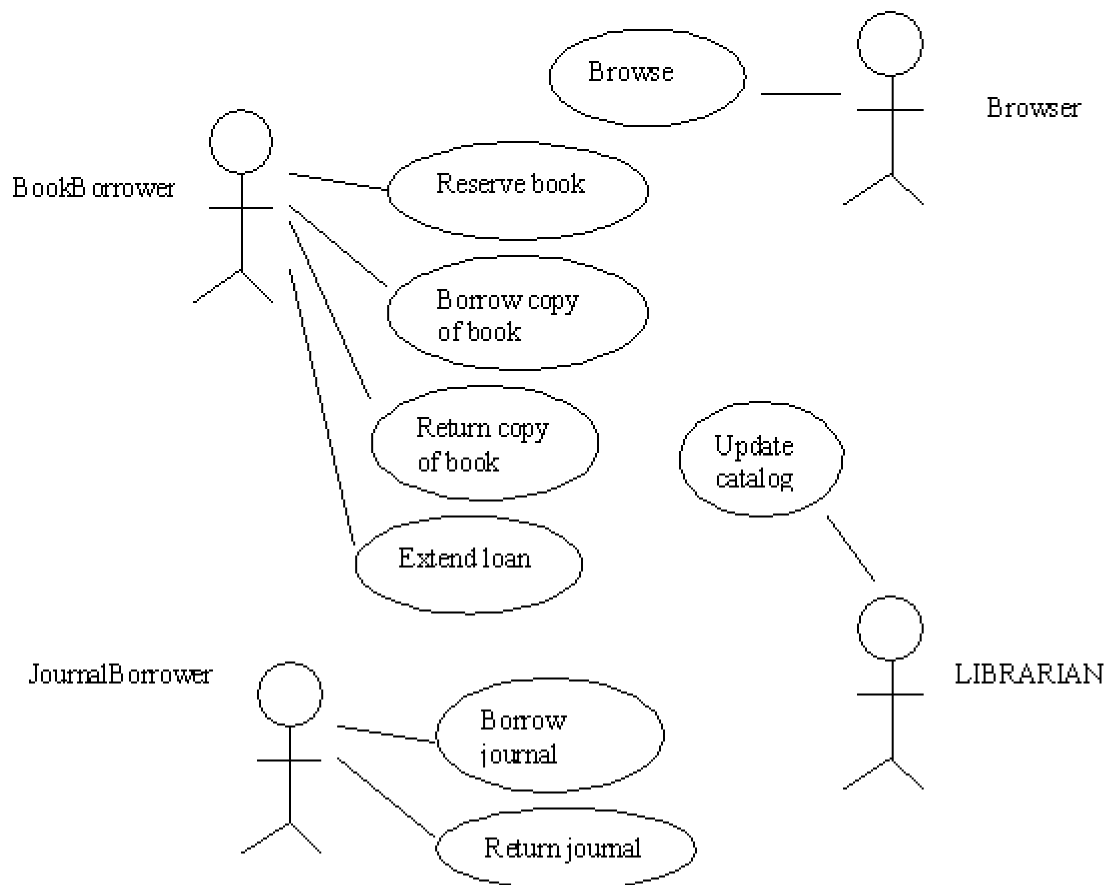
N.B.: It is very important to check such tools thoroughly before use on an actual project and to document any limitations they may have.

• *Use case diagrams*

Use case diagrams (text, p30) have been devised to represent use cases and can be a very good aid, especially, in noticing ***inconsistencies*** between use cases. Also, they can form a good, understandable means of communication between users and developers; in particular, they can make it easier for "***incompletnesses***" (things missing) to be noticed.

Case tools (e.g. WithClass) are available to create use case diagrams, to share them, and to check for consistency (to some extent at least).

Example:



The notation is self-explanatory: stick figures represent actors, ovals represent use cases, and there is a line between an actor and a use case if the actor may take part in the use case.

