More on Cucumber: Steps, Scenarios, and Troubleshooting

CSCI 5828: Foundations of Software Engineering
Lecture 13 — 02/28/2012

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Goals

- Review material from chapters 4-6 of our testing textbook
- Learn more about Cucumber and how it supports behavior-driven design
    - More about Steps and Step Definitions
    - More about scenarios
        - Examining typical problems encountered with Cucumber
- Review additional examples throughout

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Perspective (I)

- Cucumber is aimed at **integration and acceptance** testing
  - It is a testing and communication tool for expressing
    - **end-to-end** tests that cover the major capabilities of your system
      - view to controller to model and back
      - UI to database and back
      - tests that touch all of the subsystems of your system; these subsystems might exist on multiple nodes
- As such, you will still write unit tests for your system, using some other testing framework, and run them alongside cucumber-based tests
  - Your customer will only be involved with the latter

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Perspective (II)

- To make this work, cucumber requires discipline to ensure that the right people work together to create the integration tests
    - customers must work with developers
        - to prevent the developers from writing tests that are too low level
        - to ensure that tests are written using customer terminology
        - to ensure that what is being tested is important (to the customer)
    - developers must work with testers
        - testers will be looking for corner cases and good coverage
        - developers can use their expertise to ensure that the test cases are properly decomposed and help with refactoring duplicate behavior

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Perspective (III)

- All three stakeholder roles are needed to balance each other
    - customers ensure that tests are “in scope” and important
    - developers ensure that tests are well maintained
        - also help to ensure that all the information needed to run a test is present
- testers ensure that the test set is comprehensive
    - and that we are not ignoring certain tests because they are hard
    - “The first principle is that you must not fool yourself and you are the easiest person to fool” — Richard Feynman

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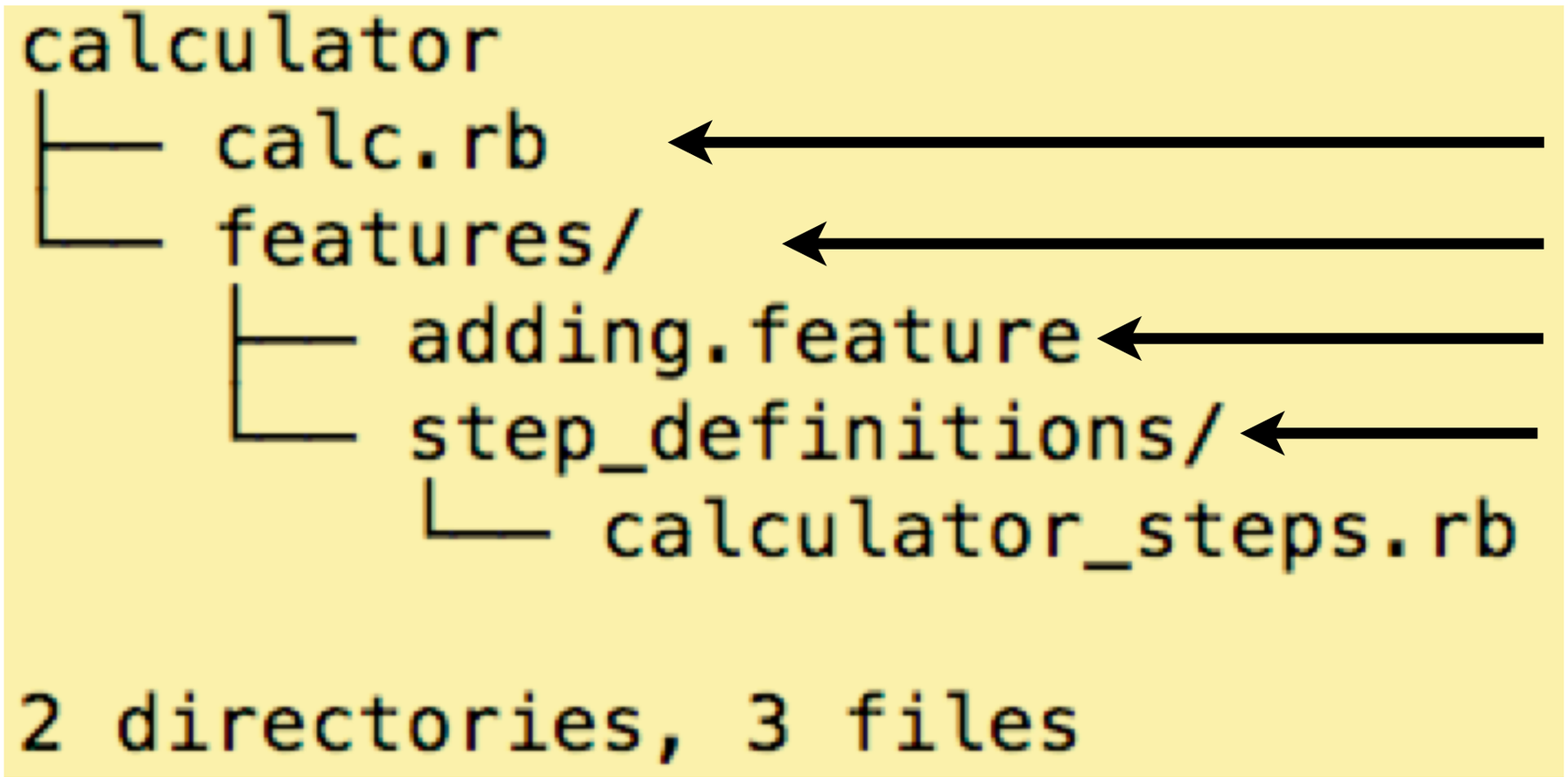
Review (and two new tidbits)



