An Approach to Computational Thinking

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Speaker

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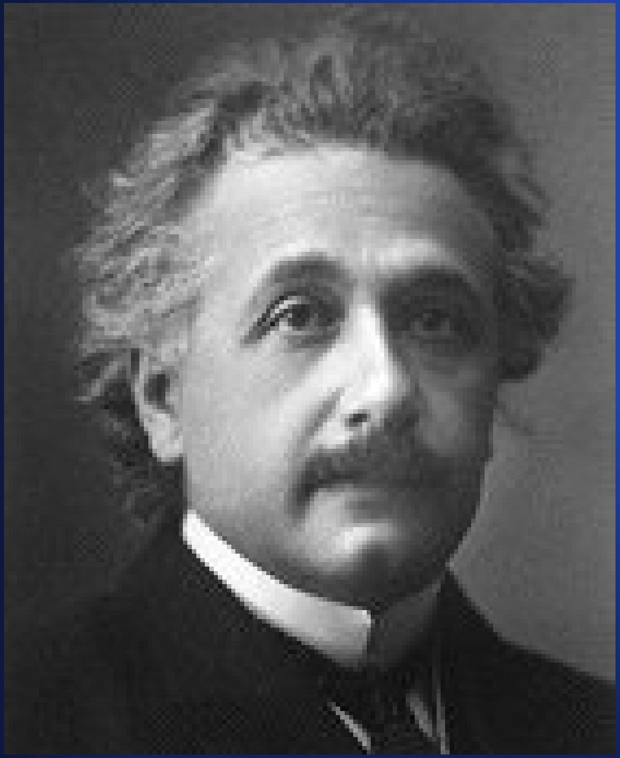
Opening remark



Problems cannot be solved by the same level of thinking that created them.

Albert Einstein
1946-11-??

Talk outline

- Challenges keep coming.
- Are we ready?
- Traditional approach.
- Computational thinking.
- Proposed approach.
- Debts and outcomes.
- A real-life example.
- Conclusions

Challenges keep coming (1/4)

- Engineers and scientists still dedicate *too much effort and time* trying to solve the computational problems they find in their professional endeavors.
- And the size and complexity of these problems *grows everyday*: a quick look at engineering standards is convincing.

Challenges keep coming (2/4)

- Best problem solving environments are quite powerful, but most users lack a *sound background* on problem solving.
- This severely lowers the *proficiency ceiling* many users meet while working with such software tools.

Challenges keep coming (3/4)

- Due to ultimate limits on Moore’s Law, every PC will have soon at least a two-core processor, whose potential is reached only when it executes parallel programs.
- Pioneers in this field warned in due time that the parallelization of algorithms asks for *new ways* to represent problems.

Challenges keep coming (4/4)

- Software development is still slow and tricky, especially when the programmers are not experts in the subject matter involved.
- One key issue is the adoption of a common language to express and exchange ideas on problems and algorithms.

Are we ready? (1/7)

A farmer has 125 sheep and five dogs. How old is the farmer?

Demonstration Test
at Pedagogic Seminar
CubaVisión, 2002-11-13

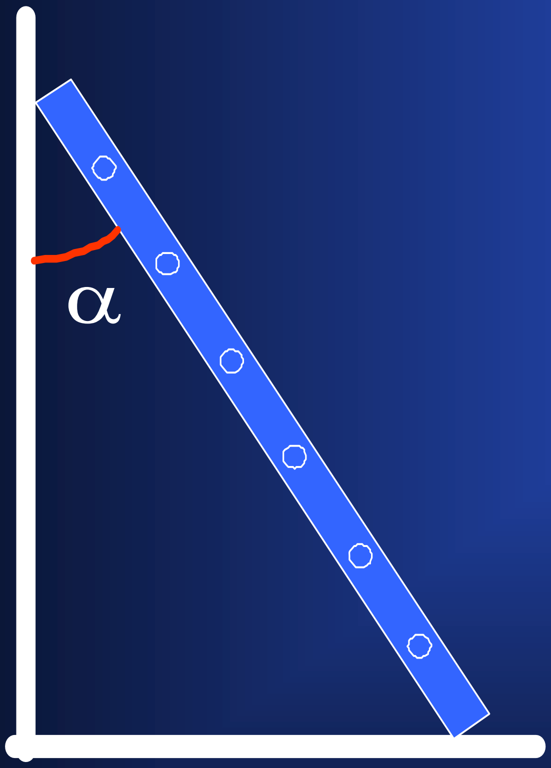
Are we ready? (2/7)

- All the kids immediately began to find a solution by computing the data.
- They did what they were trained to do: rush to compute.
- Adding, subtracting and multiplying the data gave them a set of funny outcomes.

Are we ready? (3/7)

- Asked about why the farmer is 120 years old; a kid answered that “it takes a long time to raise so many animals.”
- Adults asked about what is so nonsensical with this problem, often gave wrong explanations!

Are we ready? (4/7)



- A small ladder at rest leans against the floor and the wall.
- Knowing the two coefficients of friction, find the maximum angle of inclination of the ladder.

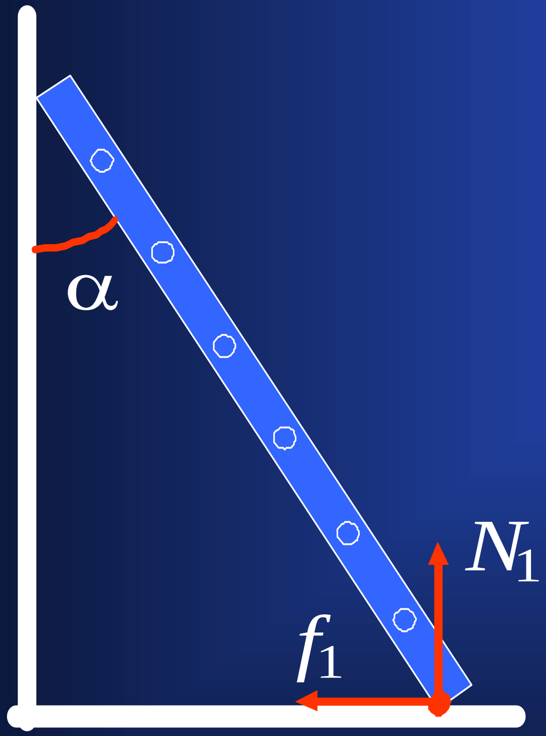
Are we ready? (5/7)

- Why this seemingly trivial problem turns so difficult to solve by engineering students, and even by some engineers?
- Why so many university textbooks assume that the contact between the ladder and the wall is frictionless?

Are we ready? (6/7)

- A tour through university websites may find more ladders leaning against smooth walls.
- These problems are only a few of the many that may be posed on the ladder under impending movement.
- Another problem from the same collection is given as follows.

Are we ready? (7/7)



- Again, we have the same small ladder leaning at rest under impending movement.
- Knowing normal and friction forces on the floor, and the angle of maximum inclination, find the coefficient of friction at the wall.

Traditional approach (1/5)

- A number of scholars *excessively simplify* their proposed problems, to skip solutions difficult to find by the students.
- Learning to solve problems just by doing, without an underlying theory, is not an efficient or far-reaching strategy.

Traditional approach $^{(2/5)}$

- In class, instructors emphasize the solution of certain, so-called *typical* problems.
- For instance: Determine the behavior of a solenoid, knowing all their design data.
- Many typical problems are *direct* problems, with a *closed* solution.

Traditional approach $^{(3/5)}$

- However, *atypical* problems do appear often in real life, and engineers are seldom prepared to solve them systematically.
- For instance: Determine the design data of a solenoid from the behavior of a sample.
- This, as an *inverse* problem, is harder to solve than its direct counterpart.

Traditional approach (4/5)

- Another traditional trend is to assign many *proposed* problems to the students, in order to reinforce their problem-solving skills.
- Nevertheless, there are so many possible problems that students can only cover an infinitesimal fraction of them.

Traditional approach (5/5)

- Actually, a mathematical model with n variables may give rise to N_P problems, as shown below.

n	2	4	8	16
N_P	5	65	6 305	599 012

Computational thinking (1/5)

- Nowadays, it is difficult to do science or engineering without a well-developed ability to think computationally.
- After some hesitation, most authors have stated that computational thinking should be focused towards *problem solving*.

Computational thinking (2/5)

- Computational thinking is now defined as the mind process of formulating problems and their solutions in a form executable by a computing agent.
- Lacking a constructive sense, computational thinking has not yet coalesced into a formal subject for academic study.

Computational thinking (3/5)

- However, the term *computational thinking* has been received with interest by a number of serious educators.
- It would be a nice substitute for the term *problem solving*, too worn as the title of elementary courses in computing.

Computational thinking (4/5)

- A similar state of affairs took place in the early 50s of the 20th century, where the term *cybernetics* became worn down by dilettantish misuse.
- Then, serious researchers, scholars and practitioners adopted the term *computer science*, to distinguish themselves apart.

Computational thinking (5/5)

- Along twenty years, the author has devised a theory of problem solving that may now set a rational and constructive path to the goals of computational thinking.
- Such an approach to computational thinking is briefly exposed in this presentation.

Proposed approach (1/20)

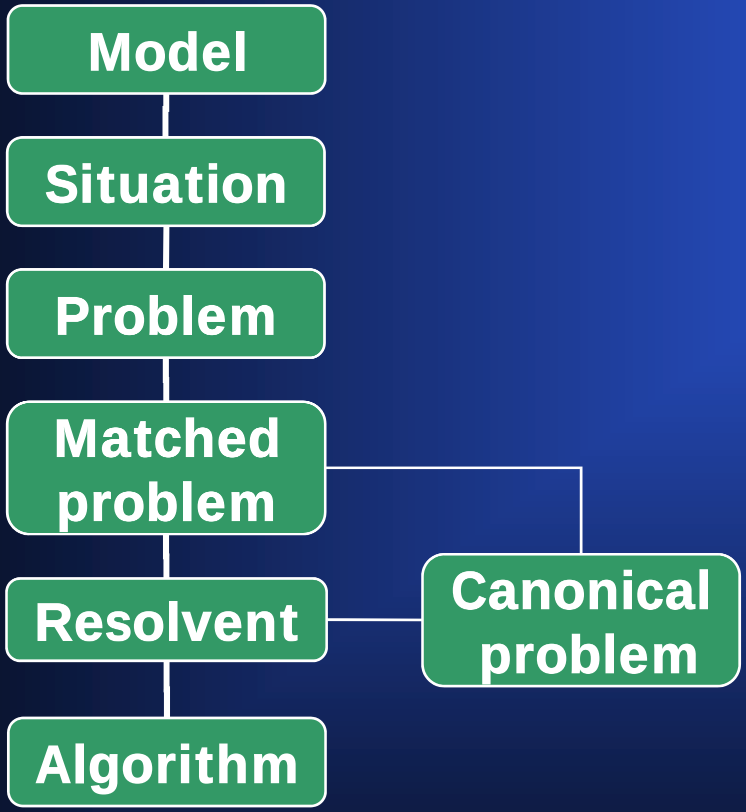
Problem solving milestones:

1. Receive or pose an informal problem.
2. Find or develop a mathematical model.
3. Pose the formal problem.
4. Find if the problem has a solution.
5. Obtain the solution, if it exists.

Proposed approach (2/20)

- The structures of the model, the problem, and the algorithm are essential in reaching most of the above-mentioned milestones.
- These structures may be effectively and intuitively represented and deduced, by *dichromatic graphs*.

Proposed approach (3/20)



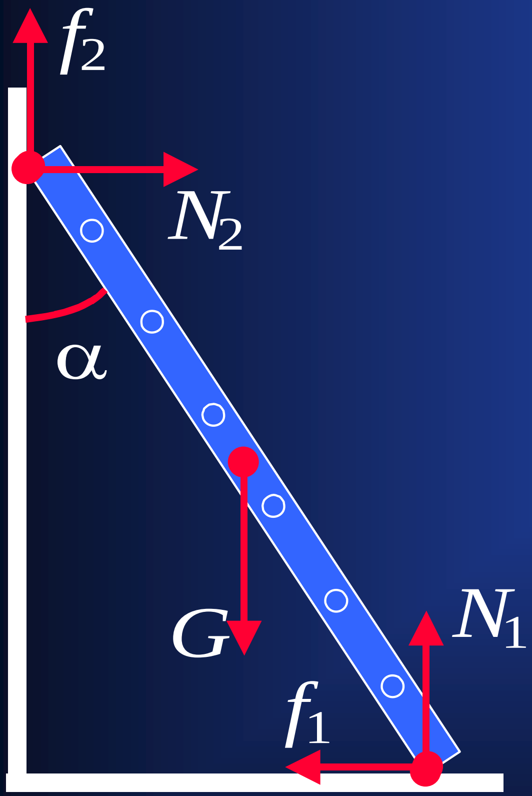
- Key concepts are linked in a hierarchy.
- Posing and solving a problem is a walk in the hierarchy.
- The walk begins in the model and finishes in the algorithm.

