Interaction Diagrams

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Interaction Diagrams

UML Interaction diagrams describe how groups of objects collaborate in some behavior.

Important: these diagrams are about *objects*. The UML class diagrams that we looked at earlier are about (surprise!) *classes*.

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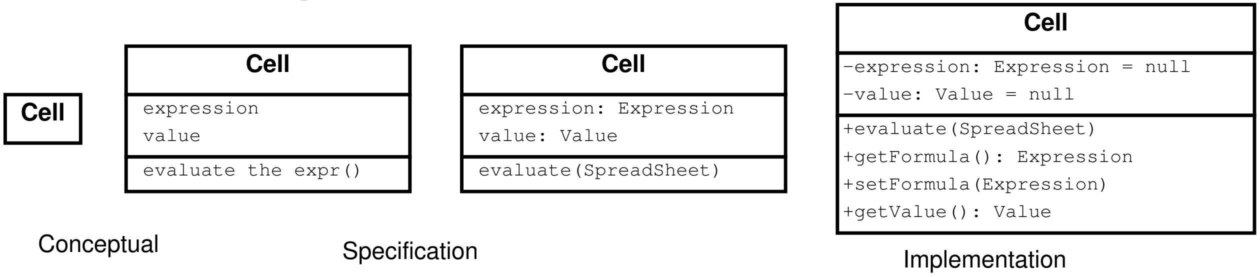
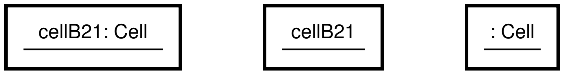
UML: Objects vs. Classes

Remember that, in UML, these represent classes:



But now we want objects:



- Note the underlining and non-bold face.
- The syntax for the text describing the object is similar to the attributes in the class diagrams.

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Two Kinds of Interaction Diagrams

We'll use these objects in two different kinds of interaction diagrams:

- Sequence diagrams
- Collaboration diagrams

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1 Collaboration Diagrams

Collaboration Diagrams

An older technique for diagramming collaborations. These are easier to read for small, simple cases, but less useful for complicated sequences of messages.

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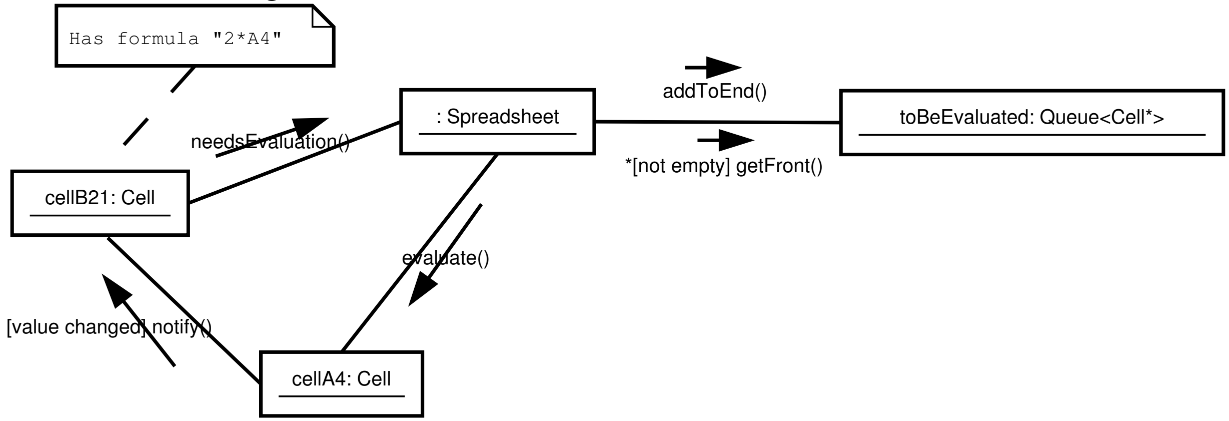
Components of a Collaboration Diagram



- The main components of a collaboration diagram are *objects*
- Objects that exchange messages are joined by *links*, shown as solid lines running from one object to another.
- If one object passes a message to (calls a member function of) another, we write the message name alongside the link, with an arrow showing the direction of the message.

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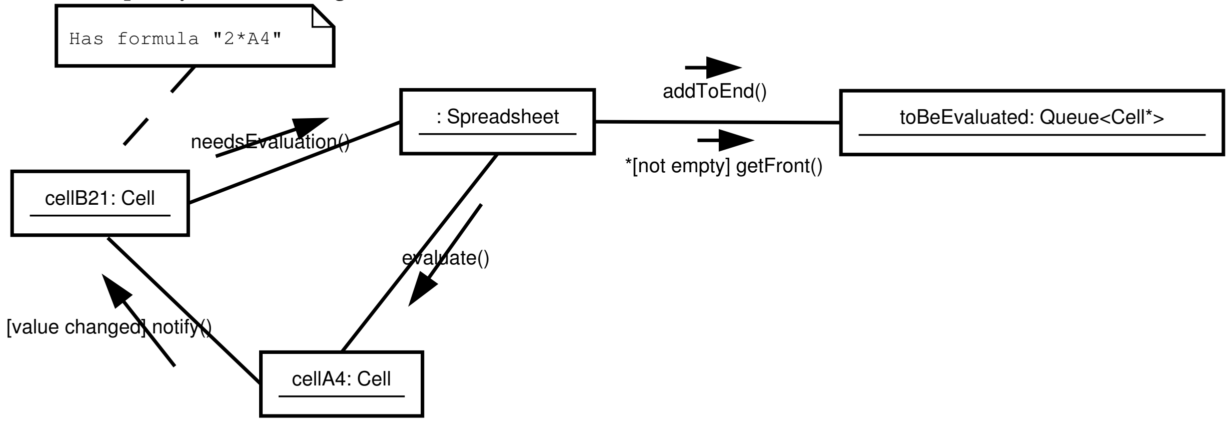
1.1 Control Flow

Control Flow: guards

There is a limited capacity for indicating control flow.