- Cucumber conventions lead to the above folder/file hierachy
  - There can be **multiple directories** under “features” to help organization
  - There can be **multiple files** in each step_definitions directory to help organize the code that implements the step definitions

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Matching Steps (I)

- In lecture 9, we encountered steps that looked like this
  - **Scenario**: Attempt withdrawal using stolen card
    - **Given** I have $100 in my account
    - **But** my card is invalid
    - **When** I request $50
    - **Then** my card should not be returned
    - **And** I should be told to contact the bank
- It turns out the step keywords (**Given**, **When**, **Then**, **And**, **But**) are **for humans only**; cucumber **doesn't care what you use**

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Matching Steps (II)

- Indeed, this is an equivalent scenario
    - **Scenario**: Attempt withdrawal using stolen card
        * I have $100 in my account
        * my card is invalid
        * I request $50
        * my card should not be returned
        * I should be told to contact the bank
- The “*” is simply used to denote a new step

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Matching Steps (III)

- The reason this is equivalent is that cucumber uses just the highlighted text...
  - **Scenario**: Attempt withdrawal using stolen card
    * I have $100 in my account
    * my card is invalid
    * I request $50
    * my card should not be returned
    * I should be told to contact the bank
- ... to match a step to its step definition
- All step definitions are read in at run-time and then regular expressions are used to find a match

