

# 计算机数学概述

魏恒峰

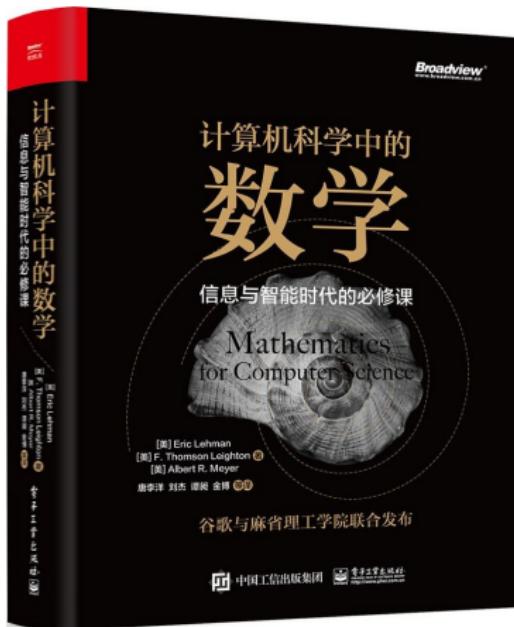
hfwei@hnu.edu.cn

2026 年 03 月 03 日



# 什么是“计算机数学”？

“Mathematics for Computer Science”  
(math4cs)

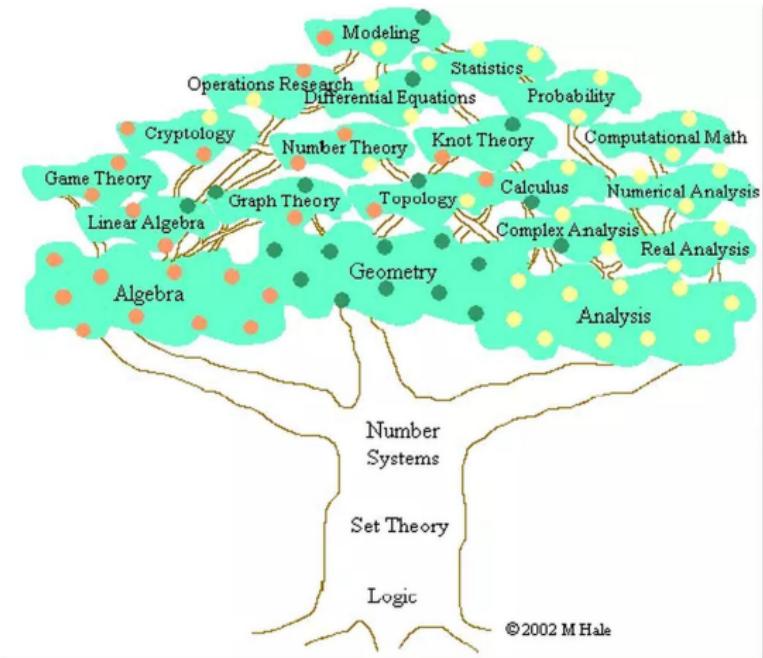


## What does “Computer Science” study?

*Computer science focuses on methods involved in design, specification, programming, verification, implementation and testing of human-made computing systems.*

math4cs is **model-and-proof** oriented.

# “计算机数学”在哪里?



计算机数学是个大杂烩，啥都学点儿，~~啥都没学好~~

# 分班教学 (共 9 个班级)

拔尖班: 独立授课, 独立考核



平时作业 *vs.* 课堂测验 *vs.* 期中测试 *vs.* 期末测试

1 : 3 : 2 : 4

每周四下午 14:00 发布平时作业

下下周四晚 22:00 前提交作业

取最高的 **12** 次作业成绩计人总评

The only way  
to learn  
**mathematics**  
is to **do**  
**mathematics.**

PAUL HALMOS

请按时提交, 过时不补

(助教: 罗熙辰)

# “教学立方”课程邀请码: PLD8QKTZ



TEX

math4cs-problem-sets Public

main 1 Branch 0 Tags Go to file + ⌂ Code

hengxin · 2026/math4cs-hw0-overview/ 40b517 · 20 minutes ago 2 Commits

2026/math4cs-hw0-overview · +2026/math4cs-hw0-overview/ 20 minutes ago

.gitignore · +2026/math4cs-hw0-overview/ 20 minutes ago

LICENSE · Initial commit 32 minutes ago

README.md · Initial commit 32 minutes ago

README MIT license

**math4cs-problem-sets**

Problem Set for math4cs (Mathematics for Computer Science; <https://github.com/courses-at-hnu-by-hfwei/math4cs>) at Hunan University by Hengfeng Wei