- A *guard* indicates that a call is conditional. Guards are written as boolean expressions inside square brackets.
- An * in front of a call indicates that the call can be performed multiple times.
  - This is often followed by a guard representign the loop condition.

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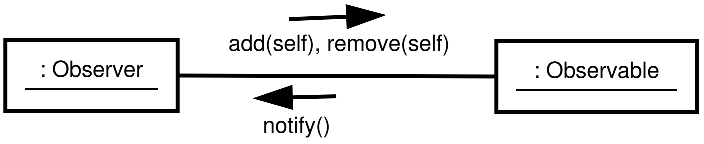
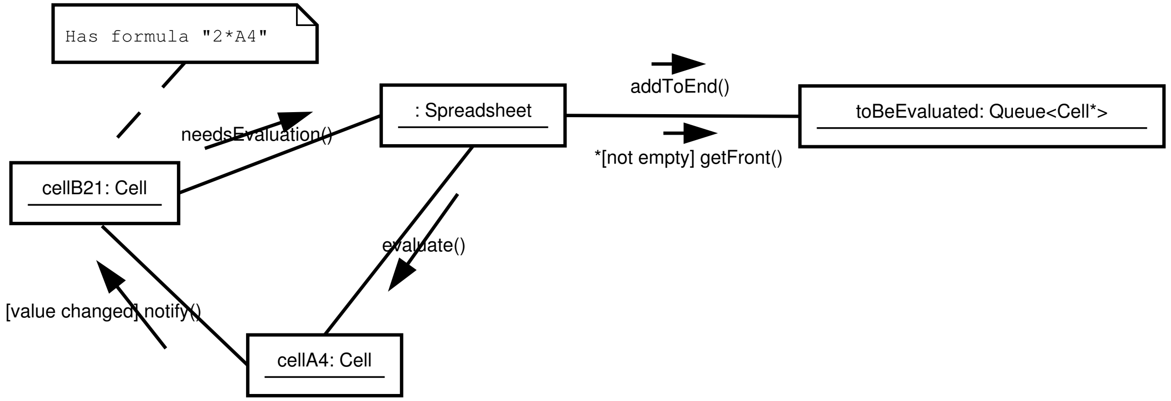
1.2 Sequencing

Sequencing

Collaboration diagrams work well in situations like this where the focus is on *what* the relevant messages are.



- But if the order of the messages is important to understanding the collaboration, then something like this



might not suffice.

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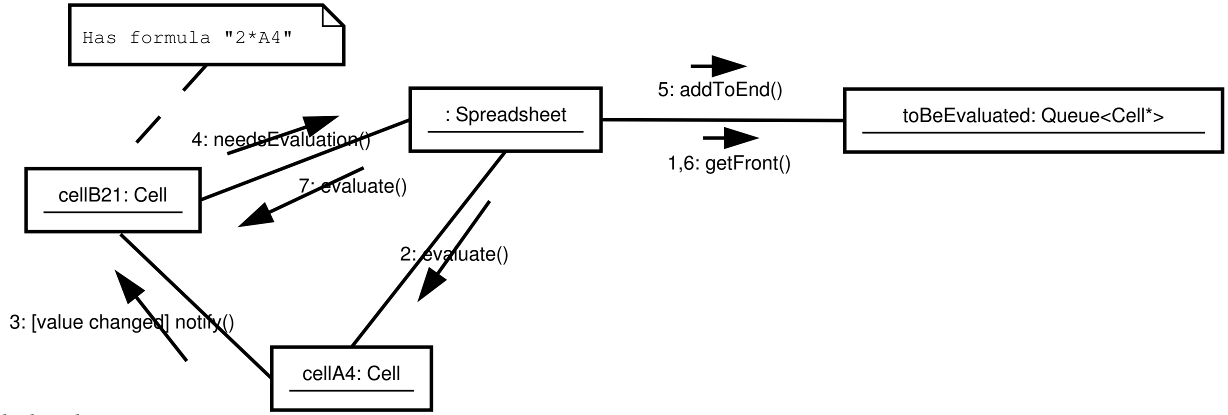
Simple Sequencing

We can try to make things clearer by adding *sequence numbers*.

- The easiest way to do this is to simply order the calls in time.



This can help a lot.

- Note, however, that it's far from clear just which of these calls come from which other calls.

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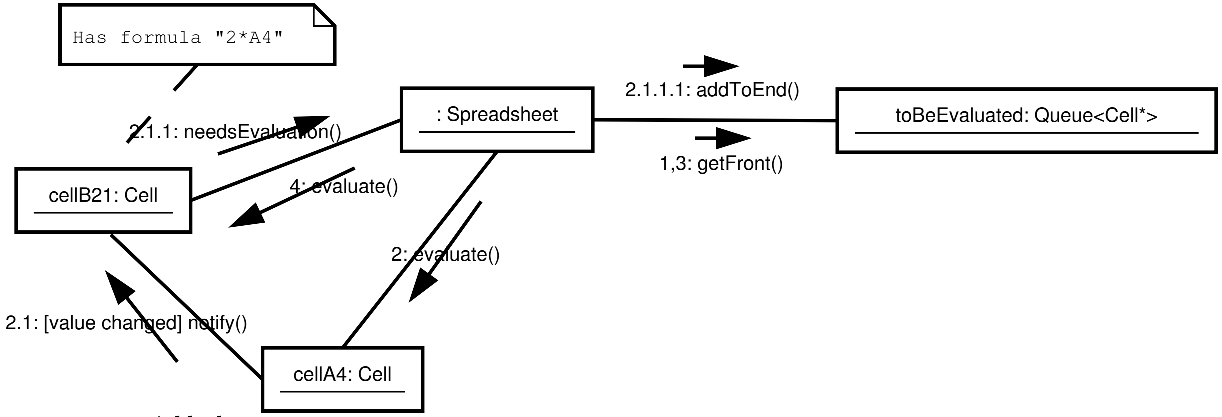
Nested Sequencing

Another possibility is to use nested sequencing calls, in which "x.y" indicates the yth step from within call# x.



