

Ulam Spiral

In 1963 Stanislaw Ulam, one of the Manhattan Project physicists and the inventor of Markov Chain Monte Carlo approximation methods, conceived of a way of visualizing the prime numbers. This visualization, called the Ulam Spiral, consists of arranging all numbers in a grid, starting at the center and spiraling counterclockwise outwards, then erasing all non-prime numbers:

```
[[ '5' '4' '3' ]  
[ '6' '1' '2' ]  
[ '7' '8' '9' ]]
```

becomes

```
[[ '5' " " '3' ]  
[ " " '2' ]  
[ '7' " " ]]
```

More information and pictures of the spiral are available at wikipedia's entry here:
https://en.wikipedia.org/wiki/Ulam_spiral

For this project, do the following using Python as your implementation language:

- 1) Create a function to generate Ulam's Spirals of arbitrary size. You may use any data structure that makes sense to you but be prepared to defend your choice. In your documentation for this function describe the runtime for this function in $O(N)$ terms, where N = spiral size.
- 2) Using a data visualization method/library of your choice, draw the Ulam Spiral for spiral size $N = 81$. (A picture of an Ulam Spiral of size $N = 49$ is available at the wikipedia link above.)
- 3) Once you have generated an Ulam Spiral using the function above, create an additional function that can, for a given grid coordinate (x,y) of a grid of size N , determine whether that position contains a prime number or not. In your documentation for the function describe what your $O(N)$ search time is, where N = spiral size.

Bonus: To really get noticed, ensure that your function in (3) can work for Ulam Spirals of arbitrarily large size. For example, given a spiral of size $N = 100$ Trillion, can your function check a given position in reasonable time? Also can your visualization function in (2) be extended to draw a subset of the spiral near the checked position?

Submit to us your working code along with documentation of the performance scaling of your methods as noted above. Assume your operating environment is Anaconda Python but you cannot use the following libraries:

itertools, numpy, pandas

Please additionally document the webpages / reference material you used to generate your answer and properly give credit where needed. There is no penalty for using the internet for help - we all do - but unattributed 'borrowing' of code will be viewed very negatively.

If you have any questions don't hesitate to contact us via email (dawei.leng@ghddi.org) seeking clarification.

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