Proposed approach (4/20)

- Let’s take a quick look of how to pose and solve the first problem on the small ladder under impending movement.
- In this problem, the coefficients of friction against the floor and the wall are known, and it is needed the maximum inclination angle of the ladder.

Proposed approach (5/20)

Model



$$N_2 - f_1 = 0 \qquad (1)$$

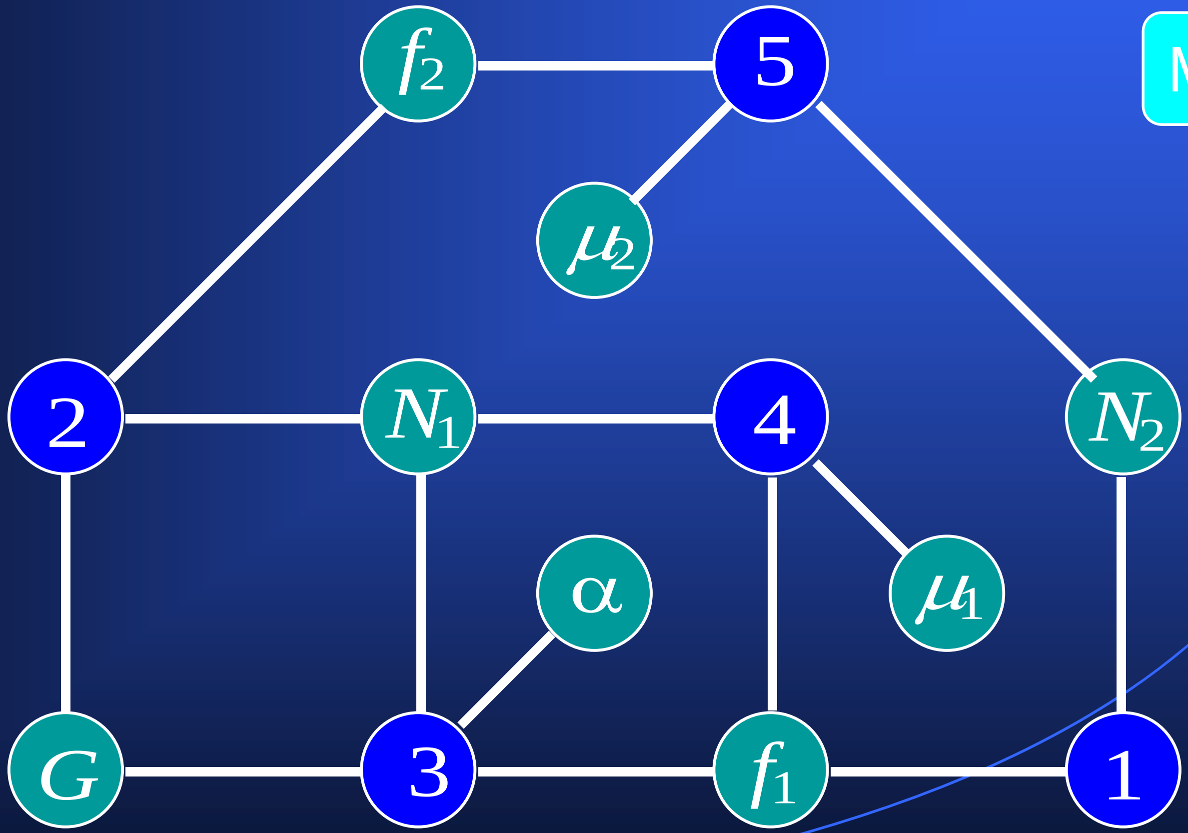
$$N_1 + f_2 - G = 0 \qquad (2)$$

$$\left(N_1 - \tfrac{1}{2}G\right)\mathrm{tg}\alpha - f_1 = 0 \qquad (3)$$

$$f_1 - \mu_1 N_1 = 0 \qquad (4)$$

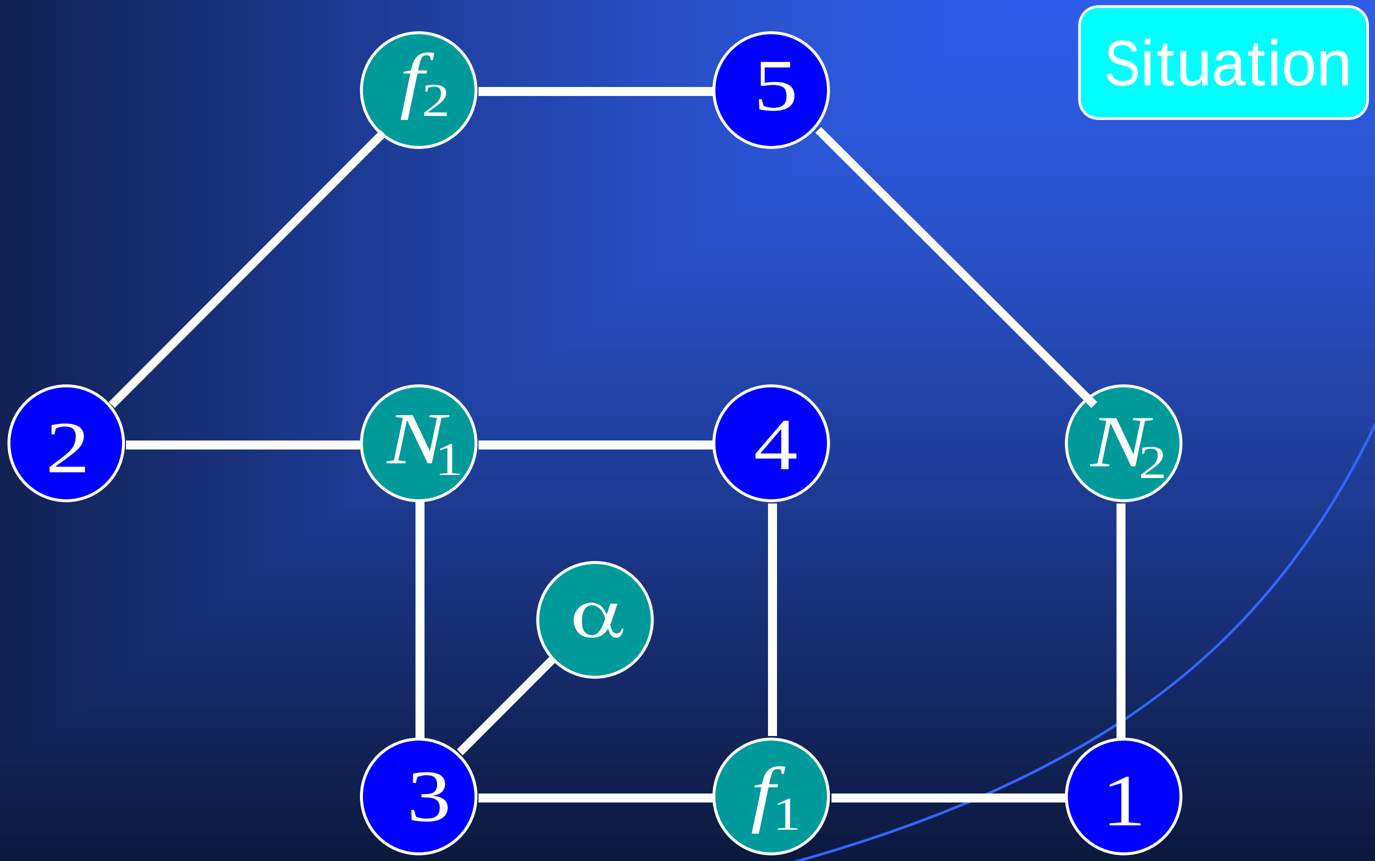
$$f_2 - \mu_2 N_2 = 0 \qquad (5)$$

Proposed approach (6/20)

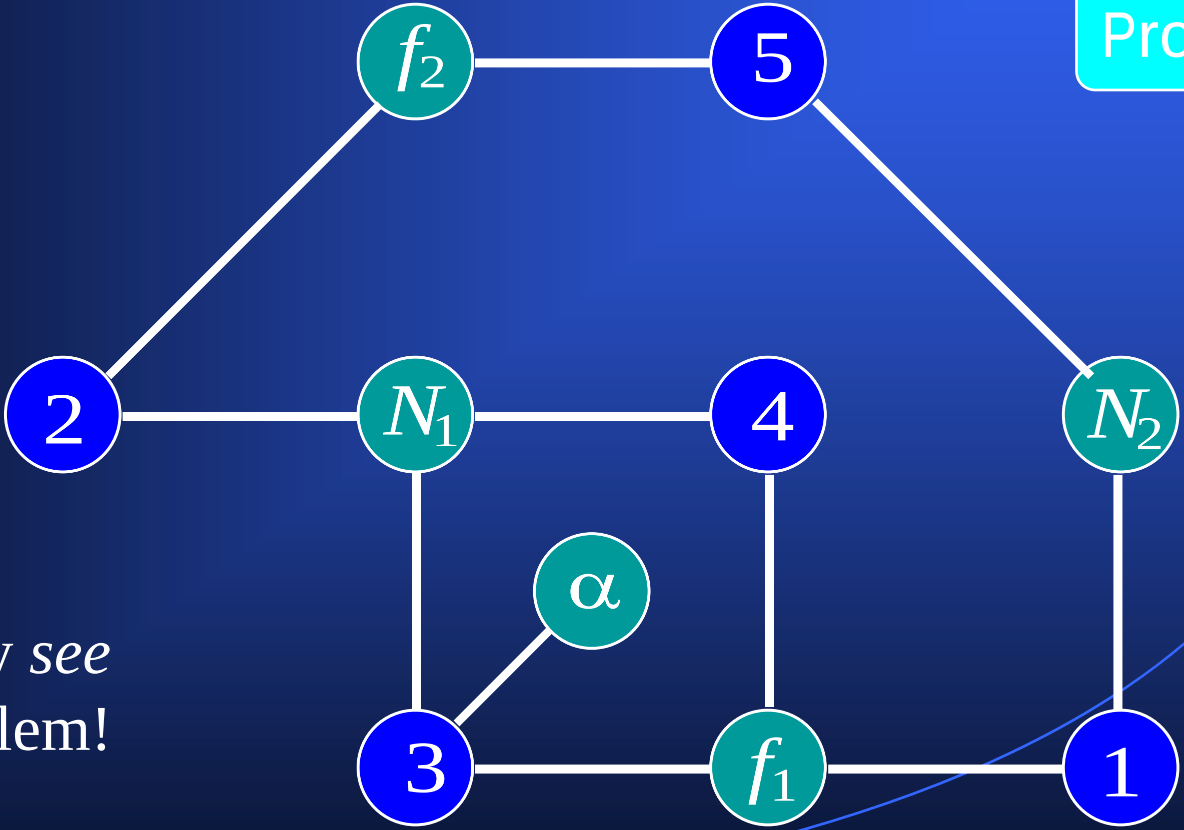


Model

Proposed approach (7/20)



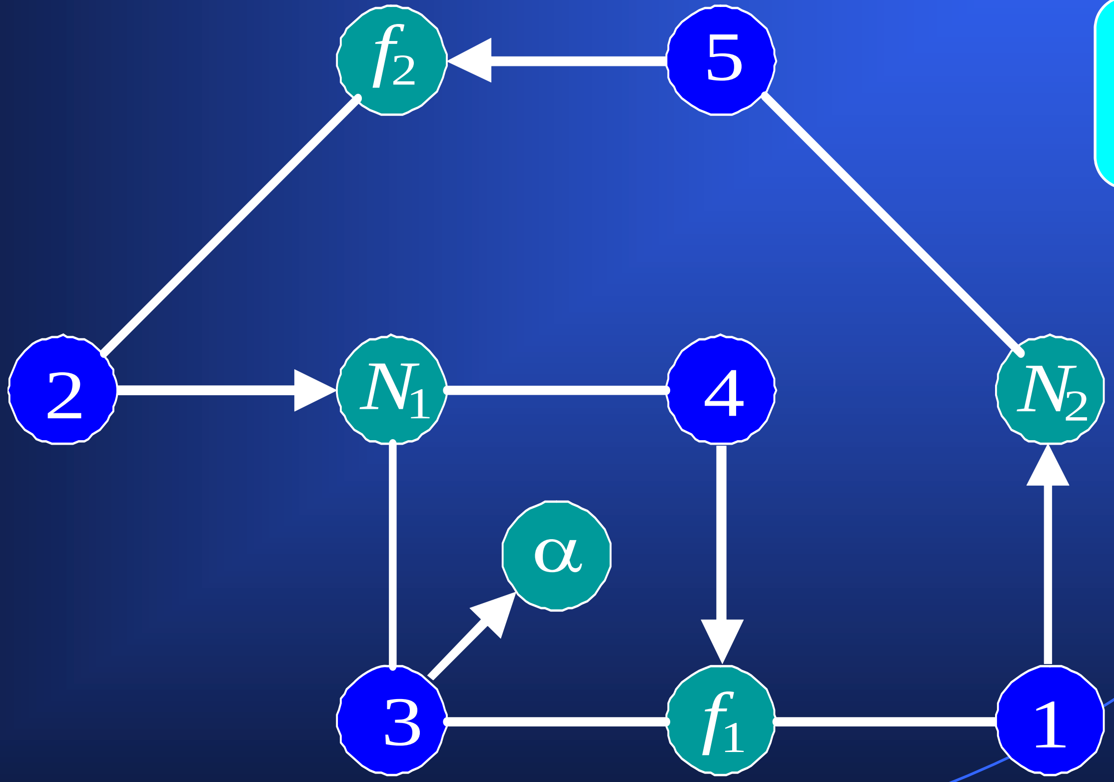
Proposed approach (8/20)