This gets messy very quickly, however.

Collaboration Diagrams do not Scale Up

If we really want to get a handle on both the order and the cause of messages, we are better off using sequence diagrams.

2 Sequence Diagrams

Sequence Diagrams

These diagrams attempt to show, for some specific use-case or some common interaction:

- what objects are involved
- what operations are involved, and on which objects
- what the sequence of operations is

2.1 Sequence Diagram Components

Sequence Diagram Components

Our domain or analysis models view the world as objects that interact by exchanging messages.

- *Sequence diagrams* allow us to demonstrate that our model suffices to represent a use case by mapping the steps of the use-case into specific messages (function calls) from one object to another.
  - Although sequence diagrams can be used to illustrate any interesting *collaborations* (sequences of related messages) among our objects, we most often draw one sequence diagram for each use case.

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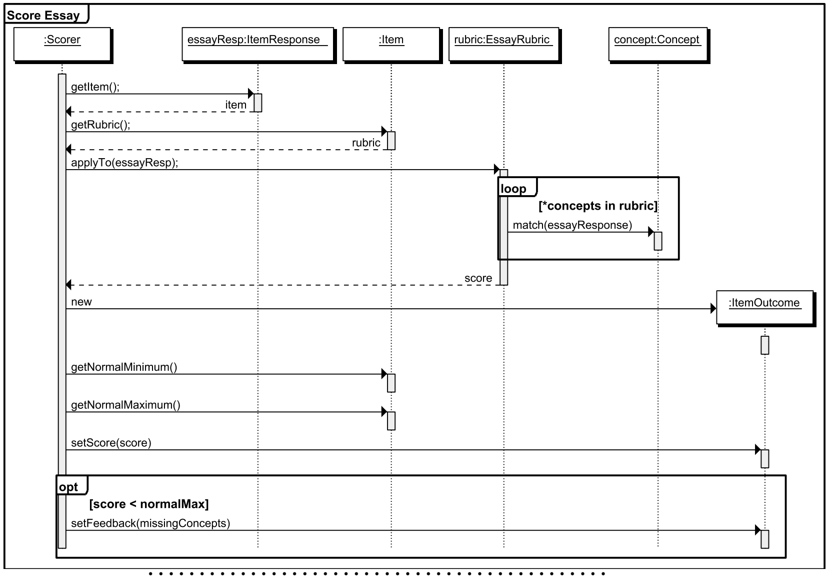
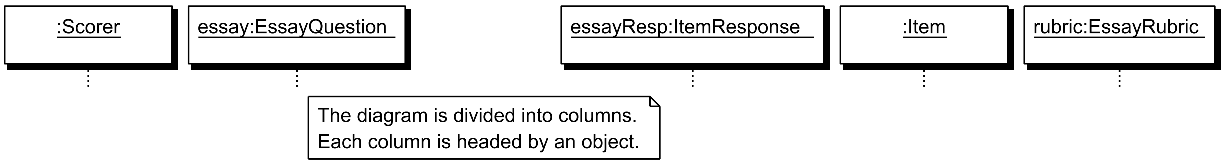
The Score Essay Use Case

Here is a sequence diagram for our "Score Essay" use-case. To help understand this, we'll take this apart, one element at a time, looking at what each one shows us.



Seq Diagrams: Objects


:Scorer
essay:EssayQuestion
essayResp:ItemResponse
:Item
rubric:EssayRubric
The diagram is divided into columns.
Each column is headed by an object.

- A sequence diagram is composed of a number of columns, each headed by an object.
  - Human objects are often indicated by a stick figure. In general, objects are shown as rectangles.
- Note that, unlike in the class relationship diagrams, the rectangles here denote individual *objects*, not classes.

If it seems confusing to use rectangles for both, there is a consistent way to tell them apart. In UML, the general form for an object declaration is

objectName : *className*

For example, `chkTrans:Transaction` indicates that we have an object named “chkTrans” of type “Transaction”.

Quite often, we know we want to discuss an object, but don’t really care to give it a name. For example, in all of our use-cases so far, there has been only a single checkbook. We know that it will be a member of the `Checkbook` class, but if we actually give it a name, the reader will think that’s something they are supposed to remember. Then, if we never actually use that name, we’ve distracted the reader for no good reason.

So UML allows to drop the object name:

objectName : *className*

as we have done for several of the objects in the diagram above, including the checkbook.

The colon (:) in front to the remaining name is our cue that

1. This is still a representation of an object, not of a class, and
2. The name that follows is a class name.

In essence, we have an anonymous object of a known class.