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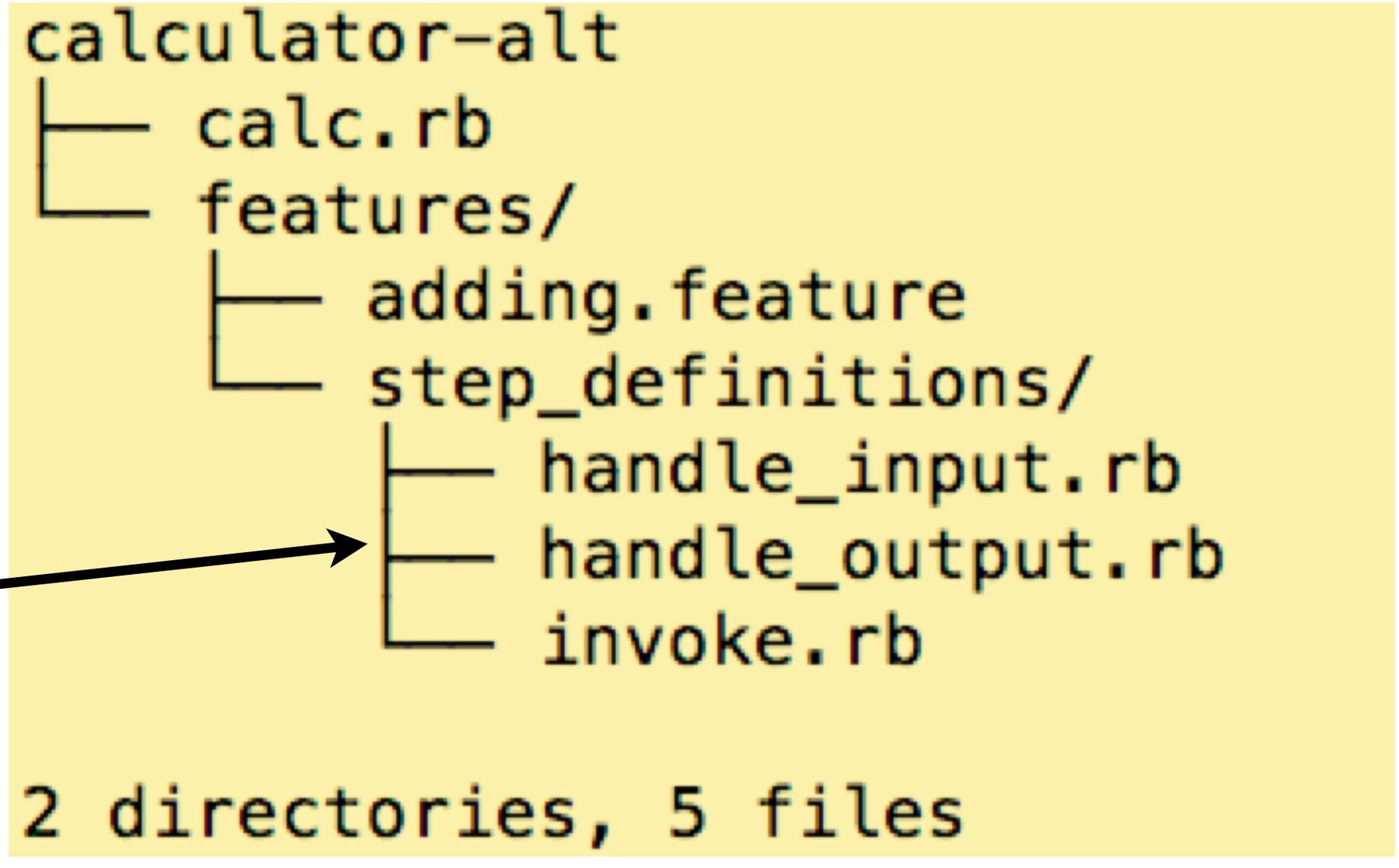
Matching Steps (IV)

- As a result, it does not matter how you organize your step definitions
  - Here is a version of calculator that splits its step defs across three files

The behavior of cucumber is identical to the previous config.

Three files with one step def. each



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Matching Steps (V)

- This also means that you have to be careful with how you write your steps
- Scenario 1:
  - Given I have $100 in my Account
  - When I request $20
  - Then $20 should be dispensed
  - And my balance is $80
- Scenario 2:
  - Given a starting balance of $20 in my Account
  - When I deposit $80
  - Then I have $100 in my Account

What's the problem?

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Matching Steps (V)

- This also means that you have to be careful with how you write your steps
- Scenario 1:
  - Given **I have $100 in my Account**
  - When I request $20
  - Then $20 should be dispensed
  - And my balance is $80
- Scenario 2:
  - Given a starting balance of $20 in my Account
  - When I deposit $80
  - Then **I have $100 in my Account**

These two statements are treated **as equivalent by Cucumber**; but in one case, it is being used **to initialize a scenario**; in the second case, it is being used **to assert that something is true** of the scenario

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Matching Steps (VI)

- When you have two equivalent steps
  - Given I have $100 in my Account **(First Step; used to initialize)**
  - Then I have $100 in my Account **(Last Step; used to assert)**
- they will both cause the same step definition to be invoked
  - **Given /I have \$100 in my Account/ do**
    - **<code goes here>**
  - **end**
- The problem is that <code goes here> will do the same thing each time, it will not be able to customize what it does based on the two different contexts
- How to fix?