Problem

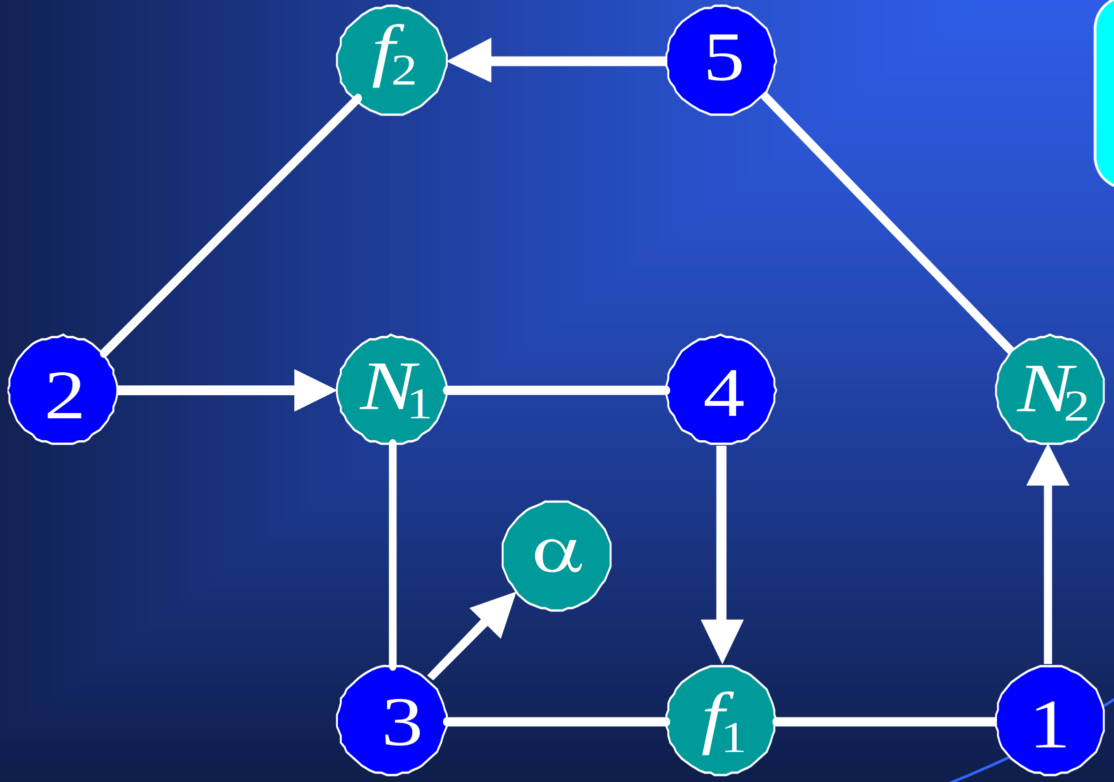
You may *see* the problem!

Proposed approach (9/20)



Matched problem

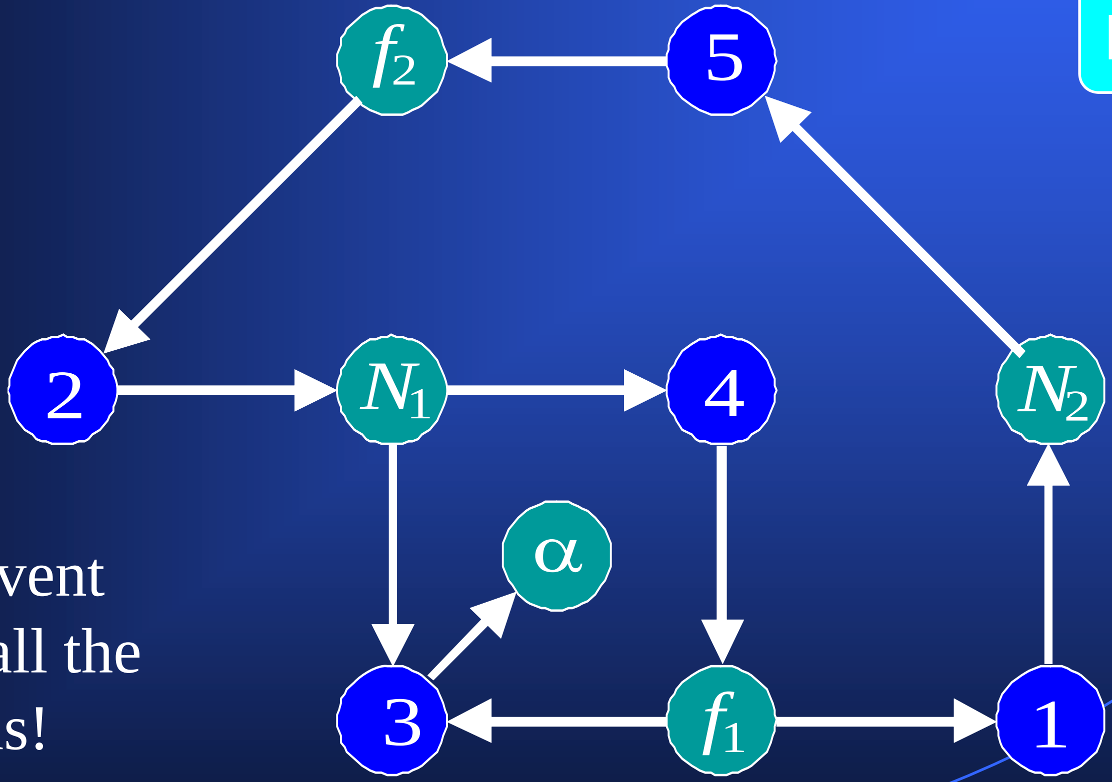
Proposed approach (10/20)



Canonical problem

Proposed approach (11/20)

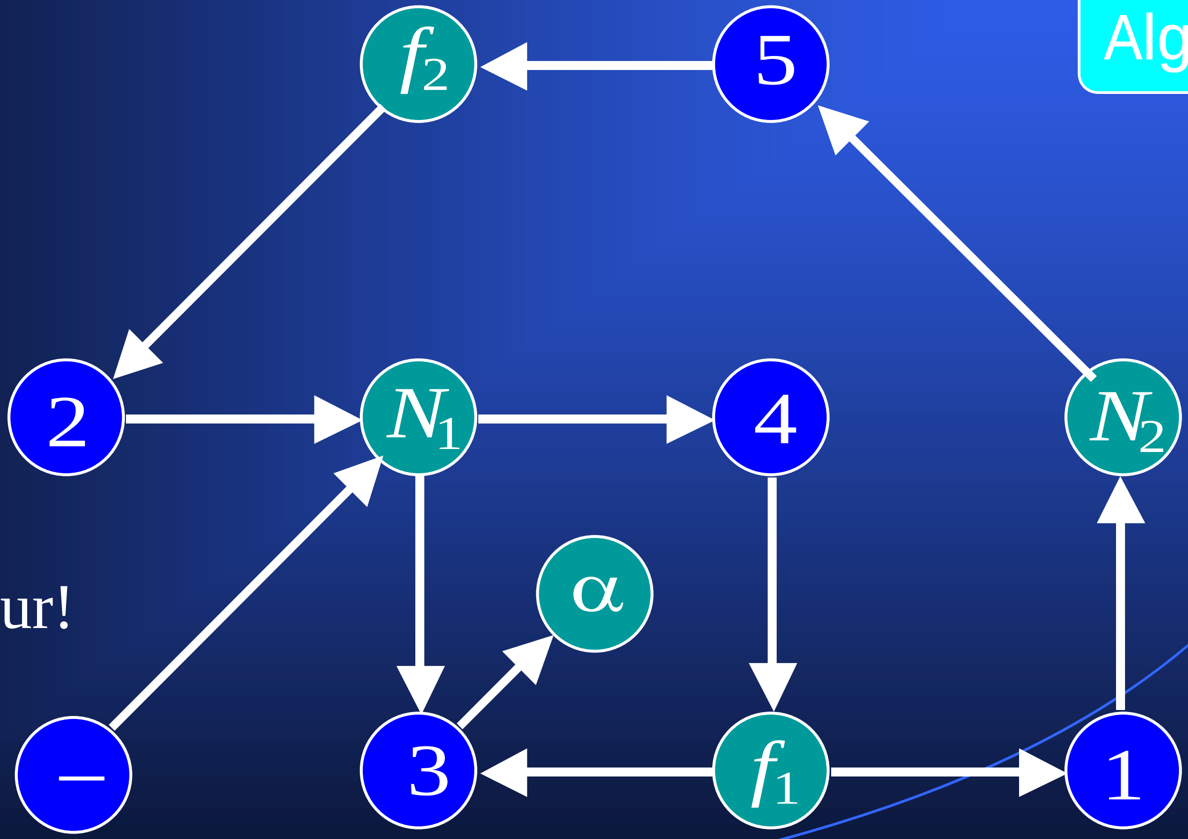
Resolvent



The resolvent contains all the algorithms!

Proposed approach (12/20)

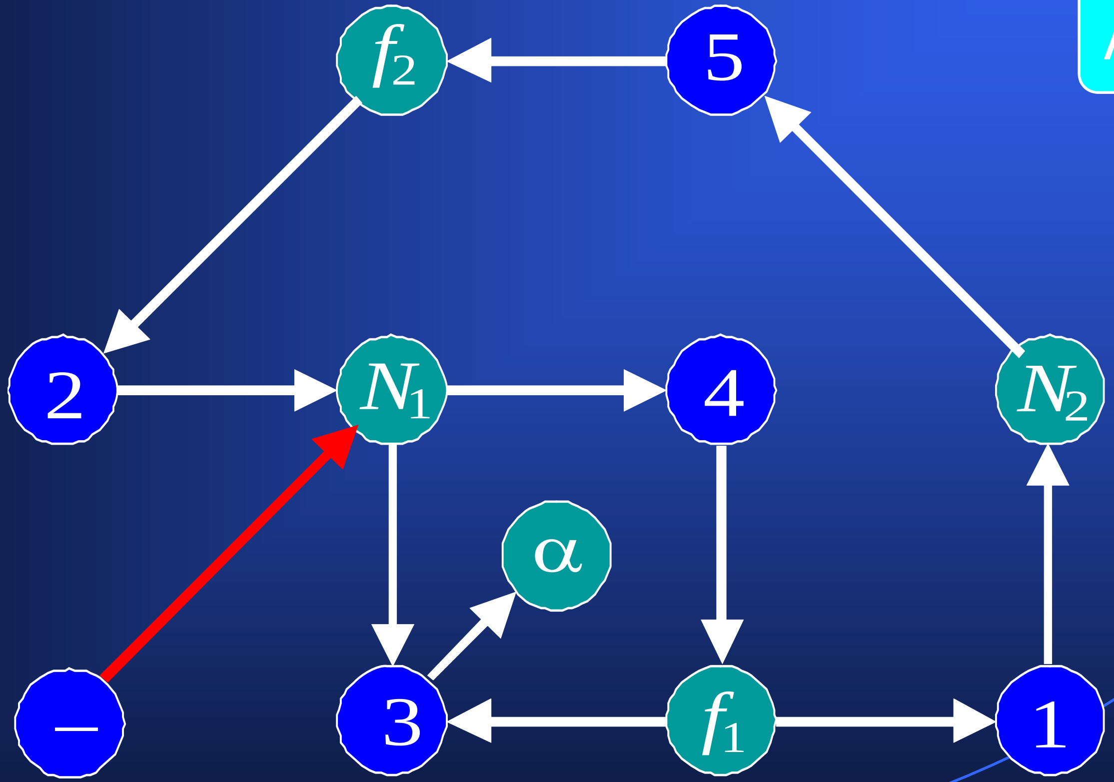
Algorithm



One of four!