• ***Some remarks and notes on use cases***

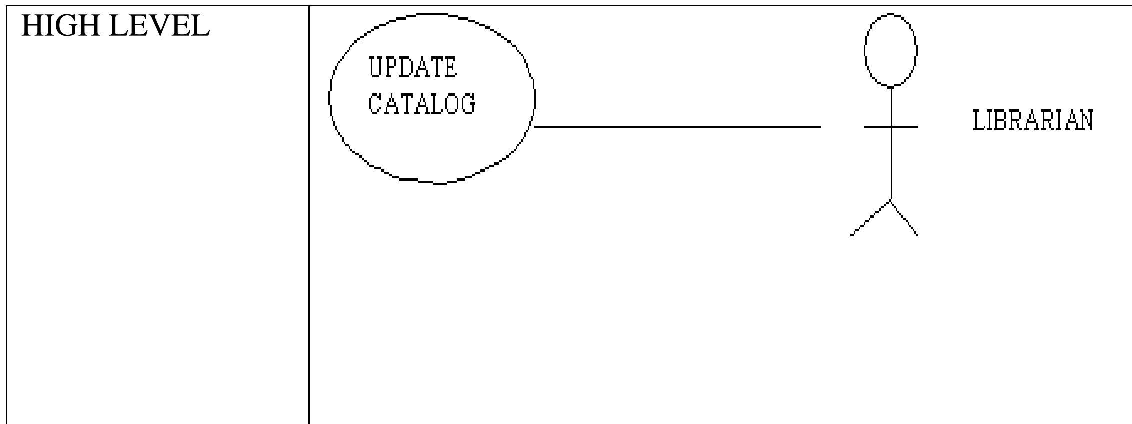
Remark: We mentioned before that in software engineering in general it is advised that "*A clear account should be developed of the real world in which the software is to operate. This narrative description may be supported by context diagrams, to summarise the interfaces with external systems* ...". The above use case diagram is such a context diagram.

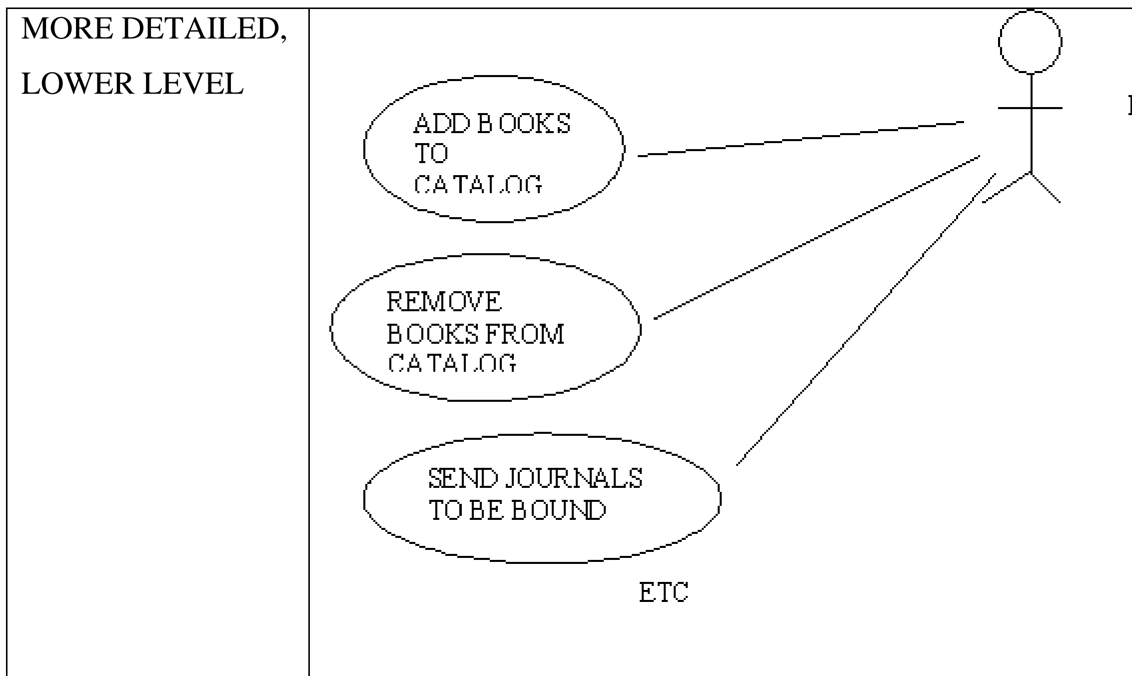
Note: Beware of making use case diagrams overly complex (see text):

If a diagram is becoming too complex can

> ***either*** -- Split Diagram
>
> ***and/or*** -- Use a higher level of abstraction

For example, the text cites the use case "Update Catalog":

HIGH LEVEL	

MORE DETAILED, LOWER LEVEL	

2.3.1.3 Some points on requirements, in general

1) In defining requirements, including when employing use cases in particular, focus on identifying ***what the system should do*** and not on how it should do it.