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Matching Steps (VII)

- To fix this problem, you need to rewrite the steps
  - Given I have deposited $100 in my Account
  - Then the balance of my Account should be $100
- Now, it will be clear that
  - the first is used to initialize the Account
  - and, the latter is used to verify the account's balance

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The Matching Process

- When invoked, Cucumber reads in all of the step definitions that it can find
    - Each step definition causes a pattern to be registered with Cucumber
- It then starts to process each feature file, looking for scenarios
    - For each step in a scenario, it checks to see that it matches one of the registered regular expressions
- If a match is found, the code associated with the step definition is executed and a result is recorded
    - If a match is not found, the step and scenario is considered undefined
- The next step is then processed (assuming the previous step passed)
    - Otherwise, the scenario either failed due to an exception in the step or the scenario is marked pending because the step itself was marked pending

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Regular Expressions (I)

- Regular expressions are a mechanism for specifying patterns that can appear inside text documents
    - Each expression can consist of
        - regular characters
        - metacharacters
        - groups
        - anchors

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Regular Expressions (II)

- A regular expression (in ruby) begins with a slash (/) and ends with a slash
  - /Ken/
- All regular expressions start and end with the "/" metacharacter. Metacharacters have special meaning; in this case, slash acts as a delimiter
- The above regular expression consists of three regular characters "K", "e", and "n", in that order
  - It would match these sentences
    - Ken is a faculty member
    - Pete called Ken on Tuesday
  - but not this sentence
    - Dirk is a faculty member

Here the regular expression is "unanchored" and so it will match any sentence that contains the string "Ken"

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Regular Expressions (III)

- If you want a metacharacter to act like a regular character, you must **escape the metacharacter** using a backslash
    - /Ken\/Pete/
- This expression would match the sentence
    - The meeting will be led by a faculty member (Ken/Pete)
- But not
    - Ken will lead the meeting
- Since backslash is a metacharacter, **if you want to match it, you need to escape it** with, you guessed it, another backslash character
    - /In LaTeX, use \\cite to reference a journal or conference paper\./

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Regular Expressions (IV)

- A period (.) is a metacharacter that will match any character in the text file
  - /I ate .... slices of pizza\./
- will match
  - I ate four slices of pizza.
  - I ate five slices of pizza.
  - I ate nine slices of pizza.
- Note: since we wanted to make sure that a period appeared at the end of a matched sentence, we explicitly matched the period by escaping the last period in the regular expression with a backslash
  - Otherwise, the expression would match “I ate nine slices of pizza!”

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Regular Expressions (V)

- If you need to specify that any one of a particular set of characters might appear in a particular spot in a regular expression, you use a character class
- A character class is specified using square brackets and then can list one or more ranges of characters assuming ASCII ordering
  - /There are [23456789] cows in the field\./
    - Matches “There are 3 cows in the field.” but not “There are cows in the field.”
- If characters appear in sequence, you can use a hyphen to express a range
  - /Your id number is [A-Z][A-Z][0-9][0-9][0-9]\./
  - “Your id number is BZ232.”

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Regular Expressions (VI)

- Beware unintended inclusions of characters when using the hyphen
  - [a-Z] is an empty range and [A-z] includes “[”, “\”, “]”, “^”, “–”, and “`” (!!!)
  - Instead, you need to do [a-zA-Z]

ASCII Code Chart

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
2		!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	DEL

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Regular Expressions (VII)

- More on character classes
  - If you want to match all characters BUT the ones listed, start the class with the “^” character
    - [^0-9] == match any character that is not a digit
  - If you need to match a hyphen, list it first
    - [-A-Za-z] == match any letter (upper case or lower case) or a hyphen
  - If you need to match a “^” character, list it in any position but the first
    - [A-Z^a-z]
- Some character classes are predefined: \s (whitespace), \d (digit), etc.
  - See page 49 of the testing textbook for examples (not required)

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Regular Expressions (VIII)

- Patterns can be tagged with repetition modifiers
  - * — the preceding pattern can appear zero or more times
  - + — the preceding pattern can appear one or more times
  - ? — the preceding pattern can appear zero or one times
- Alternative choices for a pattern can be separated by the pipe character “|”
  - Parens “(“ and “)” can be used to group patterns for alternation
- /There (is|are) [0-9]+ cows? in the field\./
- Matches
  - “There are 2 cows in the field.” and “There is 1 cow in the field.” but also “There is 5 cow in the field.” and “There are 999999993421 cows in the field.”

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Regular Expressions (IX)

- Patterns can be anchored
  - ^ at the beginning of a regular expression anchors it at the beginning of a line of text
  - $ at the end of a regular expression anchors it at the end of a line of text
- /^Ken likes to play soccer\.$/
  - This regular expression matches only the string “Ken likes to play soccer.” and nothing else.