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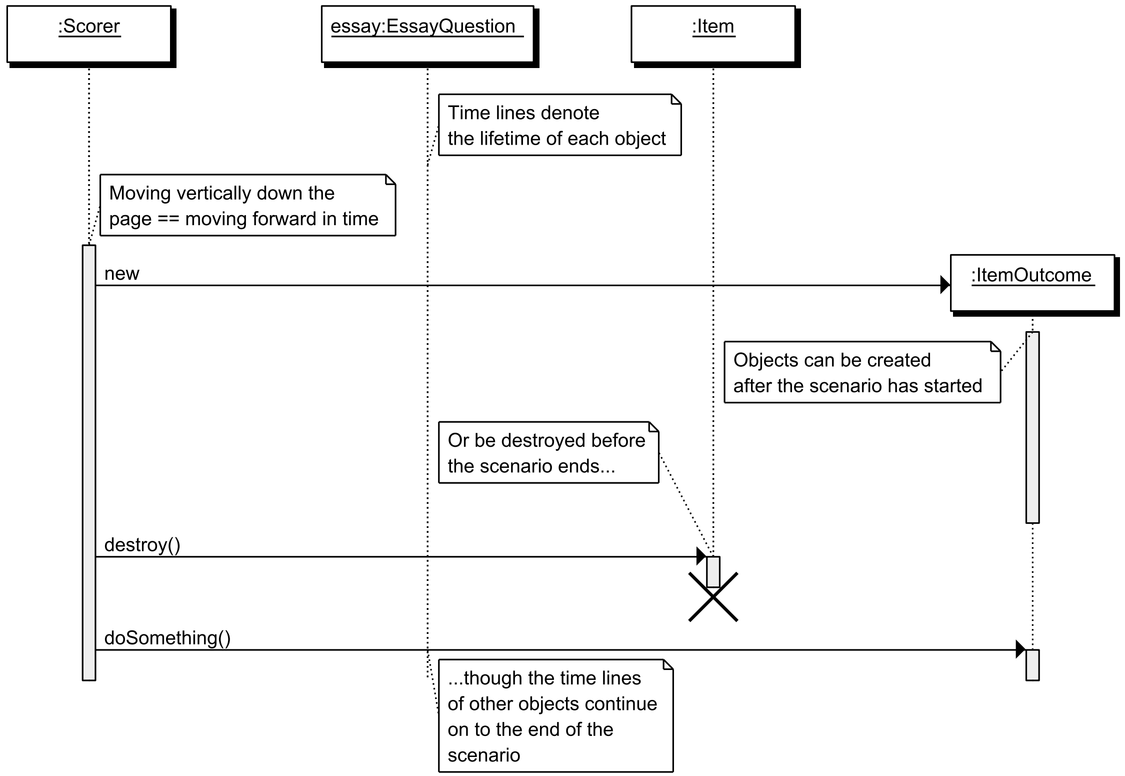
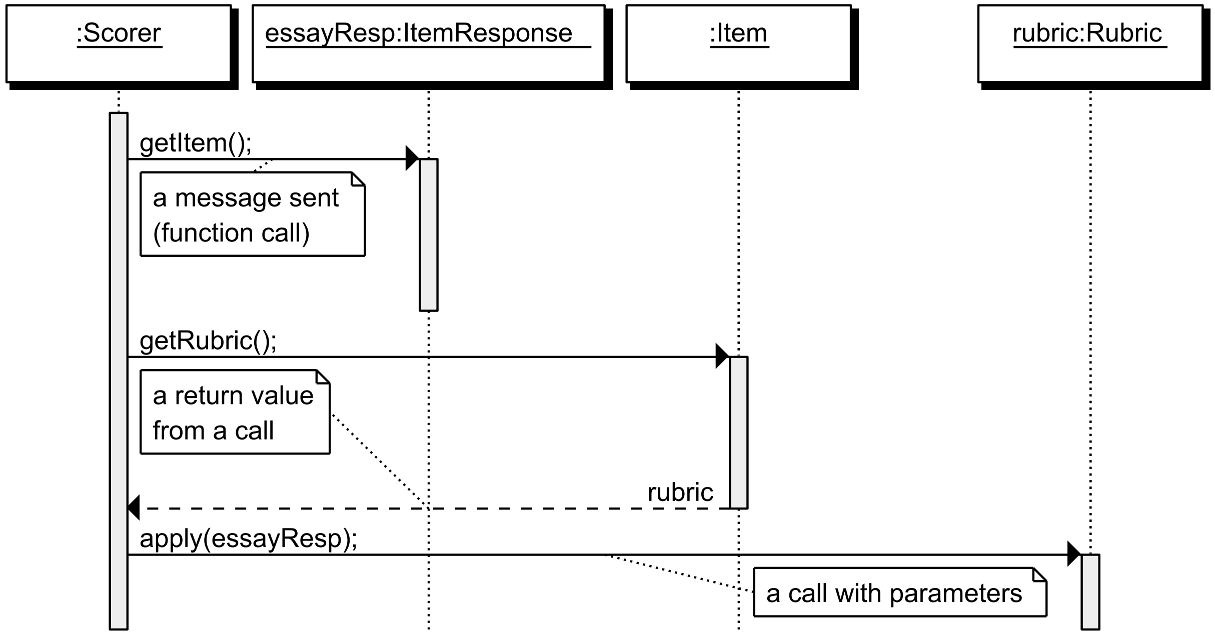
Time Lines


:Scorer
essay:EssayQuestion
:Item
Time lines denote the lifetime of each object
Moving vertically down the page == moving forward in time
new
:ItemOutcome
Objects can be created after the scenario has started
Or be destroyed before the scenario ends...
destroy()
doSomething()
...though the time lines of other objects continue on to the end of the scenario

The dashed lines are called ``time lines”.

- As we move from the top of the diagram towards the bottom, we are moving forward in time.
- Something that is drawn below a particular event actually occurs after it in our scenario.
- If an object is created/destroyed as part of a scenario, it will be shown as a shorter time line. We’ll see examples of this later.

Messages



- Each solid arrow denotes the passing of a message from one object to another.

  Or alternatively, a function call made by some code associated with the first object, calling a member function of the second object.

Parameters and Return Values

As with any function calls, these can include parameters.

- Functions can also have return values, shown as an arrow with a dashed line.
  - Normally, show these only when they are important to the understanding of a diagram (e.g., they match one of the named objects)

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Sanity Check 1

Important Sanity Check: If you draw an arrow from one object of type `C` to an object of type `T`, and you label that arrow `foo`, then the class `T` *must* have a function named `foo` listed as one of its member functions.

- If your CRC cards are still valid (eventually we abandon them as we move along in the analysis process) then `foo` should be a responsibility of `T` and `T` should be a collaborator of `C`.

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Activations

An *activation* of a function is the information associated with a particular call to that function, including all parameters, local variables, etc.

