Name of the skill:
Algorithm Design and Complexity Analysis.

Introduction: The term "Analysis of algorithms" was coined by Donald Knuth. In computer science, the analysis of algorithms is the process of finding the computational complexity of algorithms – the amount of time, storage, or other resources needed to execute them. Usually, this involves determining a function that relates the length of an algorithm's input to the number of steps it takes (its time complexity) or the number of storage locations it uses (its space complexity).

Classification of Skill:
Hard and Technical Skill. This skill requires technical knowledge and a strong mathematical background.

Hard Skills are teachable and measurable abilities, such as writing, reading, math or ability to use computer programs. Typically, hard skills are learnt in the classroom, through books or other training materials, or on the job. Hard skills can be listed on a resume and are easy for an employer or recruiter to recognize.

Technical skills refer to the knowledge and expertise needed to accomplish complex actions, tasks and processes. Technical skills can refer to the ability to perform tasks that require the use of certain tools, whether tangible or intangible, and the technology required to master their intended uses in a variety of scenarios.

Prerequisites:

Proof techniques: Extremely important topic of mathematics to learn algorithms. Mostly, two proof techniques are used. Induction and contradiction. Proof is not a thing which can be just learnt, it’s a skill that has to be mastered.

Probability: Basic probability is used mostly in the analysis of some algorithms. One most popular example is hashing. Probability is used more extensively in the analysis of some randomized data structures and algorithms like skip lists and randomized quicksort or randomized median finding.

Recurrence relations: Also a useful tool in analyzing the complexity of recursive algorithms like merge sort. It’s good to know how to solve recurrence relations.

Number theory: Widely used in cryptography. There are few must know topics in number theory which are important to learn to solve problems using data structures and algorithms. Some of them are
A. Prime numbers and finding prime numbers using Sieve's algorithm
B. Greatest common divisor and Euclid's algorithm to find GCD.
C. Little modular arithmetic might also help.

Related Software Engineering Areas:

Used in Software Construction.
Specifically, the skill has a major utilization in the **“Construction Design”** as well as “Coding” areas of Software Engineering.
Also in the area of **“Computing Foundations”**, it is widely used in Problem Solving Techniques where appropriate design of algorithm and analysis of complexity is a critical feature.

Rationale for Skill:

Algorithm Analysis is the most important step for software development. It concerns "understanding" why and what the system does . No one can set an algorithm without profound understanding of the problem and its solution.

Algorithm Analysis is done before coding. It is important to be able to measure, or at least make educated statements about, the space and time complexity of an algorithm. This will allow us to compare the merits of two alternative approaches to a problem we need to solve, and also to determine whether a proposed solution will meet required resource constraints before we invest money and time coding.

It is important to study algorithms and complexity for the following reasons:

- Useful in developing analytical skills
- To be able to write robust programs, whose behaviour we can reason about
- To learn (well-known) strategies for solving computational problems

- To learn about the inherent difficulty of computational problems

Roles for the Skill:

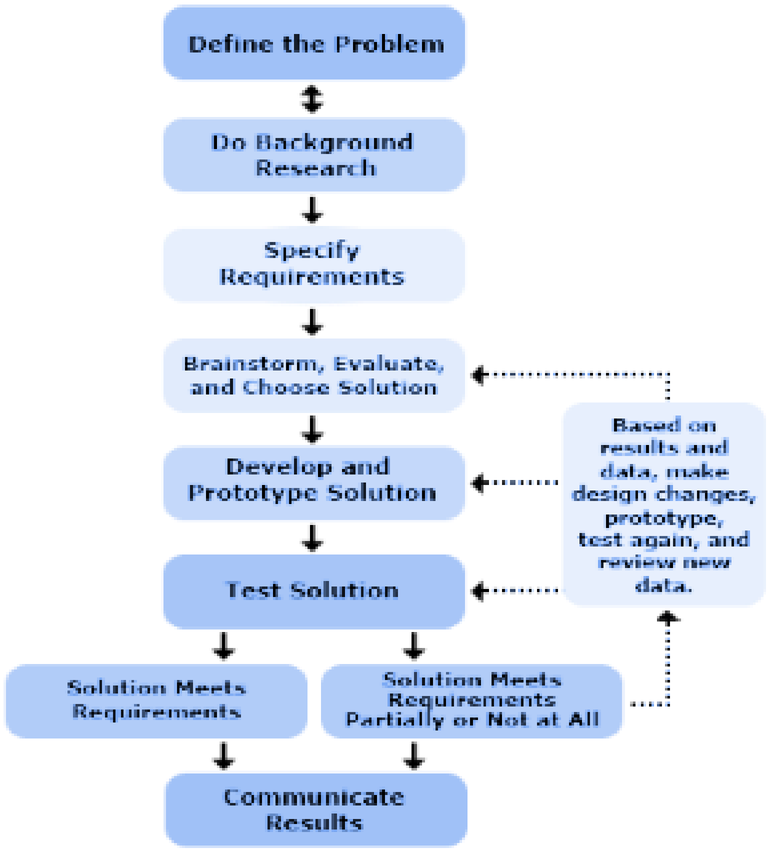
- **Machine Learning Researcher**
    - Working on innovative Machine Learning Models, developing and researching algorithms and analyzing complexities.
- **Machine Learning Developer**
- **Analyst Programmer, Operation Research**
    - Calibrating the algorithms to meet the client’s requirements.
    - Reproduce and analyze the client’s situation and propose new efficient and effective solutions.
- **Computer Vision Developer**
    - Collaborate with application and integration developers to solve complex technological problems and develop outstanding immersive applications.
    - Analyze and improve algorithms to process images.
- **Data Scientist**

Work Related to Skill (Activities and Artifacts):

There are many ways to write an algorithm. Some are very informal, some are quite formal and mathematical in nature, and some are quite graphical. The instructions for connecting a DVD player to a television are an algorithm. The development of an algorithm (a plan) is a key step in solving a problem. Once we have an algorithm, we can translate it into a computer program in some programming language.