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Regular Expressions (X)

- Parens are also used to specify “capture groups”
  - That is they “capture” what was matched inside of them and make the captured pattern available for later processing
  - /There are ([1-9][0-9]*) cows in the field./
- The above expression matches sentences like
  - “There are 10 cows in the field.” or “There are 19920 cows in the field.”
  - Also (unfortunately) “There are 1 cows in the field.”
- AND makes the actual number available
  - In a step definition, a captured pattern is passed as an argument to the step definition’s method body;

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Example from Lecture 9

- Given /^the input "([^"]*)"$/ do |arg1|
  - @input = arg1
- end

- We now should understand the regular expression better
  - “the input ” appears at the start of the step, followed by a quotation mark
  - [^”]* match any character that is not a quotation mark, zero or more times
  - the parens around the above pattern captures the result as arg1
  - the step must end with a quotation mark

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More about Steps (I)

- Any step can be augmented by a data table
- These are not the same as the table that appeared when using a “Scenario Outline” within a feature
- Instead, it is a table that appears immediately after a step, like this

```
Then my shopping list should contain:

        | Onions   |
        | Potatoes |
        | Sausages |
        | Apples   |
        | Relish   |
```

- The step definition will then contain an argument where this table is passed as a first-class object

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More about Steps (II)

- The details of what you can do with the table is provided in the cucumber documentation
  - <http://cukes.info/cucumber/api/ruby/latest/Cucumber/Ast/Table.html>
- The book provides a basic example using Tic-Tac-Toe
  - DEMO
- It also hints at what can be accomplished
  - `Given these Users:`
    -
```
| name            | date of birth |
| Michael Jackson | August 29, 1958 |
| Elvis           | January 8, 1935 |
| John Lennon     | October 9, 1940 |
```
- A step definition could process this table at run-time and create 3 instance of the User class configured as shown and stored in a collection @users

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More about Steps (III)

- Any step can also be augmented with a doc string
  - `Then I should receive an email containing:`
    - ```
      """
      Dear Sir,

      You are no longer subscribed to our mailing list.

      Sincerely,
      SpamIsUs
      """
      ```
- The entire contents of the doc string will be passed to the step definition
  - Your code can then store the string or manipulate/parse it using any of ruby's string manipulation capabilities
  - We'll see examples later this semester

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      ```

Nesting Steps

- You can have a step definition that turns around and invokes other step definitions
    - This is called “nested steps”
- This is touted initially as a way to create more abstract steps
    - A step that says “Given the account is activated for Ken” might delegate to
        - “Given the account is created”
        - “Given the account has a balance of $50”
        - “Given the account has an owner named Ken”
        - “Then Ken activates the account”
- But, the book ends up strongly warning you away from this feature

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More on Scenario Outlines

- A scenario outline can have more than one table of examples

```
• Scenario Outline: Withdraw fixed amount
• Given I have <Balance> in my account
• When I choose to withdraw the fixed amount of <Withdrawal>
• Then I should <Outcome>
• And the balance of my account should be <Remaining>
• Examples: Successful withdrawal
  | Balance | Withdrawal | Outcome             | Remaining |
  | $500    | $50        | receive $50 cash | $450      |
  | $500    | $100       | receive $100 cash| $400      |
• Examples: Attempt to withdraw too much
  | Balance | Withdrawal | Outcome                | Remaining |
  | $100    | $200       | see an error message | $100      |
  | $0      | $50        | see an error message | $0        |
```

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Staying Organized

- When creating features and scenarios, cucumber offers two mechanisms to help organize them
    - First, as already mentioned, you can have as many subdirectories under the features directory of a cucumber project as you want
    - features/
        - sorting/
        - adding_employees/
        - calculating_payroll/
- Second, you can classify both features and scenarios with tags

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Tags (I)

- A tag is a word prefixed by the @ character that can appear on the line before either the keyword Feature or the keyword Scenario
    - A tag on Feature will be inherited by all of that feature's scenarios
- Example
    - @employee
    - Scenario: Add an employee
        - Given Ken is a Person
        - And Ken is accepted for a job at our company
        - Then Ken is added as an employee
- This scenario is now tagged with the keyword "employee"

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Tags (II)