- If a function is recursive (calls itself or calls other functions that eventually call it), it can have multiple activations in memory at any given time.

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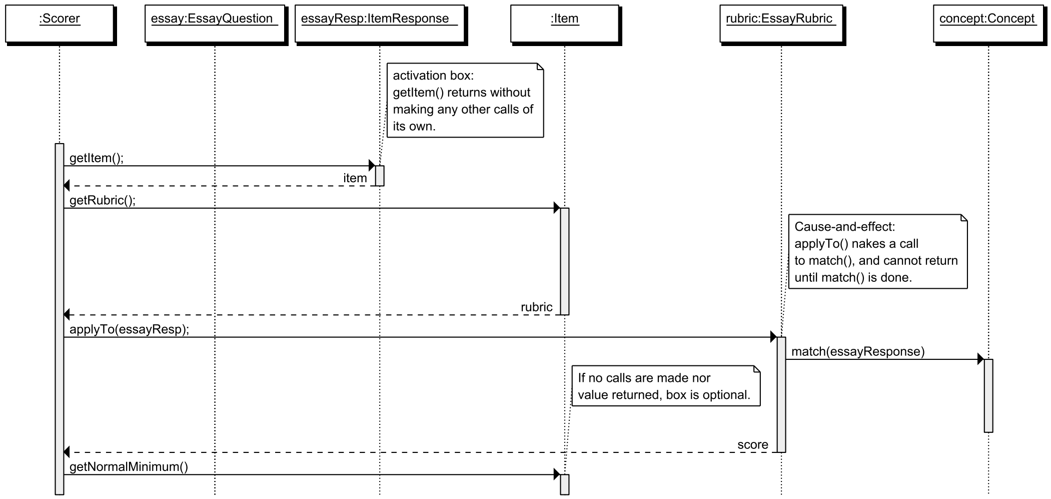
Activation Boxes


:Scorer
essay:EssayQuestion
essayResp:ItemResponse
:Item
rubric:EssayRubric
concept:Concept
activation box: getItem() returns without making any other calls of its own.
getItem();
item
getRubric();
Cause-and-effect: applyTo() nakes a call to match(), and cannot return until match() is done.
rubric
applyTo(essayResp);
match(essayResponse)
If no calls are made nor value returned, box is optional.
score
getNormalMinimum()

Sequence diagrams are all about time, so we sometimes need to indicate just how long a function call is active (i.e., how long we are executing its body or executing other function bodies called from it).

- An activation box marks off the time from the start of execution of a function body to when we return from that body to its caller.

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When to Show Activation Boxes

- You *must* show activation boxes if a the body of a called function makes other calls of its own, or if a function has a return arrow.
  - Activation boxes are essential to demonstrating cause-and-effect within the model

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Now, a sequence diagram indicates the flow of time, but it's not a strict graph. We can't say that one inch of vertical space equals some number of seconds. All that we can say is that if A is drawn below B, than A occurs after B.

Look, then at the `applyTo` call from the scorer to the rubric. You can see an activation box starting there, indicating the start of the function body of `EssayRubric::applyTo`. A little time after that, you see an arrow emerging from that box. That arrow indicates that this function body of `applyTo` eventually calls `comcept.match(essayresponse)`. There you see another function body (of `match`) start to execute.

The particular drawing tool that I use insists on putting short activation boxes at the end of every call. If there are no further outgoing calls (e.g., `getNormalMinimum()`), these boxes are optional. A message arrow with no activation box on the end simply indicates that the function call issues no interesting messages of its own.

A function body that *does* issue a message *must* show an activation box so that we can see whence that message comes.

More Sanity Checks

Sanity check 2: An incoming arrow to an activation box must connect to the very top of that box.

- We do not have psychic functions that suddenly start executing themselves in anticipation of being called at some time in the future.

Sanity check 3: Every activation box must either

- have exactly one incoming arrow, or
- have no incoming arrows but belong to an autonomous object (e.g., a human) that initiates a task spontaneously (e.g., the scorer in this scenario).

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More Sanity Checks

Sanity check 4: If a function body of `foo` calls a function `bar`, the activation box of `bar` must end *above* the end of the activation box of `foo`.

That's just the way functions work.

- If `foo` calls `bar`, then `foo` can't actually do *anything* (including returning to its own caller) until *after* `bar` returns.

Sanity check 5: If an activation box has an outgoing "return value" arrow, that arrow must emerge from the very bottom of the box.

- Function bodies do not hang around chatting after they return control to their caller.

. . . .

More Sanity Checks

Sanity check 6: If an activation box has an outgoing "return value" arrow, that arrow must point back to the caller of that function activation.

- That's just the way functions work!

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Activations Overlap (nest) in Time

The call/activation box symbols can easily accommodate simultaneous activations of different functions on the same object.

Example

Suppose we have a spreadsheet in which cell B3 contains the fomula "A1+1" and that a new formula has recently been placed in A1. A spreadsheet is in the midst of a call to

```
// Re-evaluate all cells in the spreadsheet
int evaluateAll()   {
  while(moreToEvaluate())
     partialEvaluate();
  return evaluationCounter;
}
```

. . . .

Example

Example (cont.)

- Each call to `partialEvaluate` causes one cell (e.g., A1) to be removed from a queue *moreToEvaluate* and then told to evaluate its formula.
  - If that evaluation changes the value in A1, it notifies any cells that are observing it (e.g., B3).
  - Those cells tell the spreadsheet that they require evaluation, and the spreadsheet adds them to the queue.
- On a subsequent pass around the loop, the spreadsheet makes another call to partialEvaluate that results in B3 being pulled from the queue and evaluated.