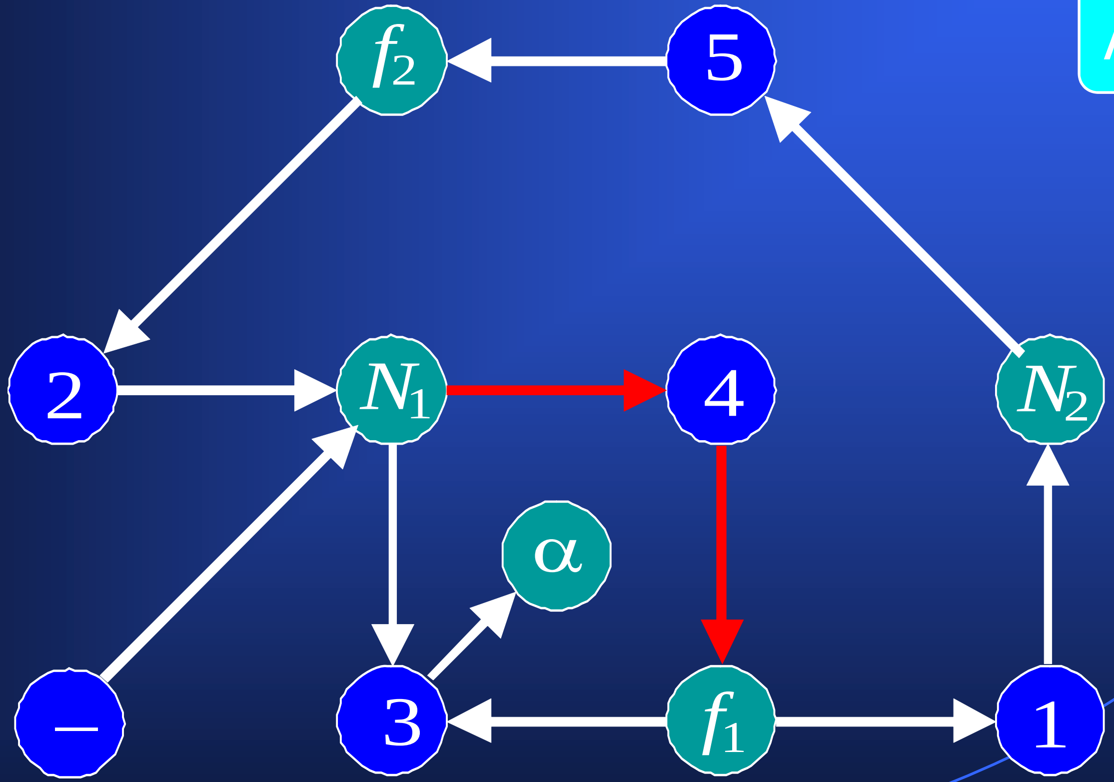
Proposed approach (12/20)

Algorithm



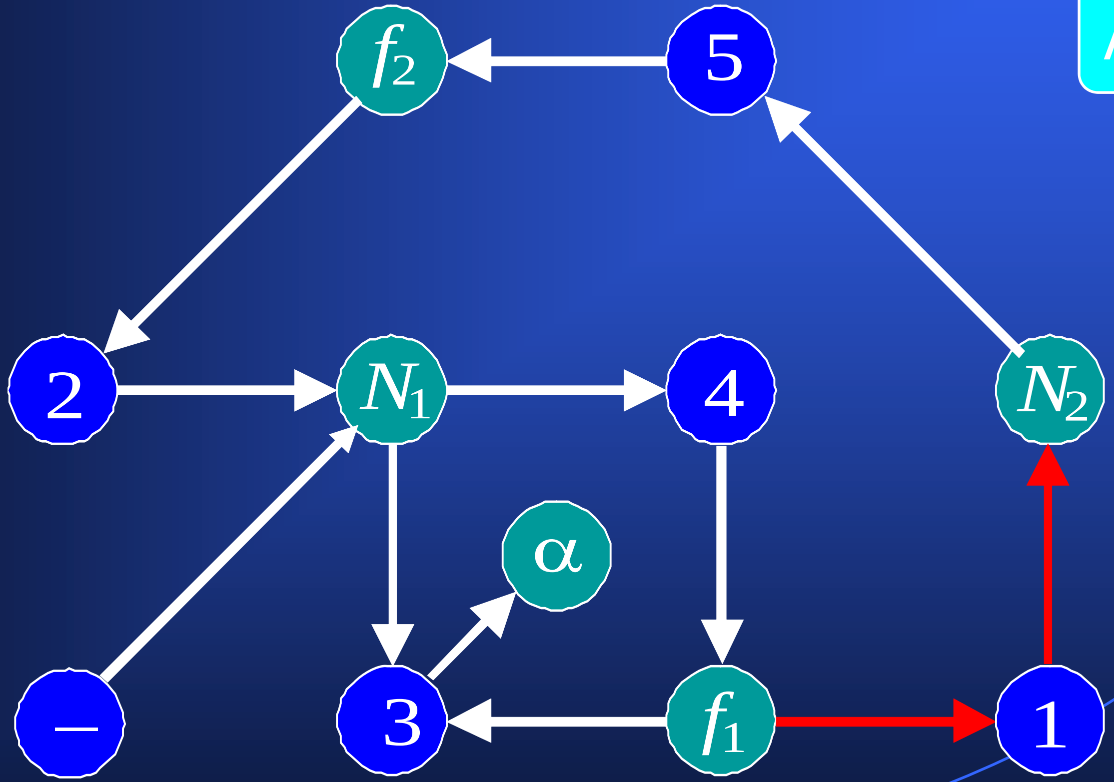
Proposed approach (12/20)

Algorithm



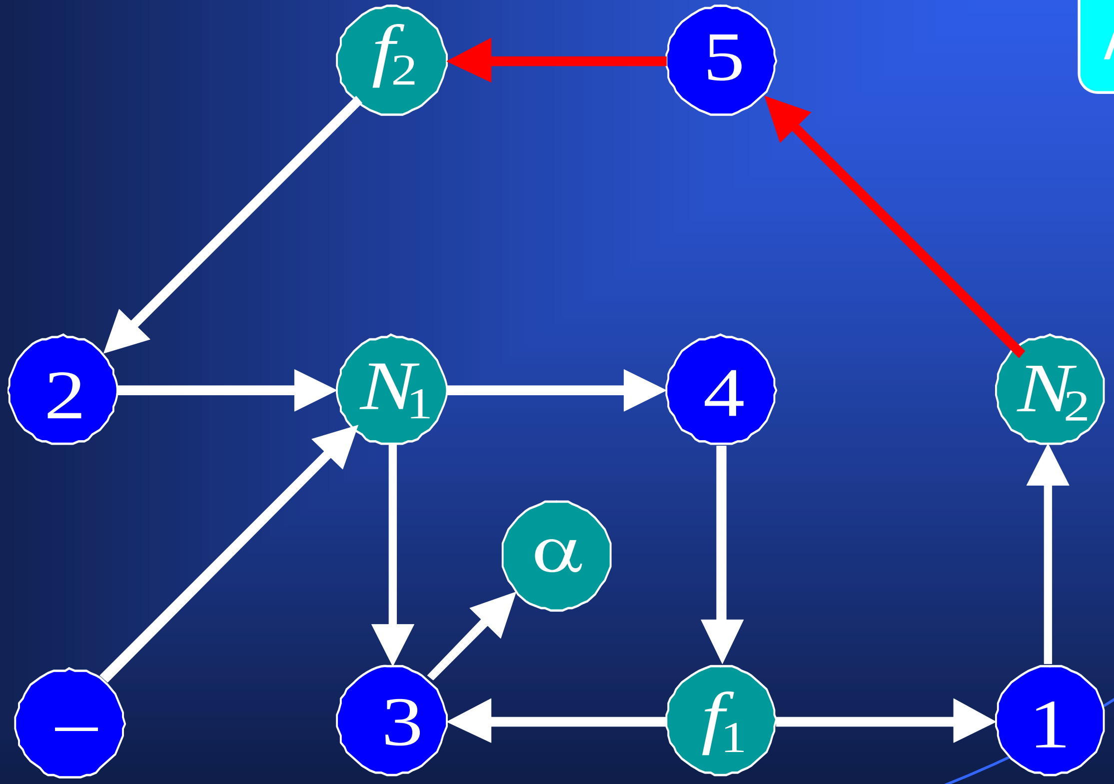
Proposed approach (12/20)

Algorithm



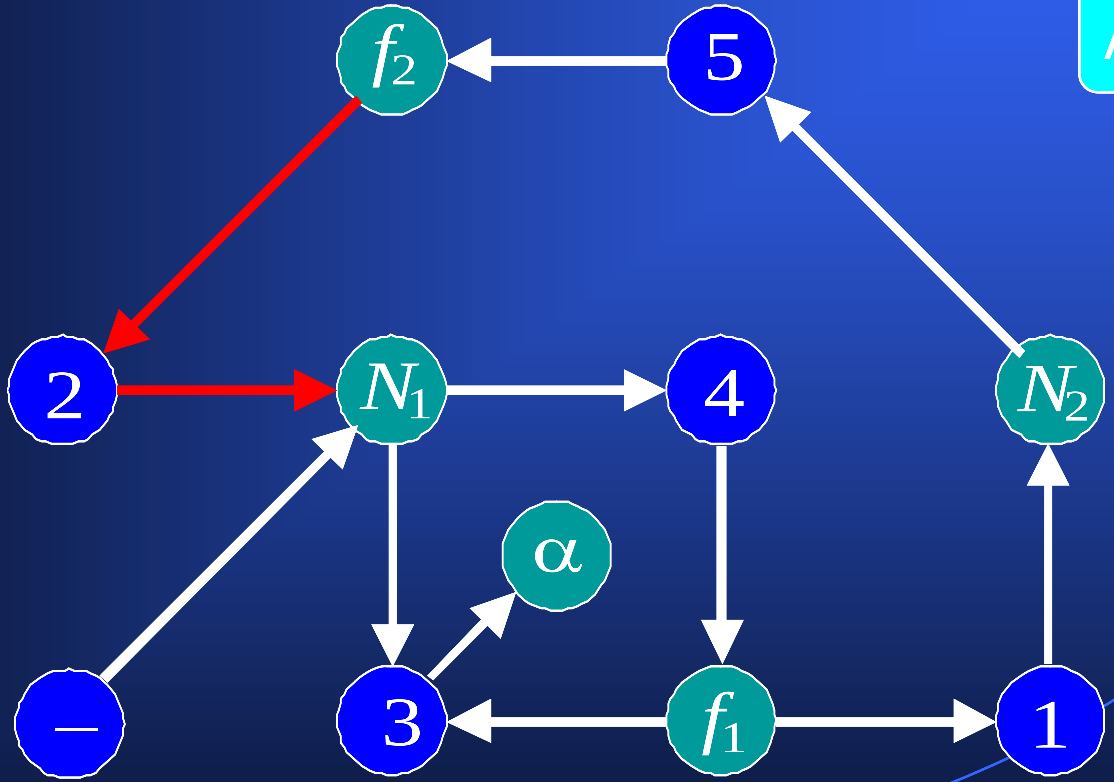
Proposed approach (12/20)

