Euler and the 336 Million Dollar Software Patent

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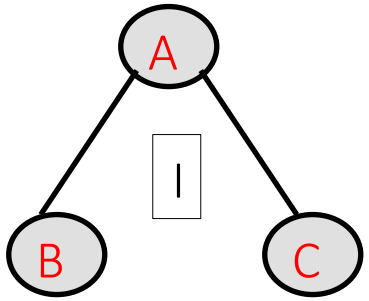
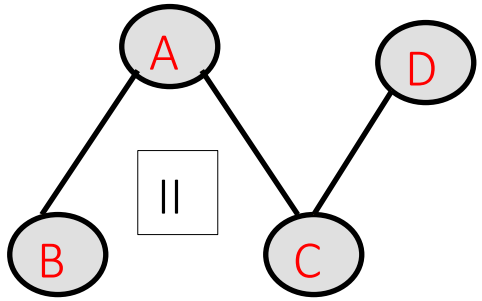
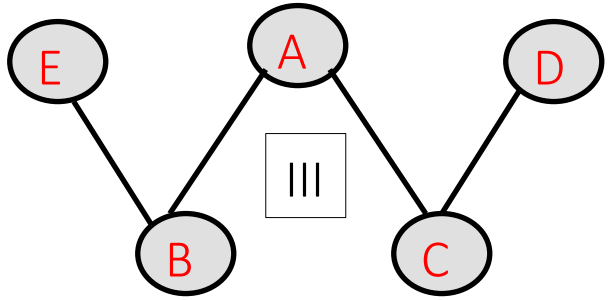
Vertex Rank problem

Think of rank as a measure of importance of the vertex.

Problem: Develop a quantitative measure for rank





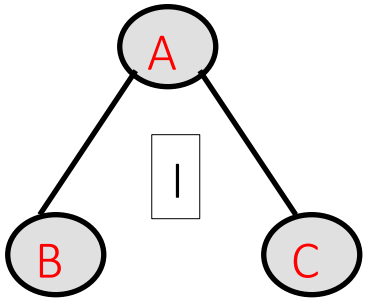


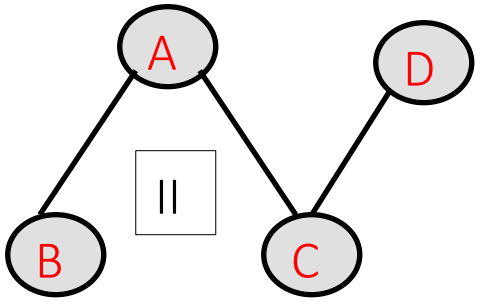
A has higher rank, B and C have the same rank

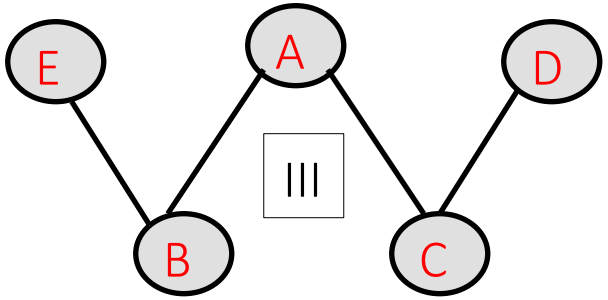
A, C have higher rank than B and D. A and C have the same rank. B and D have the same rank.

D, E have the same rank. B, C have the same but higher rank. A has the highest rank