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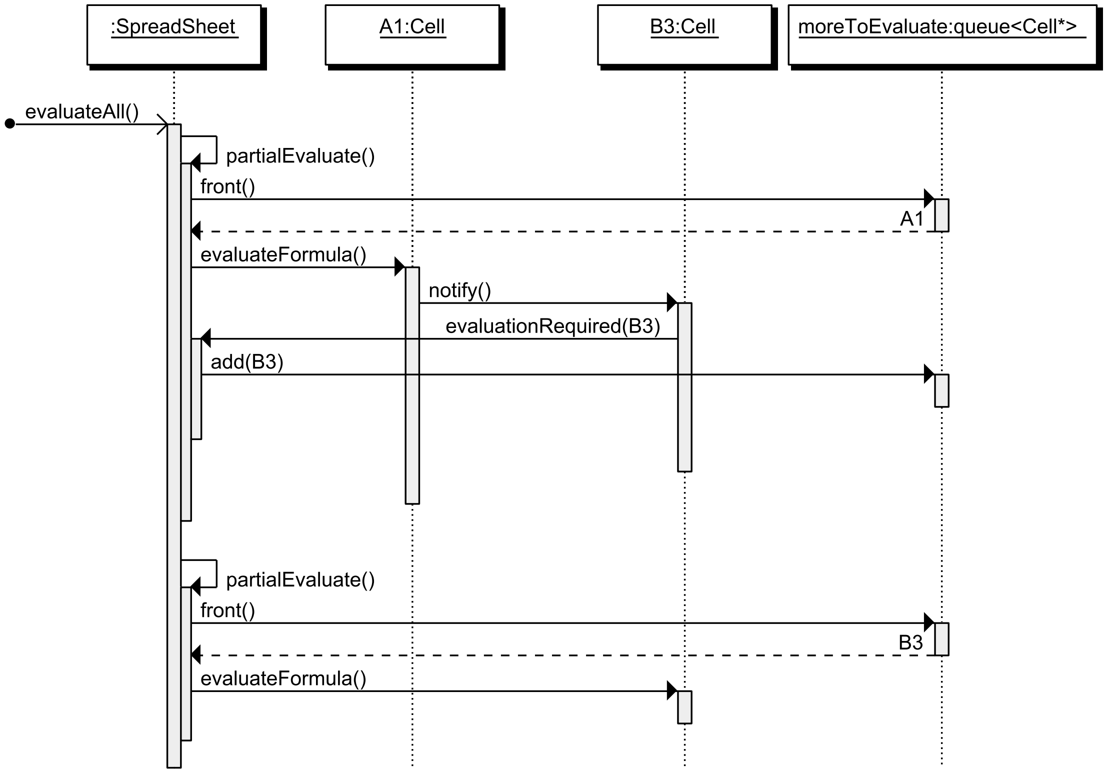
Example: Seq Diagram

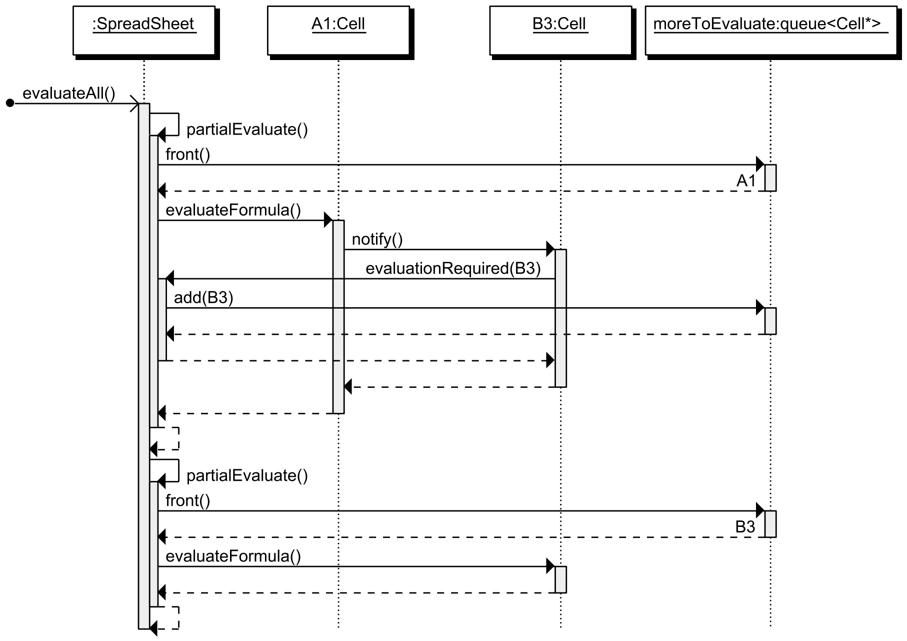


Observations:

- The call to partialEvaluate() is a call from one member function of an object to another member function of the same object.
  - We often choose not to show these because they really have little to do with the idea of whther the public interface fo a class is OK.

  - Instead, usually concentrate on inter-object messages.

- We have "unrolled" the loop in this diagram because I wanted to show the specific cells being manipulated each time around the loop.
  - We'll see other approaches to handling loops shortly.
- Note the stacking of the activation boxes on the SpreadSheet timeline to illustrate nested periods of time.
- If you have trouble following the sequence of calls and returns, you can add in the return arrows from the bottom of each activation box:



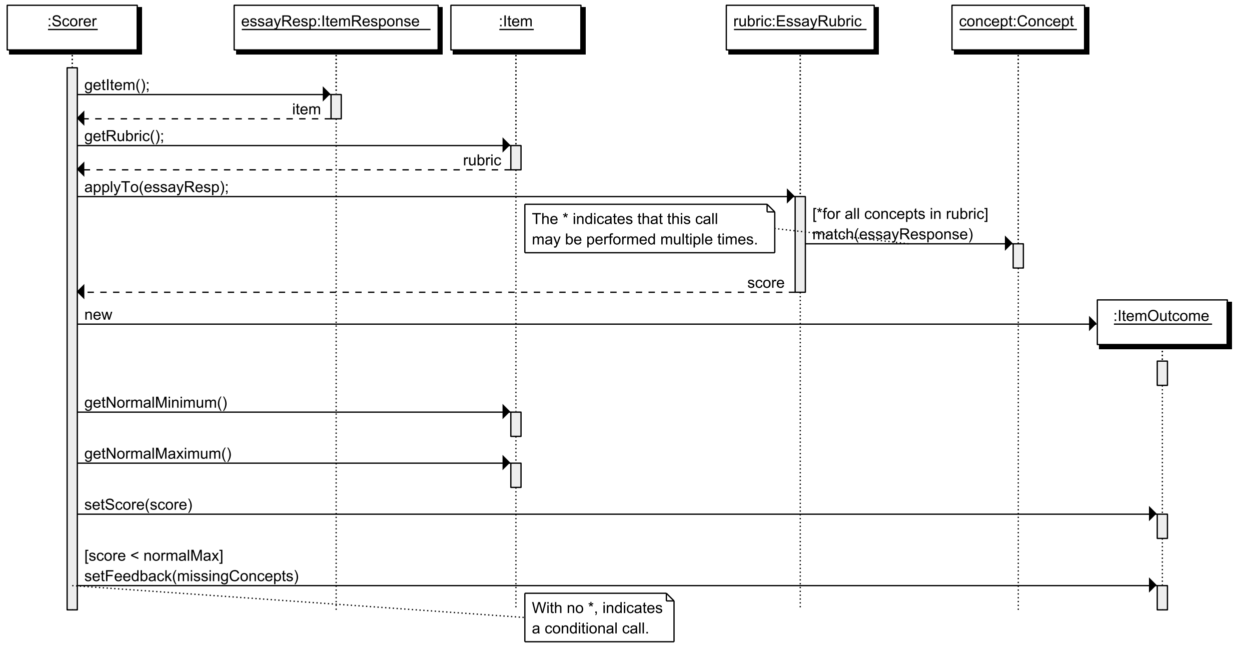
Personally, I find the extra arrows distracting and don't recommend them for general use.

2.2 Control Flow

Guards

Guards are conditions attached to messages to indicate conditional execution or loops.

- Guards are OK if only one call is repeated/conditional
- They become confusing when a sequence of messages are affected.



:Scorer
essayResp:ItemResponse
:Item
rubric:EssayRubric
concept:Concept
getItem();
item
getRubric();
rubric
applyTo(essayResp);
The * indicates that this call may be performed multiple times.
[*for all concepts in rubric] match(essayResponse)
score
new
:ItemOutcome
getNormalMinimum()
getNormalMaximum()
setScore(score)
[score < normalMax] setFeedback(missingConcepts)
With no *, indicates a conditional call.

Frames

UML 2.0 introduced *frames* to group messages
Most common varieties (identified by label):

- diagram label
- loop: repeated messages
- opt: conditional messages
- alt: if-then-else like construct
- ref: reference to another diagram, becomes a "black box" in this diagram

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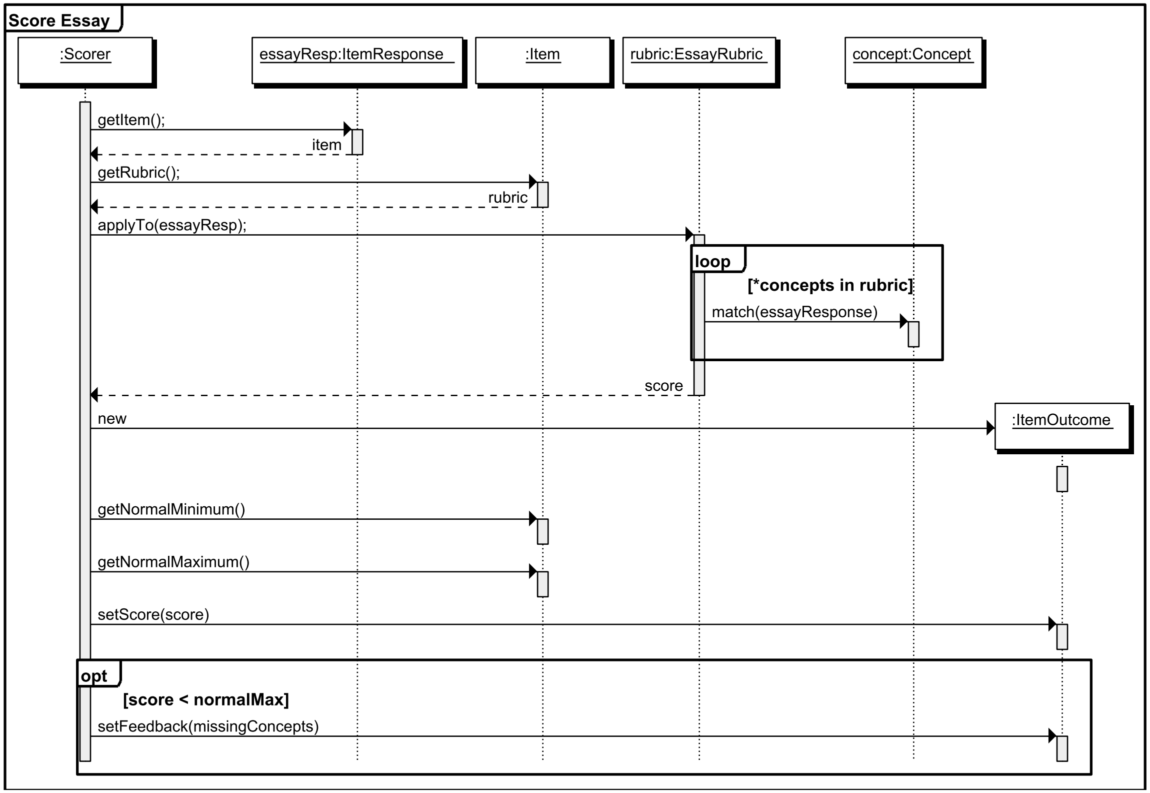
Options and Loops



- Grouping is indicated very naturally by the area of the enclosing rectangle. We can nest frames if we need to.
- We use guard expressions (in the [ ]) to indicate loop and option conditions.