2) ***Do not invent requirements***: Main point is to avoid confusing what the system *must* do (because the customer says so) and things that it might be nice to have.

- In this regard, the text's suggestion of making lists of questions and possibilities for discussion with users (or with the customer) is a good one.

- Would expect to have questions anyway to resolve unknowns, lacks of clarity etc.

- Should bear in mind when suggesting "nice to haves" that it is up to the customer to pay for them - be wary of going ahead without customer's explicit agreement.

2.3.2 Scope & Iteration

2.3.2.1 Some general points

• See text for discussion of why delivering software in iterations rather than a "big-bang" is usually a good approach.

(**HOMEWORK** - see Q19 of text p31): Draw up a table of advantages and disadvantages of iterated development:

Advantages of iterative approach	Disadvantages of iterative approach

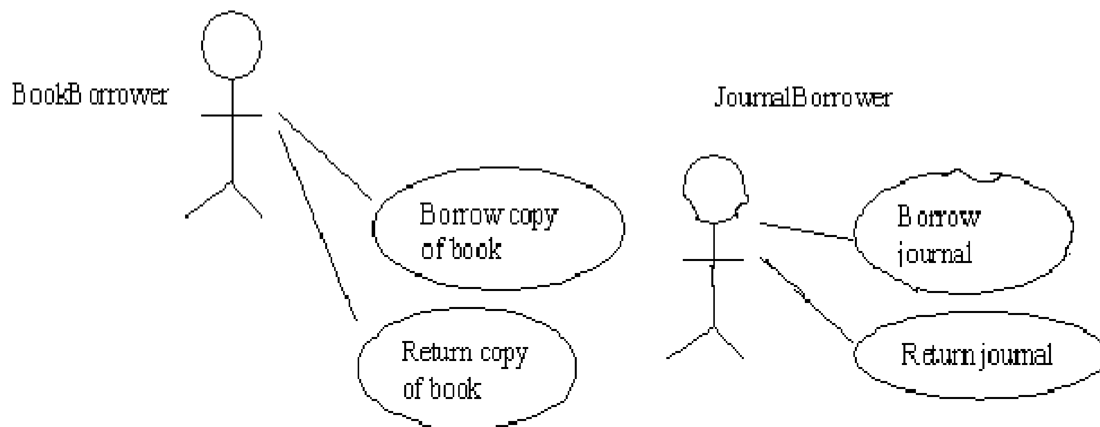
• Note that, among the attributes that user requirements should have, ESA software engineering standard includes ***priority***:

"*For incremental deliveries, each user requirement shall include a measure of priority so that the developer can decide the production schedule*"

2.3.2.2 Selection of 'use cases' to define the scope of each iteration

In general, this is a good approach to describing the scope of each iteration. In particular, it gives the customer good visibility on what to expect per delivery.

Example: Limited use case diagram selected for the first iteration:



Complementing this limited diagram, the text provides a re-statement of the requirements in which material irrelevant to the first iteration is omitted:

Books and journals: The library contains books and journals. It may have several copies of a given book. Some of the books are for short term loan only. All other books may be borrowed by any library member for three weeks. Members of the library can normally borrow up to six items at a time, but members of staff may borrow up to 12 items at one time. Only members of staff may borrow journals.

Borrowing: The system must keep track of when books and journals are borrowed and returned, enforcing the rules described above.

Note: In a real project, the diagram and statement of requirements would probably be part of a document. It would be a project decision as to whether to produce a series of documents corresponding to the series of iterations, or whether to have a single document covering all iterations. In the latter case, the particular requirements and use cases implemented in each iteration would have to be tracked in some way.

2.3.3 Identifying Classes

Essentially, this is our first (very provisional) step in the (OO) design process. We have prepared the ground to some extent by our careful clarification of requirements and (possibly) formulation of "use case" descriptions, including clear use of terms[1].

• Note specifically the process of identifying classes in text (pp32, 33):

DOMAIN = APPLICATION AREA (here the LIBRARY)

KEY DOMAIN ABSTRACTIONS = Key aspects of the DOMAIN that are important to the proposed system

⇓ (*leads on to*)

CLASSES

- The method used in this chapter ("**noun identification technique**") is to take the clarified statement of requirements (or, possibly, the use case descriptions) and to underline "nouns" and "noun phrases".