Algorithm



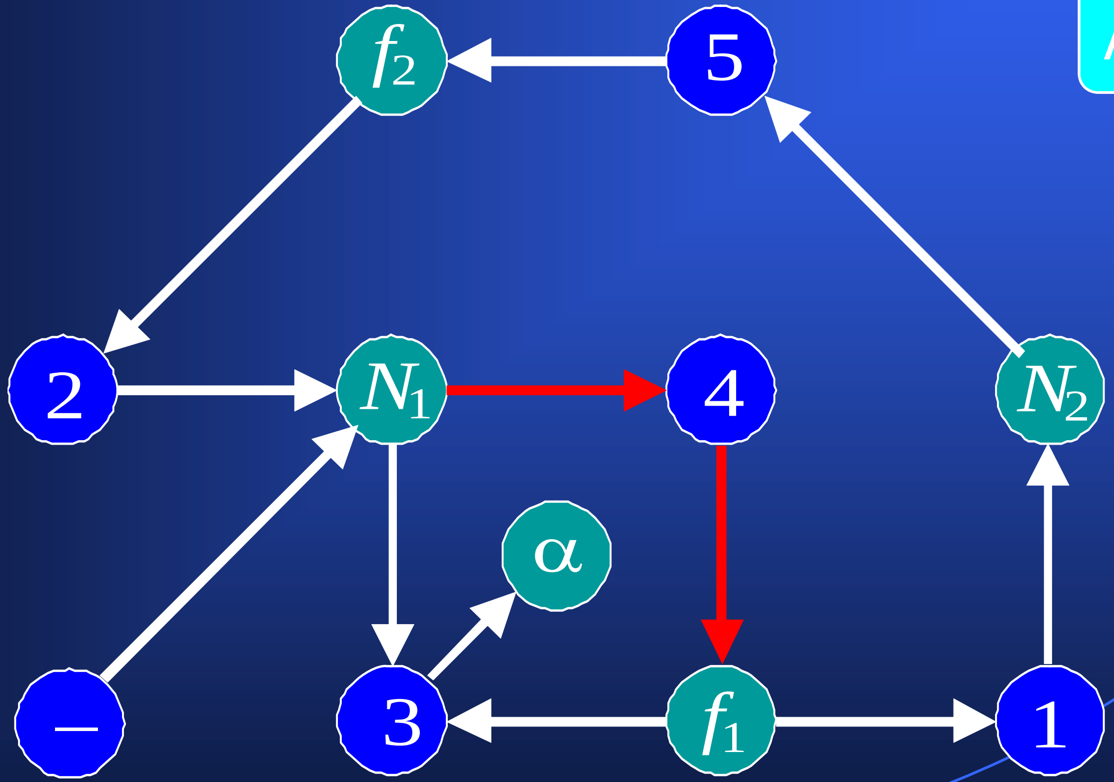
Proposed approach (12/20)

Algorithm

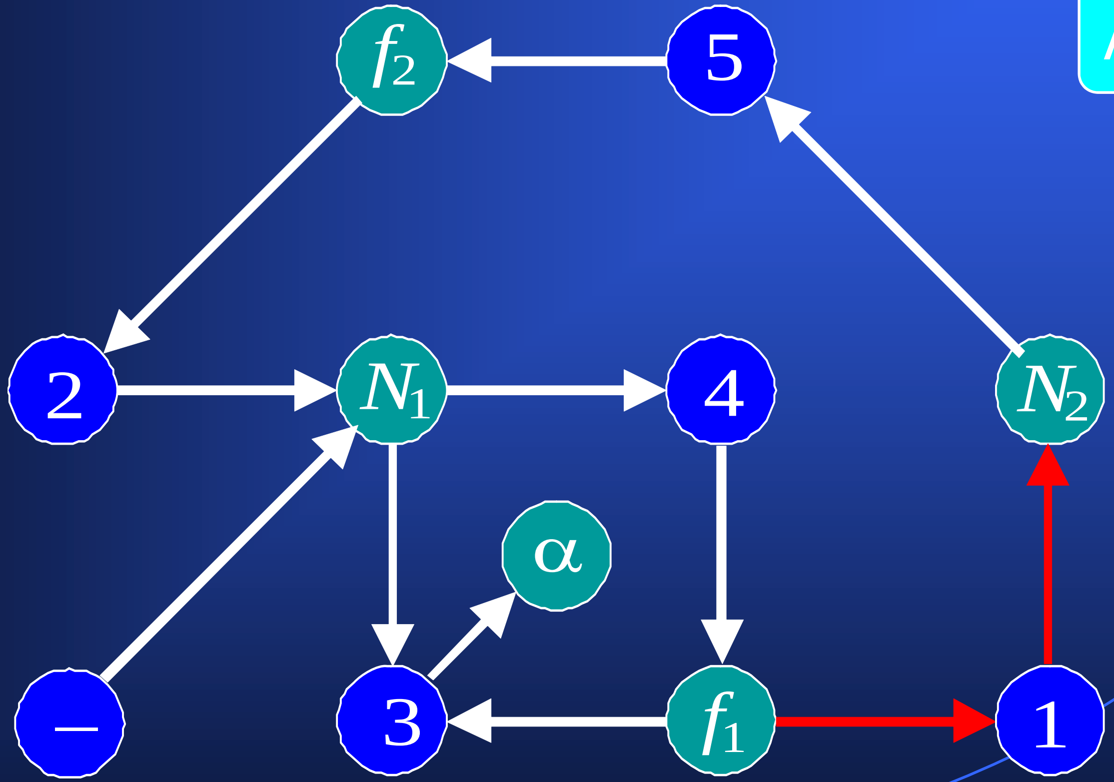


Proposed approach (12/20)

Algorithm



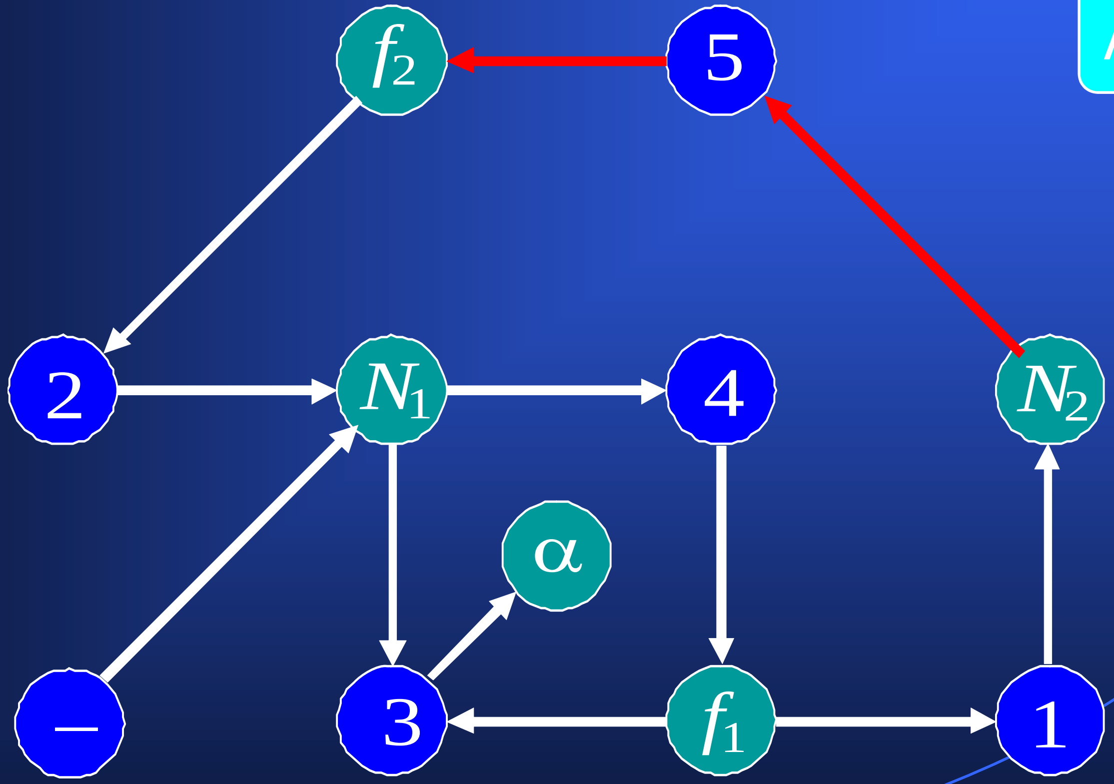
Proposed approach (12/20)



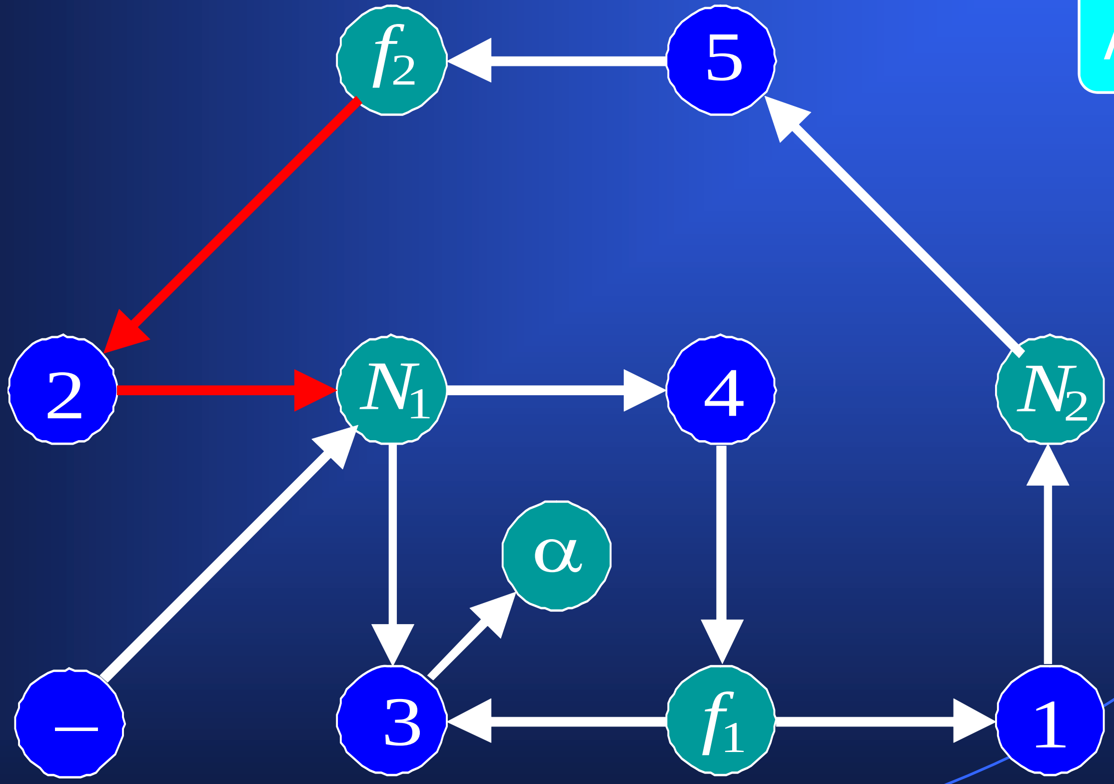
Algorithm

Proposed approach (12/20)

Algorithm



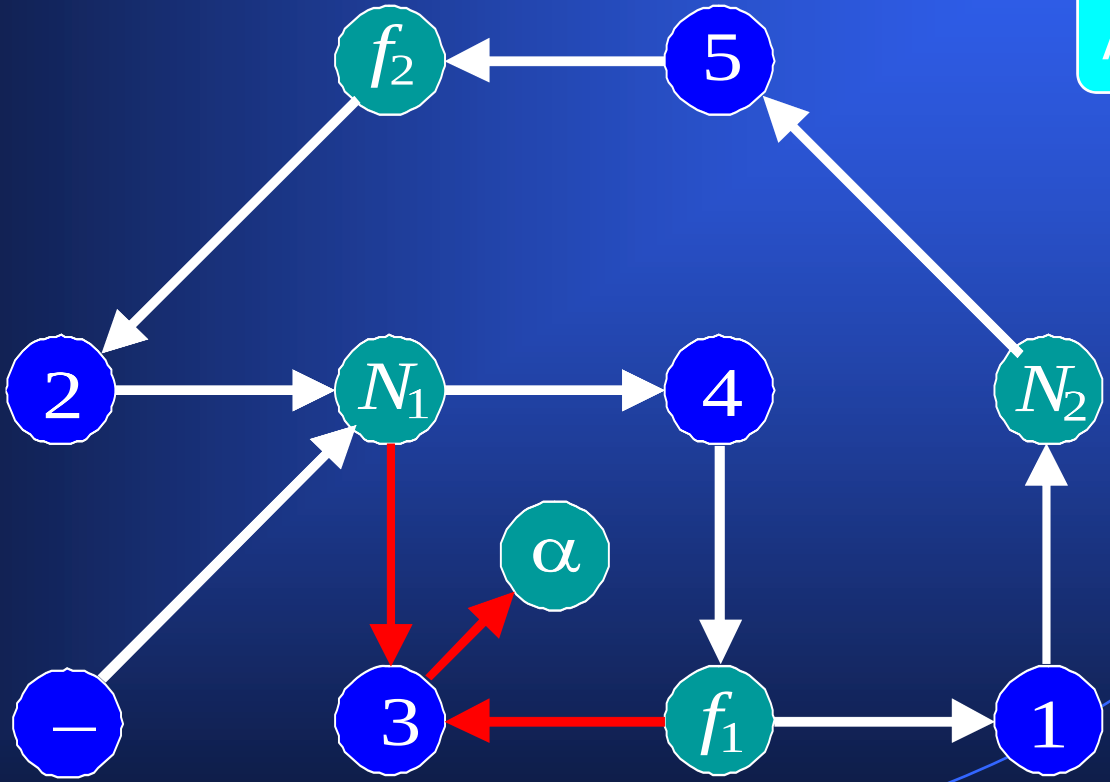
Proposed approach (12/20)