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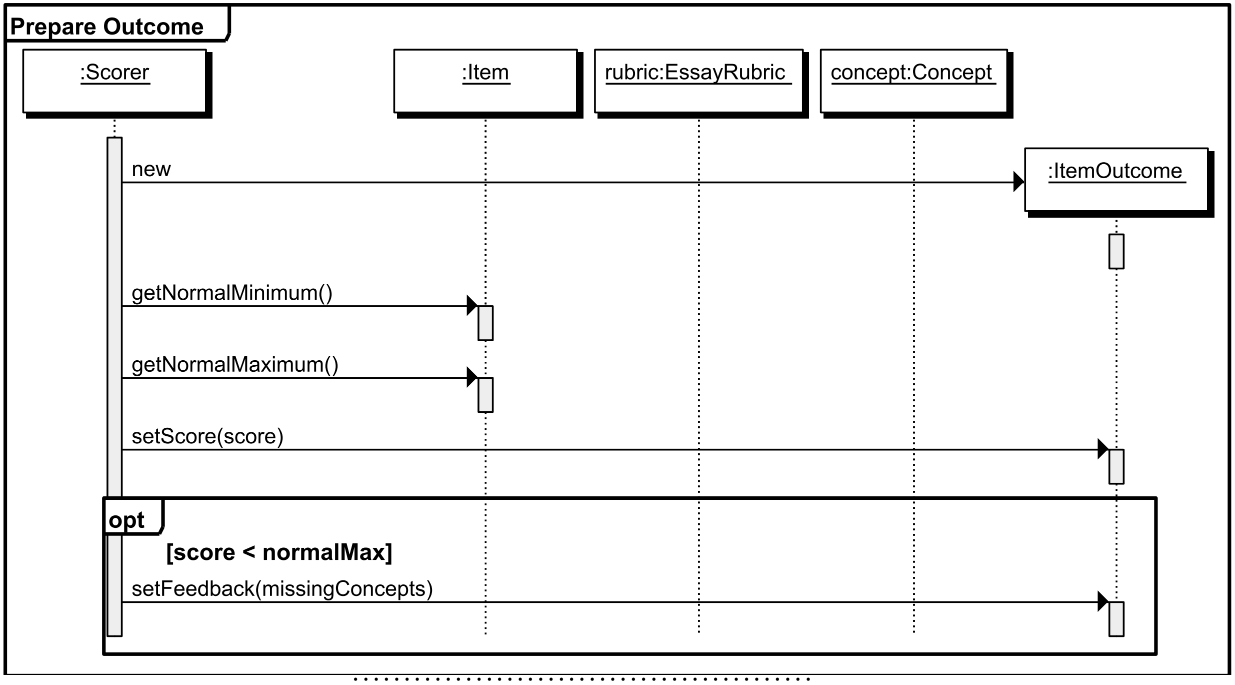
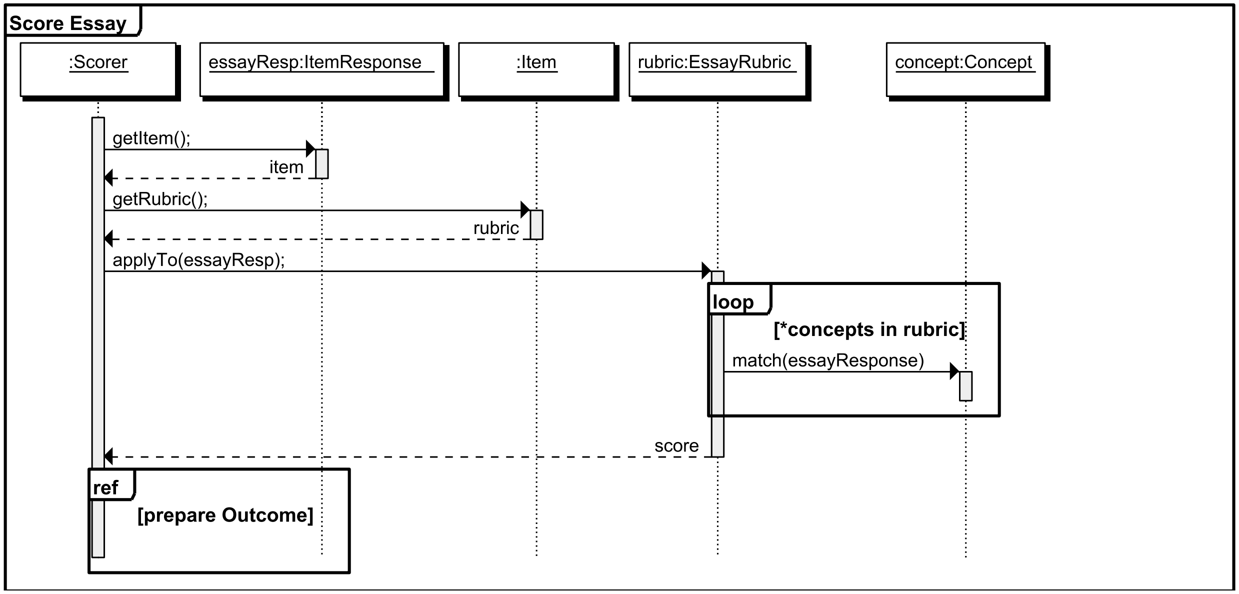
Reference Frames

We use an outer frame to name our diagram



Referring to Other Frames

And then can reference it in other diagrams



- These allow you to break up sequence diagrams into pieces and have some diagrams "include" or refer to other diagrams.

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