Books and journals: The library contains books and journals. It may have several copies of a given book. Some of the books are for short term loans only. All other books may be borrowed by any library member for three weeks. Members of the library can normally borrow up to six items at a time, but members of staff may borrow up to 12 items at one time. Only members of staff may borrow journals.
Borrowing: The system keeps track of when books and journals are borrowed and returned, enforcing the rules described above.

- This yields candidate classes: book, journal, copy (of book), library member, member of staff

[1] In fact, one could well have the processes of "defining use cases" and "identifying classes (initially)" going on concurrently, the starting point for each being a statement of the requirements.

- Notice the reasons given for discarding some entities:
    - outside scope (*library*)
    - event, not a thing (*loan*)
    - redundant (same as something else) (*Member of library*)
    - Too vague (*item*)
    - A measure, not a thing (*week*)
    - Not part of domain (*system, rules*)

[**NB:** ***These are indications, not hard and fast rules***]

• Further notes on text (page 34):

- See later for CRC [Class Responsibility Collaboration] cards.

- We have some objects (library member, member of staff) that represent users & we need to decide what behaviour such objects will have. The technique in this example is to make the system objects representing actors responsible for carrying out actions on behalf of those actors.

Example given in text is of message "borrow(theCopy)" being sent to the "LibraryMember" object that represents the member wishing to borrow. Then, the "LibraryMember" object is responsible for carrying out [or for causing to be carried out] whatever is done to record (or deny) the loan.

- Identification of classes and objects is <u>not</u> an exact science - will provide more guidance later on.

Note: Authors state (p34) that we are not yet trying to design the system [*still mainly focussed on identifying the important real-world objects within the system domain*]. This means that we don't yet expect or need to get everything absolutely right.

- Authors (p 34) make some comments about data dictionaries, that "some methodologies dictate that at this stage you draft a data dictionary entry to define each term used". As pointed out in the text, this may not be essential. However, it is not a bad idea in principle provided that undue detail is not included prematurely. Note that WithClass has a facility to generate data dictionaries.

<u>Example</u>: Some typical data dictionary entries (in a fairly informal style though fairly late in a project & so rather detailed) are shown below for actual project cited earlier (pB1-2, illustrating some actual software requirements):

O/A	Entry	Definition	Comment	Source in user documents
• • •				
---	ACC	Attitude Control Computer		UP-10
---	ACC HW	The bare ACC on which the ACC SW is installed and executes.	The operational environment of the ACC SW	US-2.5
• • •				
---	AOCS	Attitude and Orbit Control System		UP-10
A	AOCS status word	Word which summarises the high level status of the AOCS subsystem in terms of a number of key flags and conditions	See corresponding SW requirements	
• • •				

---	handler	Part of SW which responds directly to .an error .an interrupt (= service routine) .an exception or similar events.		UP-23 F3.1.1-10, 11

• • •

O	Stack high water mark	Maximum memory occupancy of Stack		-

• • •

2.3.4 Relations between classes

- We are thinking of ***objects*** as being implemented by ***classes***

- Identify & name real-world relationships (associations) between classes in order to

<table>
<tr><td rowspan="2">Clarify understanding of domain by describing how objects work together</td><td colspan="2">Sanity-check coupling in the end system - make sure good modularity principles are observed
In particular, if one object is closely related to another then is probably OK for the class that implements one to depend on class that implements the other</td></tr>
<tr><td>1. May help maintainer to anticipate dependencies</td><td>2. May help re-use - an application that reuses one of the classes will probably reuse the other too</td></tr>
</table>