Algorithm

Proposed approach (12/20)

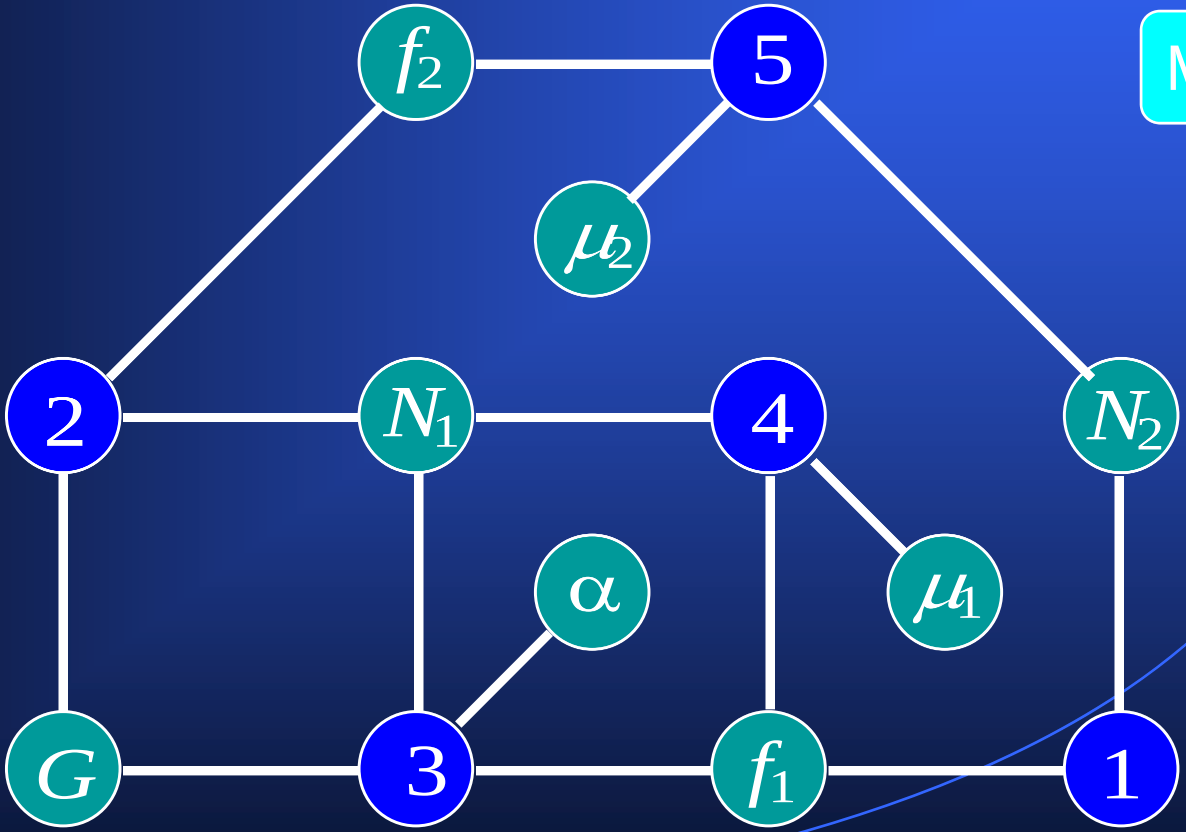
Algorithm



Proposed approach (13/20)

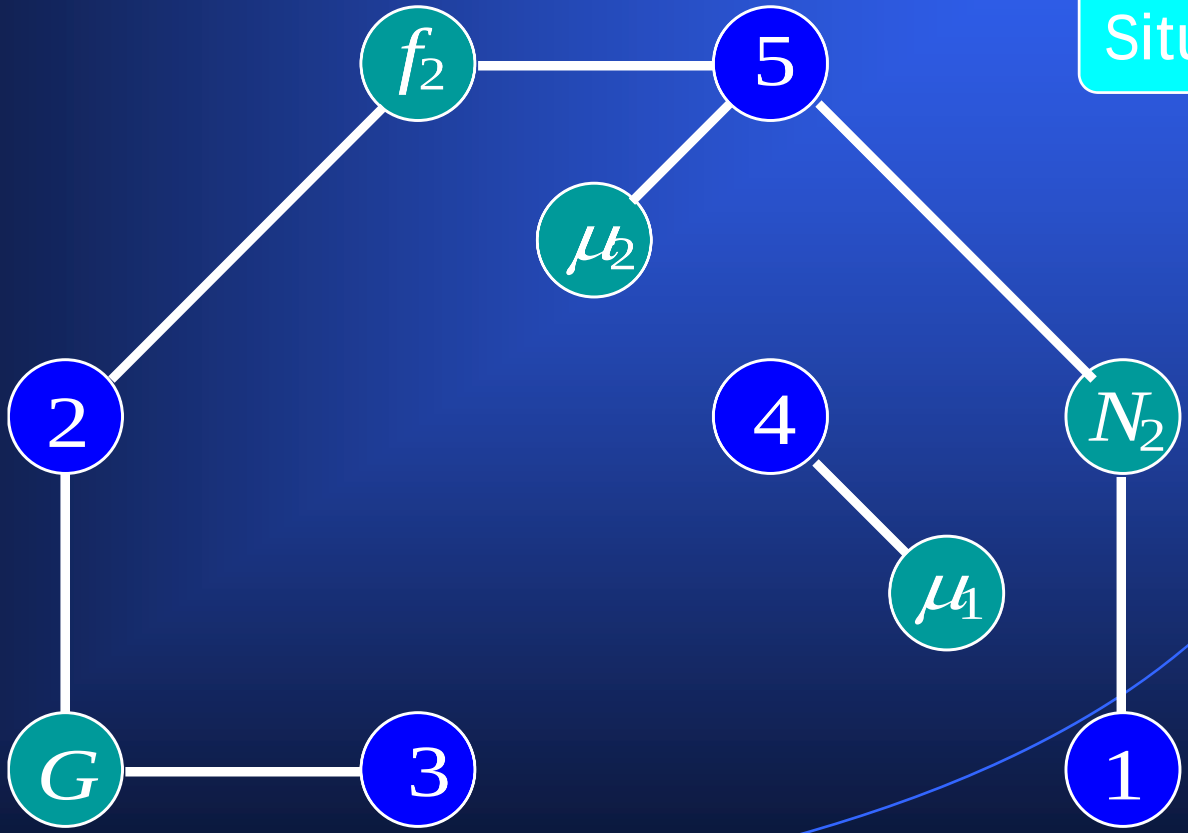
- Let’s focus now on posing and solving the second problem about the ladder under impending movement.
- In this problem, the inclination angle and the normal and friction forces against the floor are known, and we are seeking the coefficient of friction with the wall.

Proposed approach (14/20)



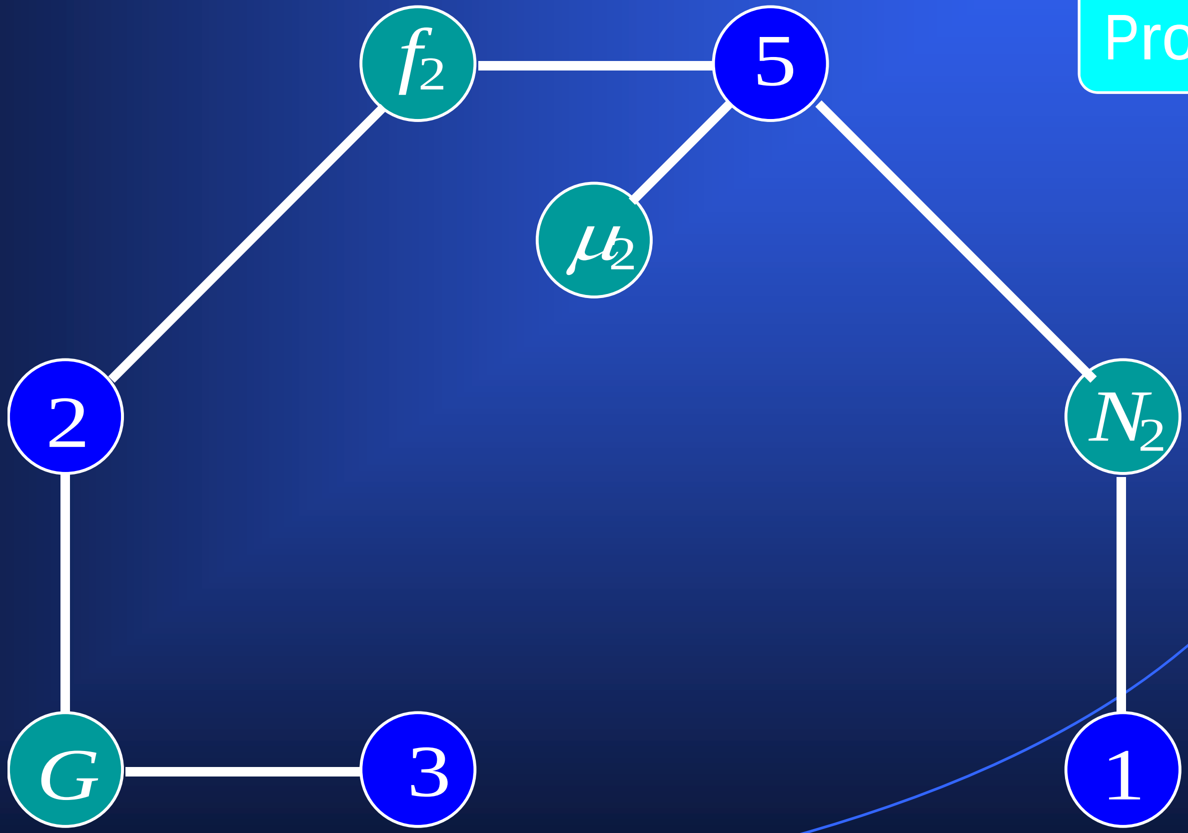
Model

Proposed approach (15/20)



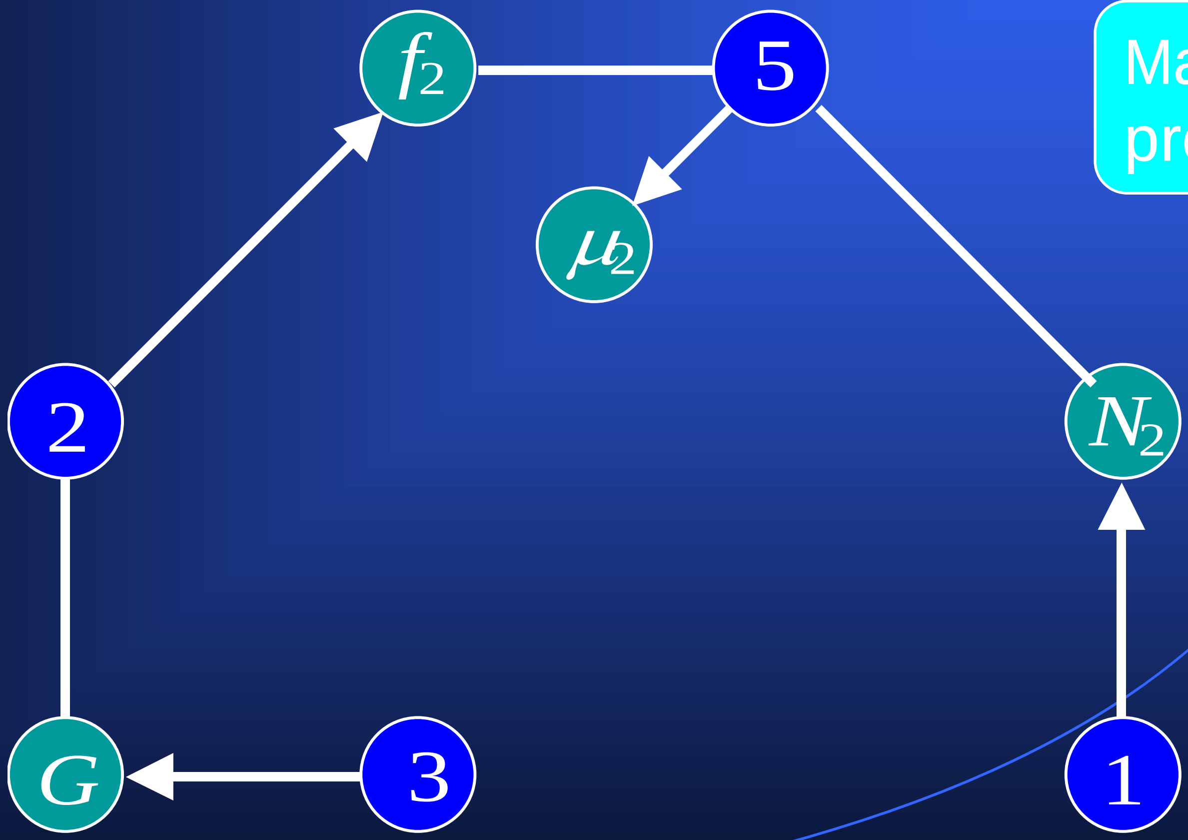
Situation

Proposed approach (16/20)