- You can have multiple tags, separated by spaces
- Example
    - @slow @widgets @nightly
    - Scenario: Generate overnight report
        - Given I am logged in
        - And there is a report "Total widget sales history"
        - ...
- This scenario has three tags: slow, widgets, and nightly

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Tags (III)

- Now that you have tagged scenarios, they become useful because you can ask cucumber to run just the scenarios with a particular tag
  - cucumber --tags @nightly,@slow
- Cucumber will now run only those features and scenarios that have been tagged with the “nightly” tag
- This enables you to raise the quality of your development process by configuring a continuous build system to invoke this command at night and log the output for review the next day

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Troubleshooting Cucumber

- The authors of the cucumber book identify
  - four types of problems that can be encountered
  - when trying to incorporate behavior-driven design into a life cycle
- Those problems are
  - **Flickering Scenarios**: Tests are unstable; some randomly fail
  - **Brittle features**: Changes to the system cause existing features to break
  - **Slow features**: The test suite takes too long to run
  - **Bored stakeholders**: Our customer is no longer creating/reading features

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Flickering Scenarios

- A flickering scenario is one that every now and then fails randomly
  - The unpredictable nature of the failure reduces team confidence
  - This uncertain situation, in turn, reduces the desire to run the test suite
- The biggest problem with this situation is that
  - you cannot fix the situation if you cannot get the bug to be reproducible
- Contributing Factors
  - **Shared Environments**
  - **Leaky Scenarios**
  - **Race Conditions and Sleepy Steps**

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Shared Environments

- Shared Environments
  - Multiple people use the same machine to test in parallel
    - The tests of the two users have the potential of clobbering each other
      - Creating/editing the same database at the same time, writing to a shared XML file, etc. **Boom!**
- Solution
  - Use techniques that isolate one instance of a test from another instance of that same test
    - For instance, have the test create a tmp directory, unique to it, where it stores all of its data
    - Multiple instances of that same test can now be run in parallel

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Leaky Scenarios

- Leaky Scenarios
  - One test creates an environment that another test depends on
    - The tests have different tags and cucumber gets invoked on just the tag of the second test: **Boom!**
    - Someone changes the first test, not realizing that a dependency exists: **Boom!**
- Solution: design tests to create everything they need from scratch
  - Have a really complex system? Use mock objects to simulate non-essential parts (with respect to the test) of the system

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Race Conditions and Sleepy Steps

- Race Conditions and Sleepy Steps
  - You have a complex system and your integration test causes two parts of the system to run in parallel
    - or the system to run in parallel with cucumber
    - The test will pass when only the “right” component finishes first
      - If the “race” is close, you end up with a flickering scenario
    - Developers combat this by causing certain steps to “sleep” to wait for the concurrent operation to end; hence “sleepy steps”
- Solution: You need to engineer synchronization points for cucumber that ensures it waits for a system component to finish its work before testing it

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Brittle Features

- Brittle features are ones that break at the slightest change to other parts of the system
    - The design of the underlying system may be too tightly coupled and will need to be refactored
- Contributing Factors
    - Fixture Data
    - Duplication
    - Leaky Scenarios (see above: related to dependencies between tests)
    - Tester Apartheid

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Fixture Data

- Fixture data refers to having a large amount of data stored somewhere in your test environment that all tests share and come to depend on
    - A change in that data can cause tests to fail because developers fail to realize that lots of tests depend on it
    - Large sets of fixture data can slow test suites down if all of the data has to be loaded for each scenario
- Solution: The book recommends an approach called test data builders in which all the data for a particular test is created by the test itself
    - It points to a ruby-based framework called FactoryGirl as an example of this approach
        - https://github.com/thoughtbot/factory_girl

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Duplication

- Duplication refers to having multiple features that test the same thing
    - Duplication can
        - make scenarios brittle (one change, breaks multiple scenarios)
        - slow your test suite down (as the same functionality gets tested again)
        - and make your customers bored (can’t attach significance to features)
- Solutions
    - Make use of the Background and Scenario Outline keywords
    - Watch out for steps with low abstraction
        - “User clicks on next button to go to the next page” vs. “Users navigates to Accounts page”