<https://github.com/courses-at-hnu-by-hfwei/math4cs-problem-sets>

约每两周一次课堂测验 (提前通知时间与测验范围)

取最高的 **6** 次课堂测验成绩计入总评



请准时参加, 不安排补考

# 约法三章

非必要，不点名

**非必要，不迟到**

**尽量吃早餐，但不可以在教室吃早餐**

~~非必要~~, 不抄袭; 一经发现, 后果严重

~~当次作业扣 0 分~~; 平时作业成绩扣 2 分, 扣完为止

QQ 群号: 108 745 6358



2026-计算机数学-拔...

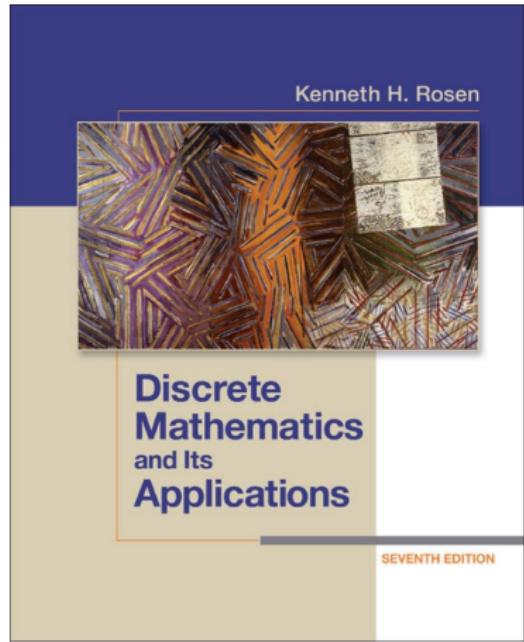
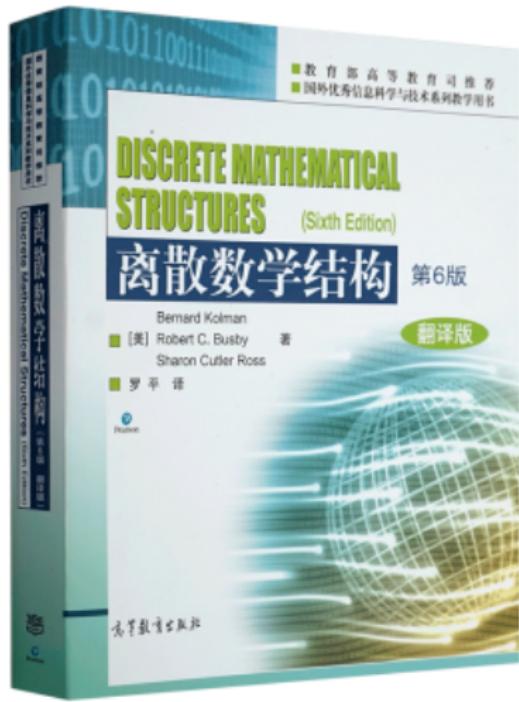
群号: 1087456358