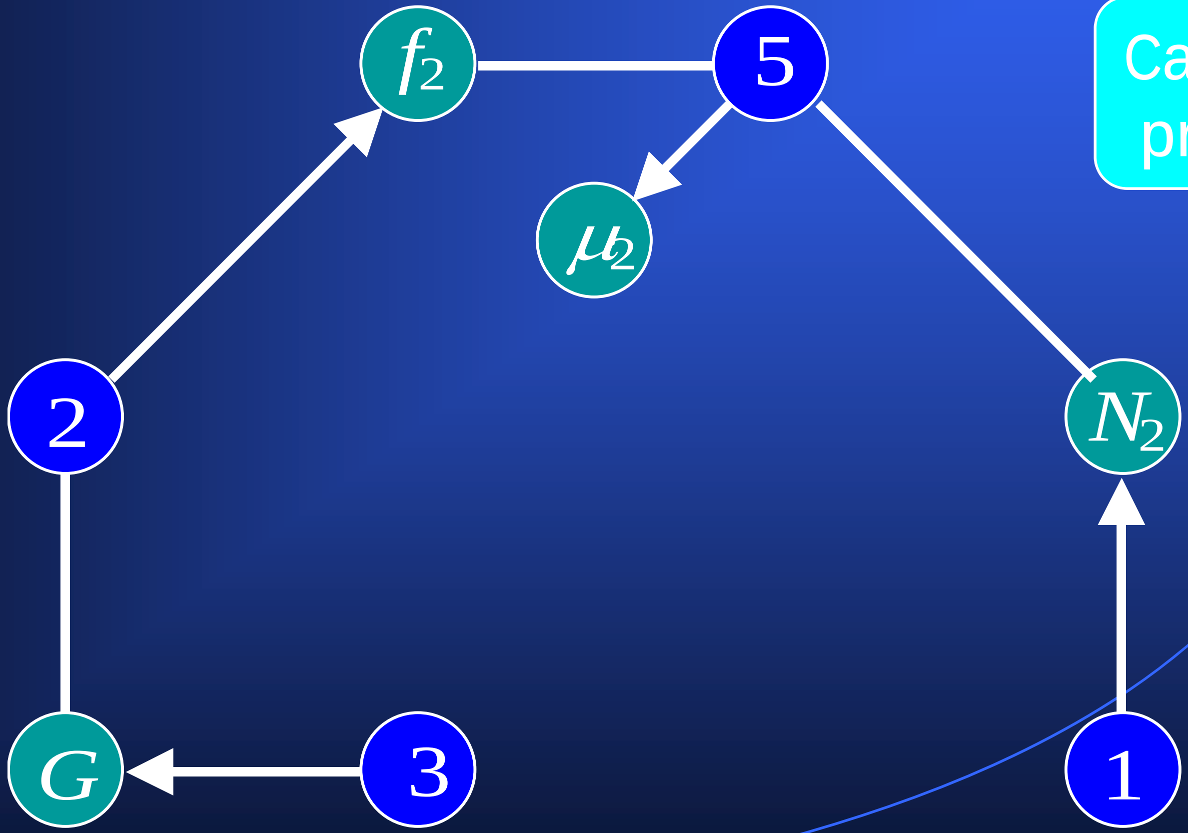
Problem

Proposed approach (17/20)



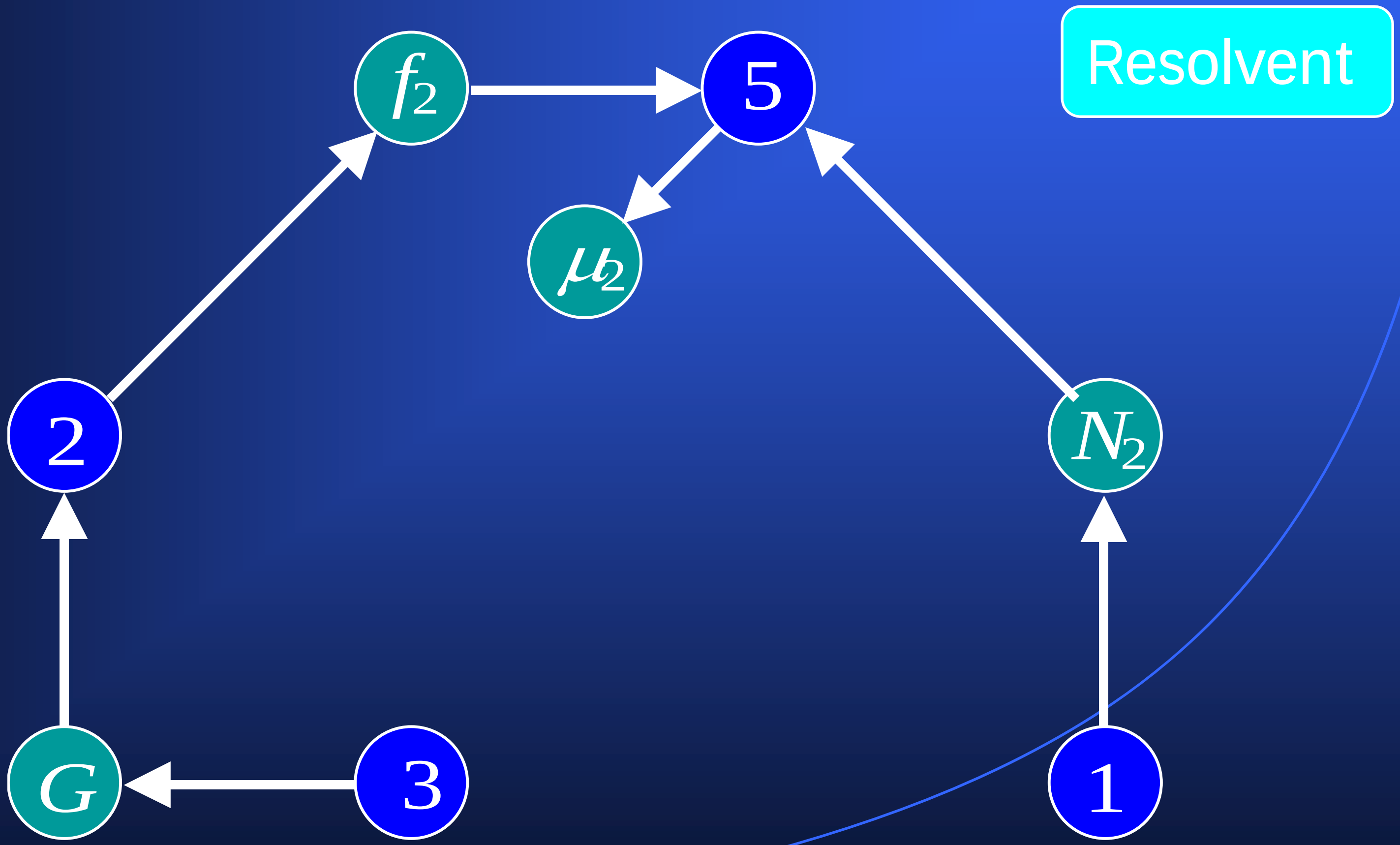
Matched problem

Proposed approach (18/20)



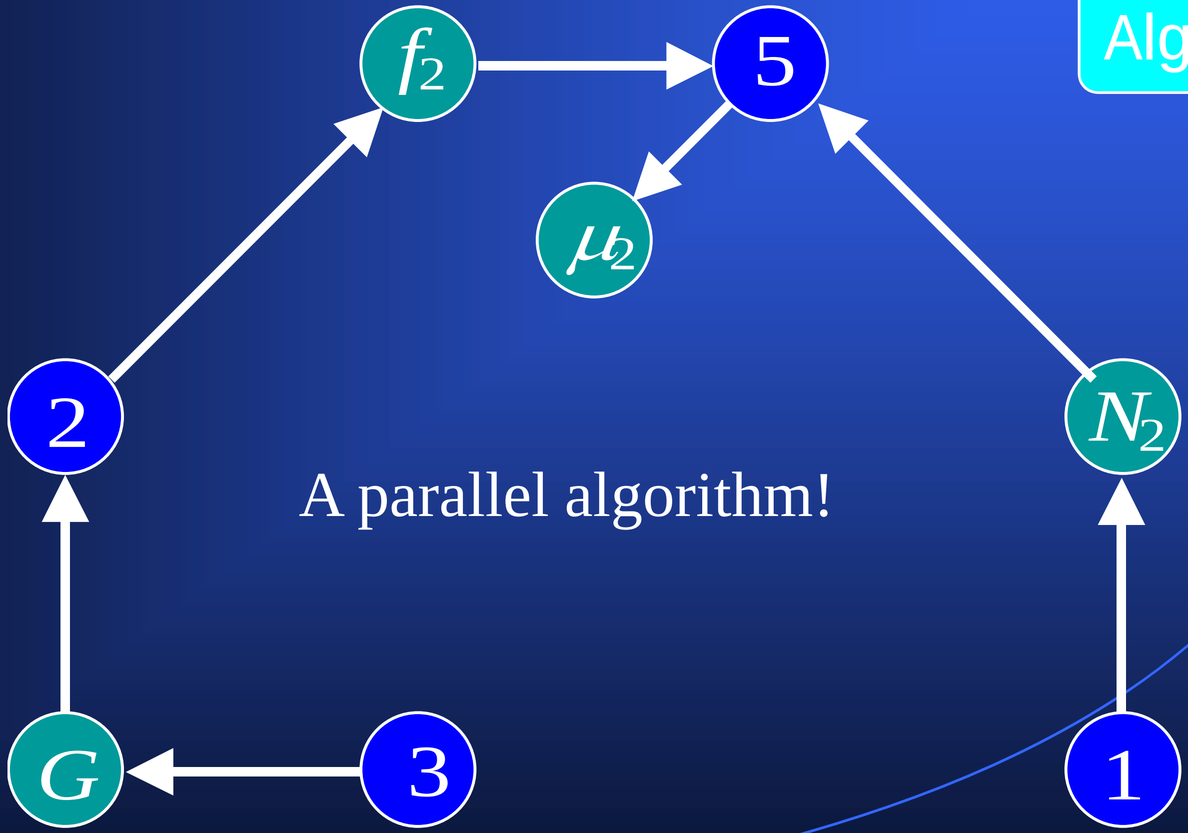
Canonical problem

Proposed approach (19/20)



Proposed approach $^{(20/20)}$

Algorithm



A parallel algorithm!

Debts and outcomes (1/5)

- It was creatively assimilated the work of a number of authors at institutions of Europe, North America, Russia and Japan.
- Some of our ideas have been published in scientific events developed in Cuba, The United States, Canada and The Netherlands.

Debts and outcomes (2/5)

- The work of Dr. Donald R. Woods, and his colleagues at *McMaster University* in Canada, is internationally recognized.
- For us, his research on problem solving has been a source of inspiration and valuable ideas. We would like to send him greetings in his well-deserved retirement.

Debts and outcomes $^{(3/5)}$

- Applying our approach, a software for the design of hydrodynamic sliding bearings was developed by one person.
- An important Cuban project centre failed to develop a similar system, even after using much more resources and time.

Debts and outcomes (4/5)

- Optimum gears have been developed using *ISO* and *AGMA* standards, considered by some experts as not appropriate for design.
- Each design of several special gear pairs in Cuba and Venezuela involved over 300 variables and a similar number of relations.

Debts and outcomes (5/5)

- Complex problems of industrial drive engineering in Venezuela were solved with the aid of the proposed approach.
- The results *surpassed* the proposals of both local experts and transnational enterprises.

A real-life example (1/18)

- *CARBONORCA* is the biggest anode factory in the aluminum industry of Venezuela; it supplies anodes to local users, and exports them to other countries in a joint venture with *Ormet*, a US enterprise.
- Its carbon plant may yield 140,000 t/year of electrode paste compacted as green anodes.

A real-life example (2/18)

- The heart of *CARBONORCA's* carbon plant is a large *Buss K550 KE* continuous kneader, which hot mixes coke dust and coal pitch to form electrode paste, at a mass flow rate of up to 28 t/h.
- Therefore, this machine is a key upstream link in the operation chain of the factory.

A real-life example (3/18)

- The Buss kneader was supplied with its drive system. As prime mover, the drive had an *ABB DMA 315* DC electric motor, with a nominal power of 300 kW at 1500 rpm.
- The fine carbon dust suspended in plant air takes down winding isolation of the motor, especially in its rotating armature.