- The structure of an OO system should reflect the structure of reality

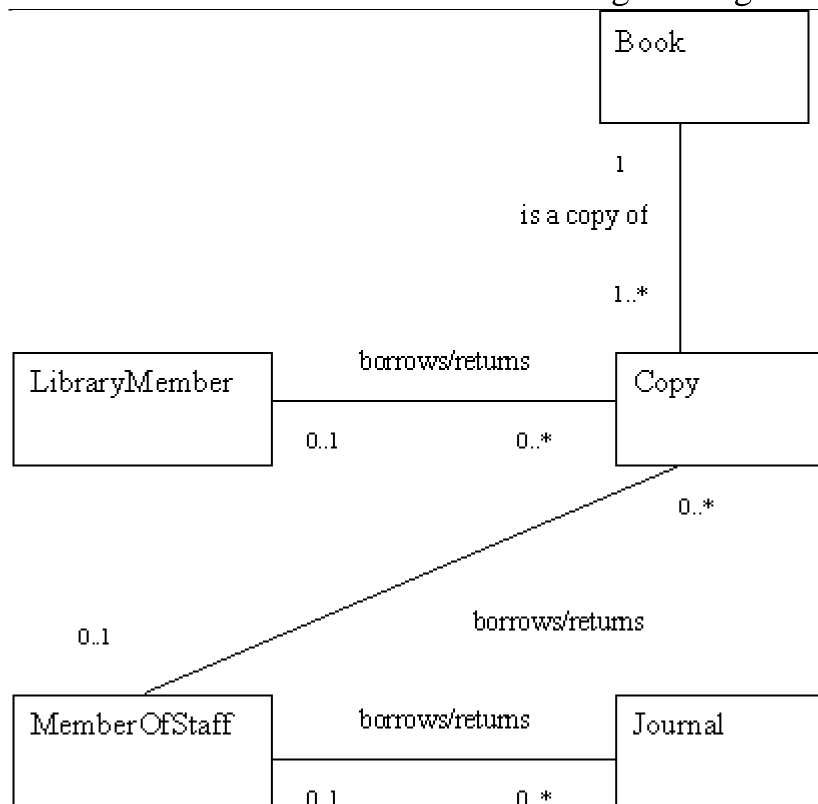
[e.g. "It is important that the system's model of the problem domain, and processes to be carried out, is compatible with the user's "model"***. This is because it is commonly found that domain objects change less frequently and dramatically than the exact functionality the user requires*****."**]

As an instance of this reflection of reality, from our case study candidate classes,

book, journal, copy (of book), library member, member of staff

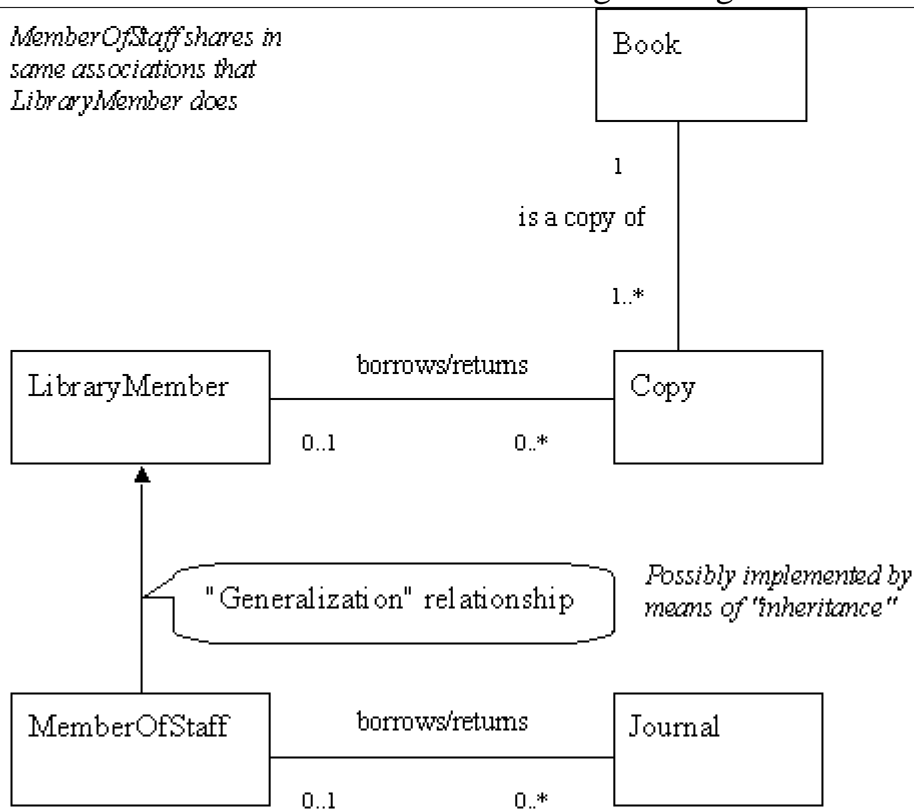
we have

- a copy *is a copy* of a book
- a library member *borrows/returns* a copy
- a member of staff *borrows/returns* a copy
- a member of staff *borrows/returns* a journal