A quantitative measure of vertex rank

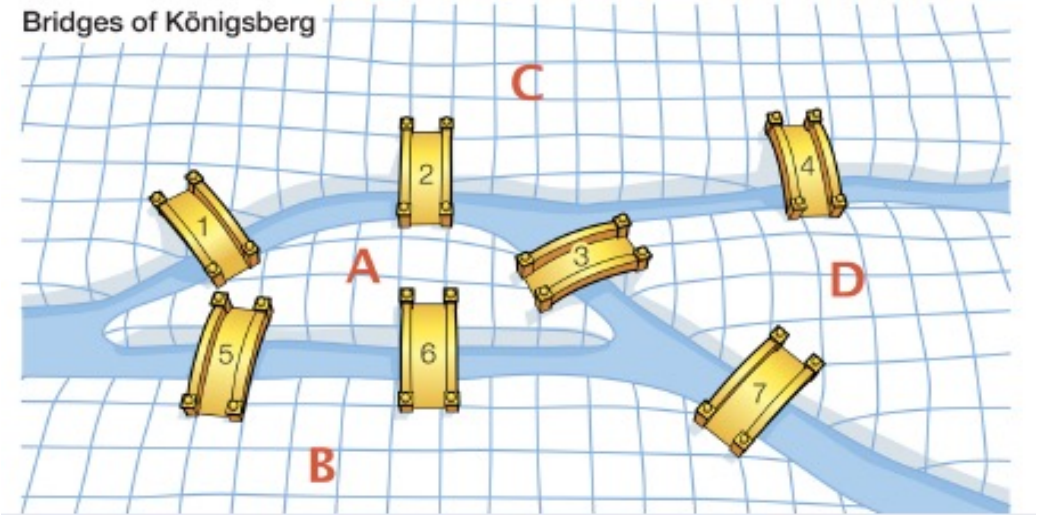






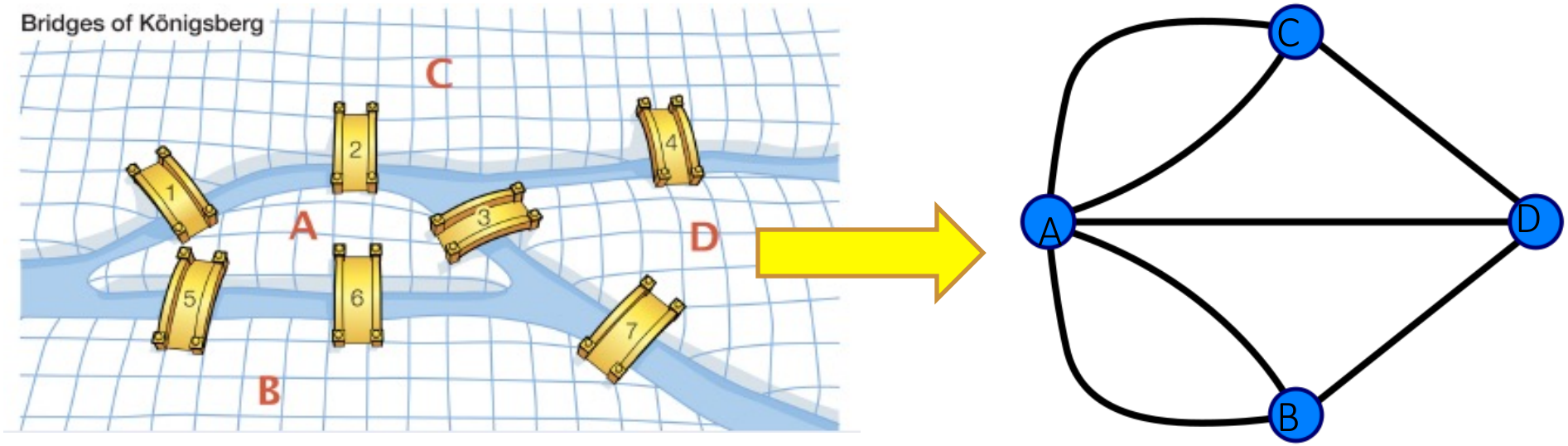
	A	B	C	D	E	Total
I	1.459	0.7702	0.7702			2.9994
II	1.298	0.7017	1.298	0.7017		3.9994
III	1.2297	1.1952	1.1927	0.6726	0.6727	4.9998

The *seven bridge* problem



Problem: Is it possible to make a loop in which every bridge is crossed exactly once?

Euler's solution (1735)



A loop that goes through all edges exactly once is called an *Euler loop*

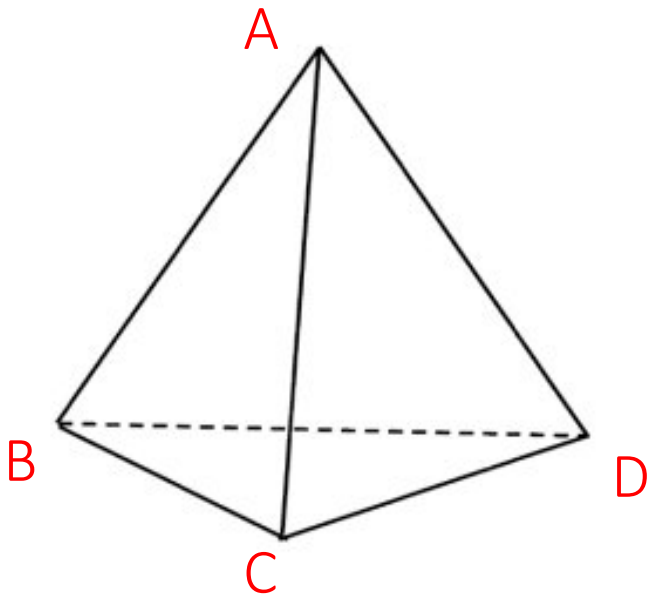
Theorem: A Euler loop exists if and only if each vertex has even degree

William Rowan Hamilton's Icosian Game (1857)

Dodecahedron – a polyhedron with 12 faces

Problem: Find a loop through the edge graph of the dodecahedron visiting every vertex exactly once.

