

## CSCA48, Assignment #2

### Due July 31, 2017, 11:55 p.m.

From an early draft of his *Canterbury tales* Chaucer removed an account of the pilgrims staying at Anne Hoy's<sup>1</sup> inn, an establishment that served bad ale but good cheese. The missing account explained how Anne kept her high-quality cheese stacked on stools, the largest rounds underneath the smaller rounds, to stop rats and mice from getting at them.

Occasionally the stool holding the cheese would need some maintenance (for example, the legs would start to buckle under the weight), and Anne would shift the entire stack from one stool to another. Since she could only move a single (hundred-pound plus) round of cheese at one time, and she refused to stack a larger-diameter cheese round on a smaller one (the outer part of the larger cheese would droop) she used three stools: one was her destination for her entire stack of cheese, one was the source (which likely needed its legs reinforced), and the third was for intermediate stacking. Chaucer immortalized the complicated routine Anne endured, lugging rounds of cheese from stool to stool as “The tour of Anne Hoy ” (TOAH).<sup>2</sup>

One of Chaucer's pilgrims had a mathematical bent. She had seen a miraculous early draft of the [Wikipedia article on the Tower of Hanoi](#) in a vision, and noticed that Anne's routine for moving cheeses was identical to the problem of moving rings between three posts. Using this similarity she calculated that to move  $n$  cheeses in this way required  $2^n - 1$  moves. This disheartened Anne, who had plans to increase her stack of cheese beyond the 8 she currently had. She decided to invest some of her profits in a fourth stool.

Anne figured that she could do substantially better than  $2^n - 1$  moves using the following strategy:

- For a stack of 1 cheese round, her four-stool configuration allowed her to move the stack in 1 move, using her previous three-stool TOAH method.
- To move a stack of  $n > 1$  cheese rounds from some origin stool to some destination stool, she reasoned that she could think of some number  $i$  between 1 and  $n - 1$ , and then:
  1. Move  $n - i$  cheese rounds to an intermediate stool using all four stools.
  2. Move  $i$  cheese rounds from the origin stool to the destination stool, using the (now) only three available stools and her TOAH method.
  3. Move the  $n - i$  smallest cheese rounds from the intermediate stool to the destination stool, using all four stools

Notice that steps 1 and 3 require Anne to know how to move  $n - i$  cheese rounds using four stools. Anne figured this wasn't a problem, since she could apply her recursive strategy to this smaller move. She presented her plan to the above-mentioned mathematically-inclined pilgrim who said that if she called the minimum

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<sup>1</sup>In Middle English her name would have been spelled *Auyne H'Oeuil*

<sup>2</sup>Chaucer conjectured Anne's muttered “cheeses crust!” and “gentle jumping cheeses!” were veiled religious oaths, not mundane references to cheese maintenance.

number of moves that her strategy needed to move  $n$  rounds of cheese  $M(n)$ , and if some  $i$  between 1 and  $n - 1$  were chosen, then (reasoning recursively):

$$M(n) = \begin{cases} 1 & n == 1 \\ 2 * M(n - i) + 2^i - 1 & \text{otherwise.} \end{cases} \quad (1)$$

After experimenting a bit Anne found she could move 3 cheese rounds in 5 moves (a little better than the 7 required by the TOAH method), and 6 cheese rounds in 17 moves — much better than the 63 required by the TOAH method. But the choice of  $i$  made all the difference. She (and the aforementioned math-geek pilgrim, who had decided to stay at her inn permanently) spent many hours with early prototypes on pencil and paper, figuring out the best strategies for moving ever-larger stacks of cheese.

This is where matters stood, for centuries, until the invention of the computer.

## Your job

The *Towers of Anne Hoy Game* is to move a stack of cheeses from the first stool to the last stool, using only valid moves as described in the previous paragraphs.

You will implement parts of a step-by-step design of an object-oriented program for a *Towers of Anne Hoy game*. In order to guide you, we present the steps below, in the order we recommend.

**Step 1:** Read and understand the Cheese class in `TOAHModel.py`.

**Step 2:** Read the `ConsoleController` class in `ConsoleController.py`, looking for how it uses a `TOAHModel` object. For questions you can't answer there (such as what the method header for `__init__` should be), you will have to look in `GUIController.py` to see how `GUIController` uses a `TOAHModel` object. Unlike `ConsoleController`, `GUIController` is already completely implemented for you. You do not need to understand all the code in the files `GUIController.py` and `GUIViewables.py`, but your implementation of `TOAHModel` will be expected to work with both `ConsoleController` and `GuiController`.

Write the method headers for `TOAHModel` in `TOAHModel.py` according to their uses by `ConsoleController`.

**Step 3:** Write the implementations of the `TOAHModel` methods from Step 2. Notice in particular how `ConsoleController` and `GUIController` rely on a `TOAHModel` object to throw exceptions in certain circumstances (and without altering the state of the `TOAHModel` object).

When you're done you should be able to run `GUIController.py` to manually play the *Towers of Anne Hoy game*. Do not change anything in `GUIController.py` or `GUIViewables.py`.

You also need to implement `TOAHModel.__eq__`. The header in `TOAHModel.py` has instructions.

**Step 4:** Now we want you to get a console-based version of the game working. Implement the methods `play_loop`, `__init__`, and `move` of the `ConsoleController` class in `ConsoleController.py`. The headers are already written for you, and the docstrings provide additional instructions. You will also need to put appropriate code under `if __name__ == '__main__':`.

When you're done you should be able to run `ConsoleController.py` to manually play the *Towers of Anne Hoy game* through the console.

**Step 5:** Implement the module-level function `tour_of_four_stools` in `Tour.py` to solve four stool instances of Anne Hoy's cheese-moving problem, trying to minimize the number of moves. You should be able to move  $n$  cheeses in considerably less than  $2^n - 1$  moves achievable with just three stools.

We will check your solution using `TOAHModel.get_move_seq`, so make sure to use the class `MoveSequence` in `TOAHModel.py` to record the moves your solver makes.

**Step 6:** Add an option to your `Tour` class that enables animating your solver using `ConsoleController`. The header for `Tour.tour_of_four_stools` already has two optional arguments for this; when `console_animate` is `True`, animation should be displayed in the console, and `delay_btw_moves` gives the number of seconds to wait between showing two moves. We recommend using `TOAHModel.__str__`, but you aren't required to (you can make your own string-based representation).

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## What to submit

You'll need to submit your version of the following files to MarkUs:

- `TOAHModel.py`
- `Tour.py`
- `ConsoleController.py`