[*Should there be provision for handling individual journal issues?*]

The above (UML class model) depicts the identified relations:
- It also shows **multiplicities** of the associations. For example, the fact that each copy is a copy of only one book is indicated by putting "1" at the book end of the relation "is a copy". On the other hand, the fact that there may be one or more copies of a given book is indicated by putting "1..*" at the copy end of the relation "is a copy". [*More details of this later*]
- Our diagram does not indicate which class depends upon (or "knows about") which. This is referred to the "navigability of the associations". The direction of navigability impacts on the degree of coupling.
- We can improve our diagram by reflecting the fact that a MemberOfStaff is a special kind of LibraryMember:


MemberOfStaff shares in same associations that LibraryMember does
Book
1
is a copy of
1..*
LibraryMember
borrows/returns
Copy
0..1
0..*
"Generalization" relationship
Possibly implemented by means of "inheritance"
MemberOfStaff
borrows/returns
Journal
0..1
0..*

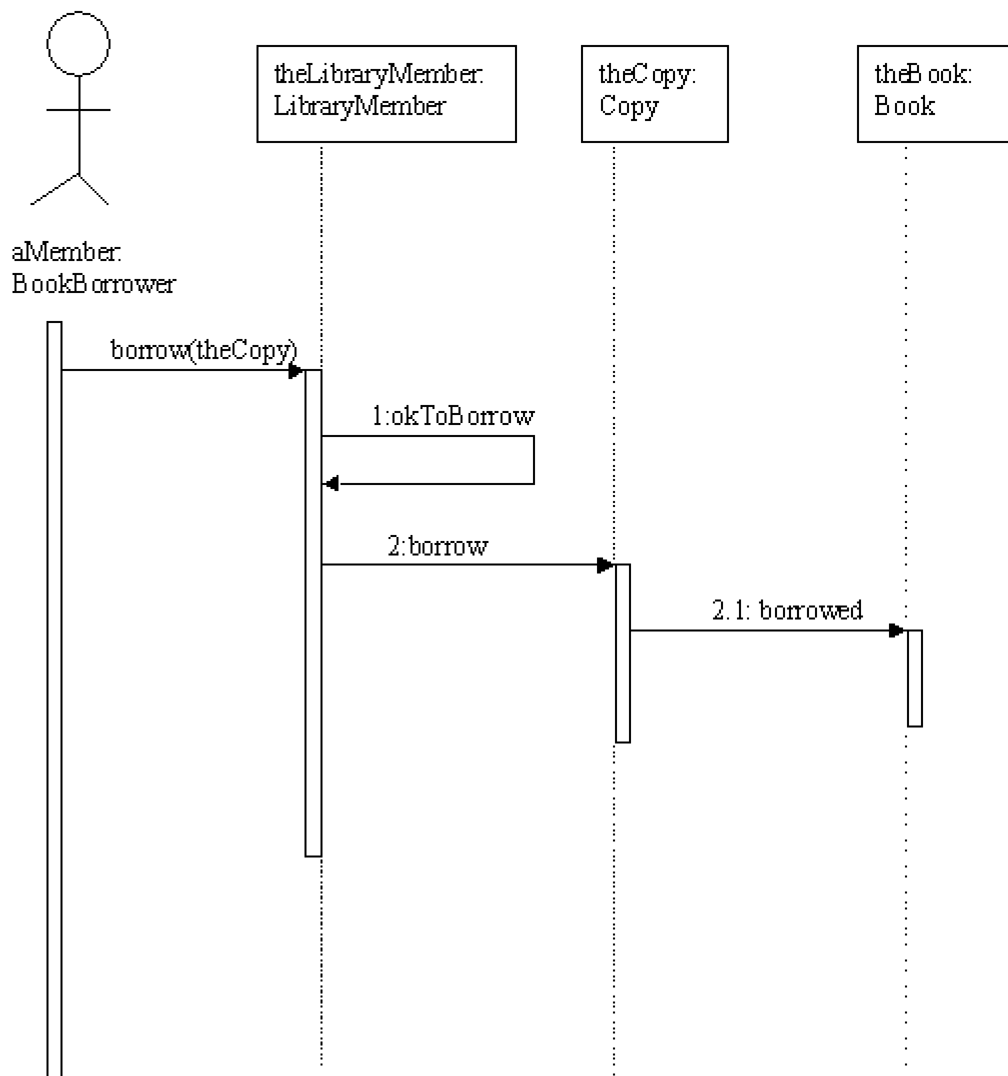
2.3.5 The System in action

2.3.5.0 Example of a sequence diagram ("dynamic")

We want next to make a connection between

Use Cases		**Objects**
we derived from requirements		we have decided make up the system