Let us do a simpler case.



Loop: ABCDA

A brief history

1. **Euler (1735):** Find a loop through a graph visiting every edge exactly once.

2. **Hamilton (1857):** Find a loop, visiting every vertex exactly once.

3. **Traveling Salesman Problem (1930):** Find a loop with the shortest distance, visiting every vertex exactly once.

4. **PageRank (1996):** the backbone of Google search engine, U. S. patent 6,285,999 – Google paid Stanford University received 336 million dollars.

We live in the age of large graphs

Two broad categories of Mathematics: (A)Continuous mathematics, (B)Discrete mathematics

With the advent of powerful computers, many applications of of Discrete Mathematics have evolved: genetics, computer networks, internet search engines, social networks, the so called big data, … and many yet to evolve

Calculus of variables (Leibnitz and Newton) came hundreds of years after introduction of "variable" (Diophantus, Brahmagupta, Khwarizmi)
Calculus of graphs in 21-th century three hundred years after Euler introduced graphs

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Customers in 29 countries, includes all major avionics and automobile companies in Europe, Japan, and America

http://www.ensoftcorp.com/atlas/

Atlas: a graph database platform with interactive visualization for managing the complexity software systems.

A loop iteration count problem

```
For J = 1 to n
        for K= 1 to J
                count = count + 1;
```

How many times will the innermost loop iterate?

J	1	2		3						
K	1	1	2	1	2	3				

The answer is $1 + 2 + 3 + \ldots + (n-2) + (n-1) + n$

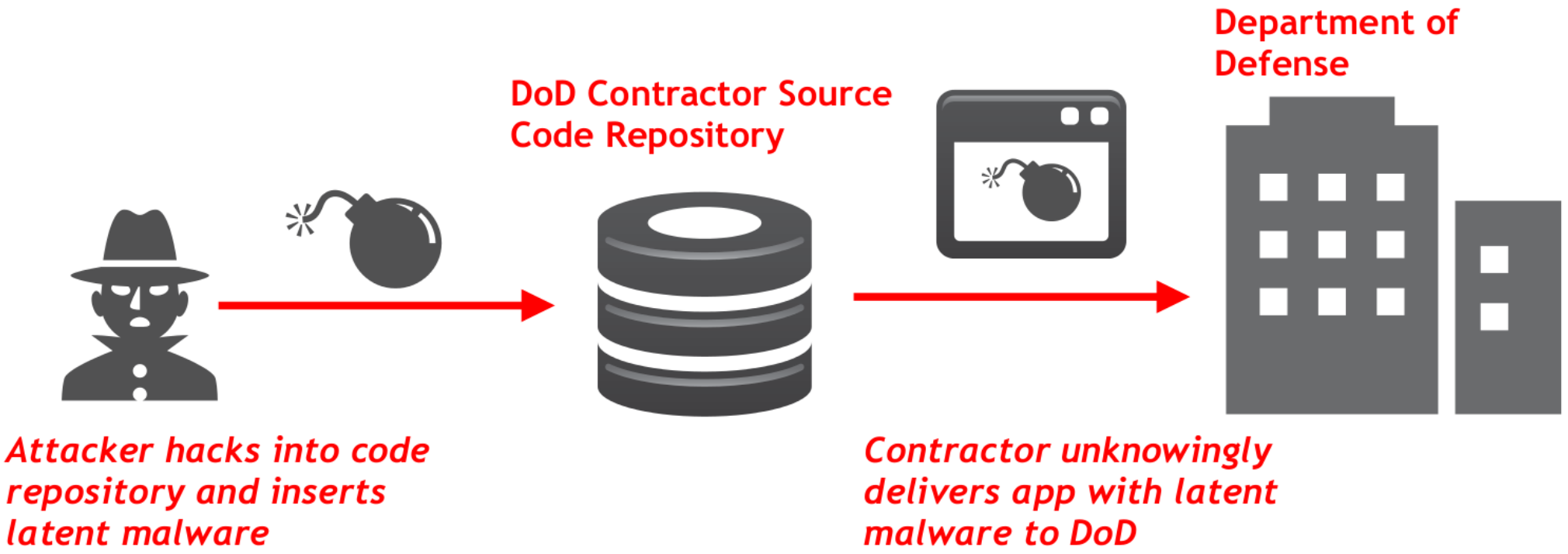
The formula $\frac{1}{2}\, n(n+1)$ works for counting the number of iterations of a 2-level loop.

Consider a **t**-level nested loop. For example, a loop with **t** = 3

```
count = 0;
        for J = 1 to n
            for K = 1 to J
                for  L = 1 to K
                 count = count +1;
```

How many times will the innermost loop iterate?

DARPA: We created the Internet, we will create the technology to defend it



What have we learnt?