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Tester Apartheid

- Testers are often regarded as second-class citizens on a software team.
    - They may not have as much technical or software engineering skills as developers but they are
        - capable (and good at) writing automation scripts
        - good at coming up with corner cases
        - good at coming up with comprehensive test suites
- However, if they do not work with developers their test code can degrade if it is not properly maintained
- Solution: Have testers and developers work together and encourage this as part of company culture; developers can refactor the test suite when needed and learn from the testers about how to best test their code

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Slow features

- After creating a lot of tests, it takes a long time for the entire test suite to run
  - You accumulate tests because you want to know when a change has broken previously passing tests; You can back out the change and/or figure out how to fix the regression
- When test suites take a long time to run
  - developers shy away from running them and as such, they start to commit their changes without testing them!
  - This leads quickly to a situation where a broken build is the norm
- Contributing Factors
  - Race Conditions and Sleepy Steps (see above)
  - Lots of Scenarios
  - Big Ball of Mud

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Lots of Scenarios

- Lots of scenarios will, of course, lead to slow test runs
    - It takes a certain amount of time for each scenario to run and that adds up
- Often, however, this is a symptom of the system architecture
    - For instance, a big, monolithic system might require all the features/ scenarios to live in one place and all be tested together
- Solutions
    - Decompose the system architecture and have features that target just individual components and then add features that target inter-component interactions
    - Divide feature folders into hierarchies and tag features so that subsets can be easily run independently from one another

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Big Ball of Mud

- No software design has been applied to a system at all
  - My friend once encountered a “system” which implemented “shopping cart” functionality for websites
    - it consisted of a single method that when printed covered 42 pages (!)
- These systems have low cohesion (one component doing too many tasks) and tight coupling (too many dependencies between components)
  - As a result, its difficult to test “just one thing” and your scenarios will have lots of unintended duplication, slowing things down
- Solution:
  - Refactor, refactor, refactor
  - Have the team focus on the architecture of the system for an iteration or two

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Bored Stakeholders

- Stakeholders become disengaged with the process of developing the test suite that is needed to help guide development
  - They no longer read existing features
  - They no contribute to the creation of new features
  - They are unwilling to meet with the development team
- Contributing Factors
  - Incidental Details
  - Imperative Steps
  - Duplication (see above)
  - Ubiquitous What?
  - Siloed Features

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Incidental Details

- Scenarios contain a lot of detail that are not relevant to what is being tested
    - The book presents an example that is testing whether an e-mail is received after it has been sent
        - The original example had steps that declared the passwords of the users but these passwords were never used
            - The example was rewritten to be much shorter by abstracting away most of the incidental details and leaving clear what exactly was being tested
- Solution
    - Always ask yourself if you are writing at the right level of abstraction
    - Do not let yourself be influenced by existing step/step definitions

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Imperative Steps

- Imperative steps are ones that are written in the style of “do this; do that”
    - The problem is that it is very easy for the steps to be written at too low level of abstraction, containing lots of unnecessary detail
- Declarative steps are written at a higher level of abstraction and allow the programmer leeway in how they are carried out
- Contrast this
    - User is not logged in; He goes to home page; He is redirected to login page
- with
    - User is not authenticated; He tries to view restricted content; System authenticates user

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Ubiquitous What?

- The team has failed to incorporate the language of the customer (and their application domain) into the system design and project culture
    - If you are developing a ticketing system, you might have words in your system like concert, performance, artist, venue
- If you ignore those terms, and use arbitrary or terms so generic that there is no obvious mapping (or the terms could be mapped to anything)
    - then your customer can become discouraged and disengaged
- Instead, encourage your team to develop and use a language which is shared with the customer
    - it will reduce mistakes and misunderstandings, improve team confidence and morale, and foster/strengthen the relationship with the customer

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Siloed Features

- Cucumber is a command line tool and the features it processes are text files stored in the file system and checked into configuration management systems
  - As a result, it is very easy for the features to “hide” from the customer
  - They might not feel like they can access the features easily
    - Access might require the use of unfamiliar tools (git, text editors)
- Solution
  - Publish the features in a way that your customer can access them
    - Use scripts, for instance, to convert them to HTML and share them with the customer via a website
  - Engage with the customer to ensure they are always reading/writing the features and scenarios with the development team

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Summary

- We learned more about Cucumber
    - Steps and the step matching process
    - Regular expressions and their use in steps
    - Scenario Outlines
    - Tags
- We also learned about some of the problems that can be encountered when executing behavior-driven design
    - and solutions that can be used to address those problems

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