There is a systematic multi-step process involved to approach the solution of a great variety of problems, particularly those presented in computer programming. This approach consists of the following steps.

- Read and comprehend the problem statement.
- Select theoretical concepts that may be applied.
- Qualitative description of the problem.
- Formalization of a solution strategy.
- Test and description of the solution


Define the Problem
Do Background Research
Specify Requirements
Brainstorm, Evaluate, and Choose Solution
Develop and Prototype Solution
Test Solution
Solution Meets Requirements
Solution Meets Requirements Partially or Not at All
Communicate Results
Based on results and data, make design changes, prototype, test again, and review new data.

Real-World Example/Scenario of Skill:

Page Rank Algorithm used by Google

- Page rank algorithm is designed by two PHd students i.e Larry page and Sergey Brin. This had given birth to Google.
- Search engine is an algorithm to find things efficiently in the world wide web, the algorithm developed by google is called Page rank algorithm.
- This website shows a nice visualization of working of the Page Rank Algorithm as well as shows the simulation process. http://bl.ocks.org/emeeks/f448eef177b5fe94b1c0

Some other real world applications of the skill are:

Dijkstra’s algorithm
It is a very powerful algorithm, we can say if this algorithm would not be implemented then browsing the internet would never be much efficient. It is used to find the shortest path between two nodes. Router uses this algorithm in making ip tables. Although we have much better solutions available today, this algorithm is used so widely. Google maps also uses this algorithm to find the shortest path.

Huffman coding
This algorithm is used for lossless data compression. This is based on probability and implemented in such a way so that you need not keep several copies of the same thing.

Heaps
Due to it’s less time complexity and space complexity and use of priority queue,heap sort is used widely.Heapsort works great when you need to know just the "smallest" (or "largest") of a collection of items, without the overhead of keeping the remaining items in sorted order because of priority Queue.

Dynamic programming
Dynamic programming is widely used in bioinformatics ,mathematics,economics. For example in bioinformatics the tasks such as sequence alignment, protein folding, RNA structure prediction and protein-DNA binding is done with the help of dynamic programming. In mathematics it is used in matrix multiplication and matrix multiplication has very wide applications such as it’s used in Rocket technology, where the path of rockets are decided by solving so many parameters. Almost all the decision making problems use dynamic programming to solve optimally.

Sorting/Searching Algorithms
Quick sort, merge sort, insertion sort, bubble sort , bucket sort, binary search etc are used for sorting according to the requirement.Suppose you have very less no of data and you want to sort it then quicksort will give you better solution,when you want to make comparisons then merge sort will work more efficiently.when you are interested in inserting an element without any overhead insertion sort gives you better performance. In real life these algorithms are used in mp3 players,video players,making dictionaries and there are many examples for searching and sorting.Searching Algorithms is used in Quantum computing also.

Role of Academia or Industry in Cultivating the Skill:

Algorithm Design and Complexity Analysis courses at universities help students in developing techniques needed to design algorithms and analyze complexities. The courses prepares students on:

- Various algorithm design techniques
- String Pattern Matching
- Modulo Arithmetic Algorithms
- Geometrical and Network Flow Algorithms

Many of these programs offer co-op work and internships or placements, where students can apply their knowledge and skills from what they have learnt. As the tech industry is growing rapidly, companies in all areas such as business, robotics, mobile application development and many more employ Algorithm Designers or Analyst Programmers.

Tools supporting the skill:

Microsoft BI: The Microsoft BI suite comprises a set of products that offer services ranging from data visualization to advanced algorithm and data analysis.

Weka: Also known as Waikato Environment is a machine learning software developed at the University of Waikato in New Zealand. It is best suited for data analysis and predictive modeling. It contains algorithms and visualization tools that support machine learning.

Knime: KNIME is the best integration platform for data analytics and reporting developed by KNIME.com AG. It operates on the concept of the modular data pipeline. KNIME consists of various machine learning and data mining components embedded together. KNIME has been used widely for pharmaceutical research.

Apache Mahout: Apache Mahout is a project developed by Apache Foundation that serves the primary purpose of creating machine learning algorithms. It focuses mainly on data clustering, classification, and collaborative filtering.

Skill Self-Assessment:

Score: 7 (Out of 10)
Reason: Not much experience working in this area of software engineering, but I worked as a junior Machine Learning Developer intern for 5 months and learned some basic algorithm design techniques as well as I have undertaken data structures and discrete mathematics courses in undergraduate degree and algorithm design course in graduate degree so I have acquired some basic skills in this knowledge area. So I think 7 is an appropriate score for the skill.

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