A real-life example $^{(4/18)}$

- Finishing May, 1995, the *ABB DMA 315* suffered a catastrophic failure that damaged beyond repair the interior of the motor. This halted the production of green anodes.
- The production of baked anodes continued as they were taken out of the well furnaces, but this buffer would last only a few days.

A real-life example (5/18)

- No spare motor was available, and key world electric motor manufacturers asked for several months to built one.
- As the author was already working there in another project on drives, *CARBONORCA* asked him for help in the solution of this urgent problem.

A real-life example (6/18)

- The author suggested top management to seek a temporary substitute motor at the large warehouses of other state-owned companies of the zone.
- He suggested to look first at the opencast iron ore mines of *FERROMINERA*, where the author had taught a course on gear units.

A real-life example (7/18)

- At a *FERROMINERA* depot, the author found a *GE MD 418* CD shovel motor, with a nominal power of 150 hp at 400 rpm.
- He suggested *CARBONORCA* to borrow this motor, and soon it was delivered to the central workshop of the company.

A real-life example (8/18)

- Meanwhile, the author posed himself the problem of driving the *Buss* kneader with the means now at hand.
- The *GE MD 418* has a nominal armature tension of 230 V, while for the *ABB DMA 315* this value is 530 V. The *BBC Veritron* armature converter installed for the latter can supply up to 620V and 800A.

A real-life example (9/18)

- Hypothesis 1: increasing armature tension of the *GE MD 418*, its speed also rises, and delivers a nominal power closer to 300 kW.
- Hypothesis 2: this rugged motor, with a peak torque 500% nominal, and a top safe speed of 1150 rpm, will endure the intended burden, at least a year.

A real-life example (10/18)

- Intuition is useful in engineering, but some hard numbers were badly needed, to check if dreams could come true.
- With this aim, the author posed and solved some appropriate computational problems, applying the same method proposed today.

A real-life example (11/18)

- Next two slides show a steady-state model of the separately-excited DC electric motor under full field flux.
- After that, it is shown one of the problems posed on the above-mentioned model, and the algorithm that solves said problem.

A real-life example (12/18)

$$U_a - \left(E_a + I_a R_a\right) = 0 \qquad (1)$$

$$E_a - cn = 0 \qquad (2)$$

$$P_e - I_a U_a = 0 \qquad (3)$$

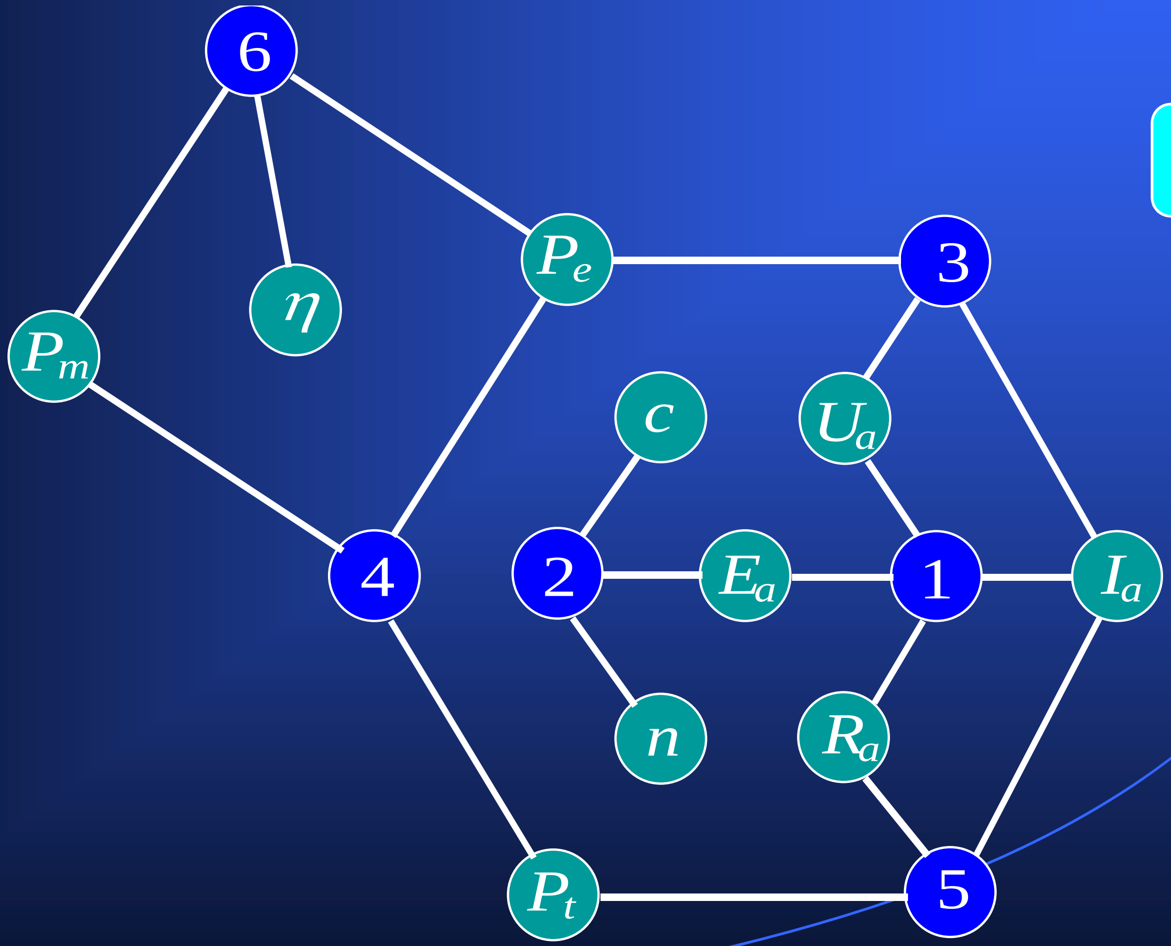
$$P_e - \left(P_m + P_t\right) = 0 \qquad (4)$$

$$P_t - R_a I_a^2 = 0 \qquad (5)$$

$$\eta P_e - P_m = 0 \qquad (6)$$

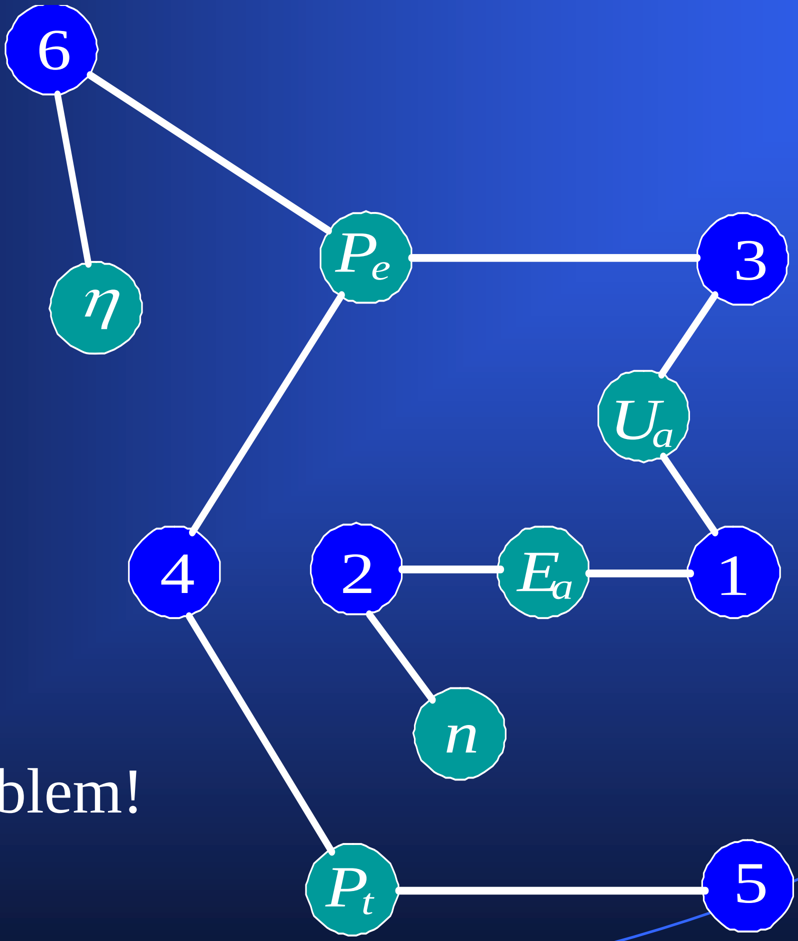
Model

A real-life example (13/18)



Model

A real-life example (14/18)

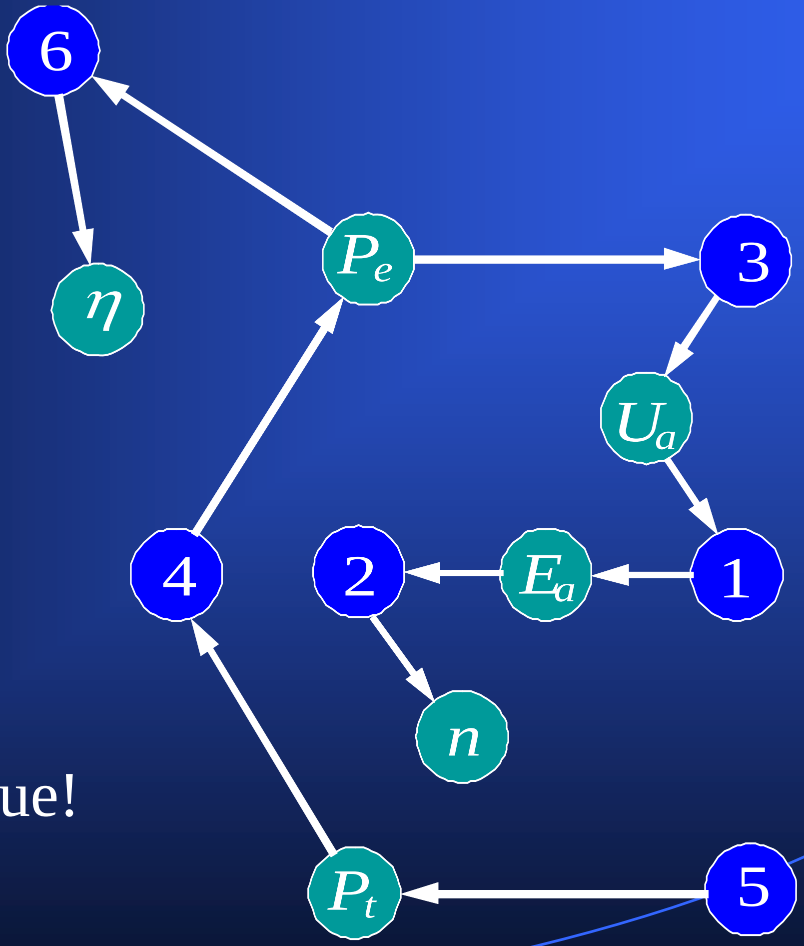


Problem

You *see* the problem!

A real-life example (15/18)

Algorithm



Parallel and unique!

A real-life example (16/18)

- Calculations found that the shovel motor could deliver a mechanical power of up to 300 kW, but available pulleys for the V-belt transmission limit the value to 220 kW.
- This should be enough to drive the kneader and sustain a production close to normal, which is a good emergency solution.

A real-life example (17/18)

- Experts on application and repair of electric motors at the local state-owned companies told us that our ideas *would not work at all*.
- However, *they worked well*, allowing a rate of production of anode paste of 22 t/h, close to the normal level of 24 t/h.

A real-life example (18/18)

- Spare motors hastily acquired in China and the US lasted less than 15 days each, before being irreparably damaged.
- Again, the shovel motor came to the rescue, reassuring a nonstop 22 t/h production flow.
- The shovel motor was successfully relieved only by a new *ABB DMA 315* motor.

Conclusions (1/4)

- The proposed approach may determine whether any posed computational problem is solvable or not.
- This capability eliminates unnecessary doubts and trials, that become expensive losses of time in problem solving.

Conclusions (2/4)

- If the problem is solvable, the proposed approach can determine all possible algorithms that solve the problem.
- Wherever parallel algorithms exist, the proposed approach identifies them with crystal-clear transparency and precision.

Conclusions (3/4)

- The method has been successfully used in the solution of complex practical problems in different places and industries.
- This clear-box approach helps users feel the level of confidence required in applications of *great responsibility*.

Conclusions (4/4)

- The method is adequate to solve both simulation and optimization problems.
- It naturally offers an *integrated* treatment of simulation and optimization.

Closing remark

Resolve the problem after knowing its elements is easier than resolve the problem without knowing them.
[…]
Knowing is resolve.

José Martí
1891-01-30

Thanks for your attention

Are there more questions, please?