Sequence diagrams in UML can be used to show the interaction involved, i.e. how messages pass between objects of the system, in carrying out a task such as a use case. For example, for the use case "Borrow copy of book" we have



- Diagram shows which messages are passed between objects and in what order they must occur - read the messages from top to bottom

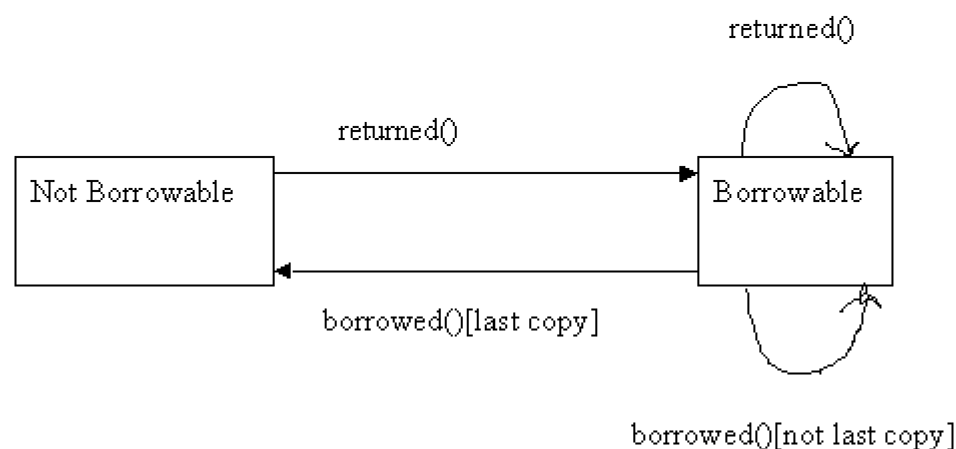
- The diagram shows what happens when a library member borrows a copy of the book. It starts from the position of having a certain object of class "LibraryMember" called "theLibraryMember" and a certain object of class "Copy" called "theCopy" (corresponding to a person bringing a physical copy to the issue desk to borrow it)

- "theLibraryMember" acts (as decided earlier for this example) on behalf of the real library member so interaction begins with a message "borrow(theCopy)" passed to it

- Then, after a check if allowed to borrow, object "theLibraryMember" sends the message "borrow" to "theCopy". Finally, "theCopy" sends a message "borrowed" to "theBook" - we need to update system information on how many copies are on loan.

2.3.5.1 Changes in the system: state diagrams

In our case study, if a *copy of a book* is borrowed, then the **state** of the ***book*** in question may change from "borrowable" to "not borrowable". A state (or state transition) diagram can be used to show this:



- State transition depends on the number of copies in the library
- Concept of "state" is by no means unique to OO or UML

- Instead of a diagram we can use a state transition table (or matrix): For example,

Destination Origin	NOT Borrowable	Borrowable
NOT Borrowable	-	Pre: - (*implicit?*) Action: returned() Post: **Borrowed** = **Total**-1
Borrowable	Pre: **Borrowed** = **Total** - 1 Action: borrowed() Post: **Borrowed** = **Total**	Pre: **Borrowed** < **Total** - 1 Action: borrowed() Post: **Borrowed** < **Total**
		Pre: - (*discuss!*) Action: returned() Post: **Borrowed** decreased by 1

where "**Borrowed**" = No. of copies borrowed, "**Total**" = Total number of copies in library, and "-" = Not applicable.

2.4 Conclusion to case study (thus far):

Once we have identified how all the use cases are realised (as per Figure 3.6 of text - above), it is fairly straightforward to implement the classes. The result is the first iteration of the system, which can be verified by developers and validated by the users (are there any misunderstandings? failings? etc). Thereafter, further iterations can be made, to get closer to the ideal.