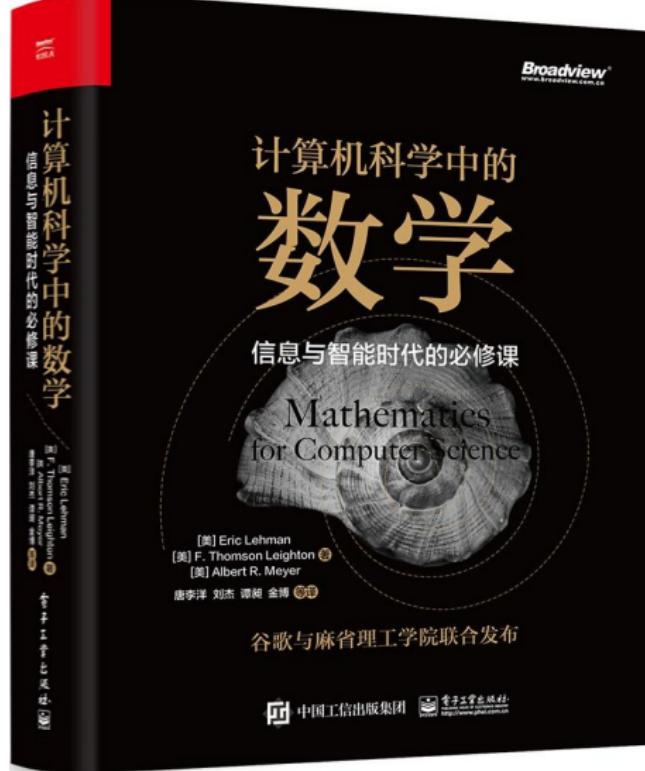
扫一扫二维码, 加入群聊



授课内容不局限于教材，认真听讲很重要



内容与习题偏简单，略显琐碎；可用于课前预习及课后基础练习



推荐阅读; 其它参考书随课程进度安排

 **math4cs-lectures** Public

Edit Pins Watch 0

main ▾ 1 Branch 0 Tags Go to file t + ⚡ Code ▾

 hengxin	+course info	97d802d · 20 hours ago
 0-overview	+course info	20 hours ago
 1-prop-logic	+0-overview, +1-prop-logic: old version	yesterday
 .gitignore	+0-overview, +1-prop-logic: old version	yesterday
 LICENSE	Initial commit	2 days ago
 README.md	+0-overview, +1-prop-logic: old version	yesterday
 preamble.tex	+course info	20 hours ago

<https://github.com/courses-at-hnu-by-hfwei/math4cs-lectures>

0-overview.pdf

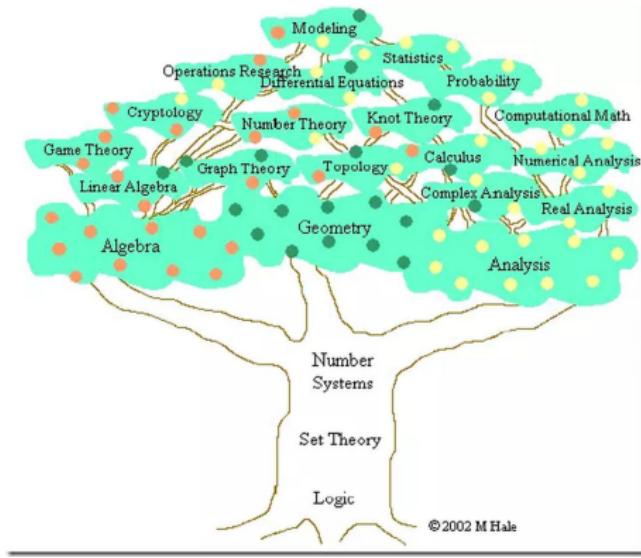
0-overview-handout.pdf



# 计算机（离散）数学

研究**离散对象的结构、性质、操作等**的数学分支 (**大杂烩**)

# 四大主题：逻辑、集合论、图论、抽象代数（群论）



支流遍布：组合与计数、数论、（离散）概率

关于计算机 (离散) 数学的古老传说:

我太难了

啥用没有

真得有那么难吗？

确实蛮难的：知识点多而分散、概念抽象

真得没啥用吗?

太基础, 用了但不自觉 ([逻辑](#))

浅尝辄止, 想用但用不上 ([群论](#))

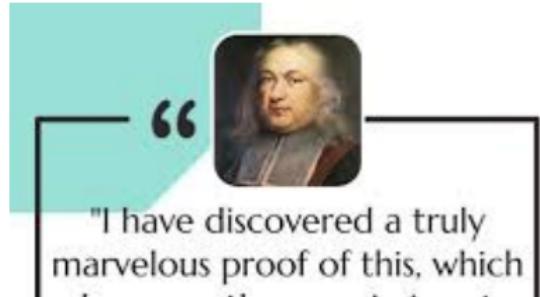
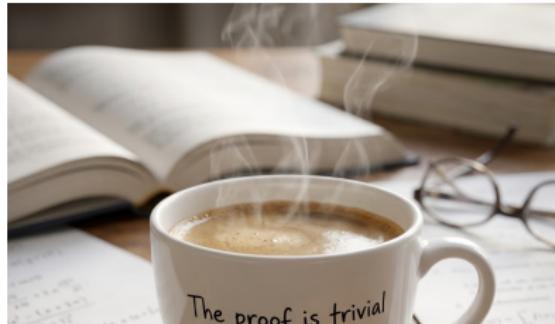
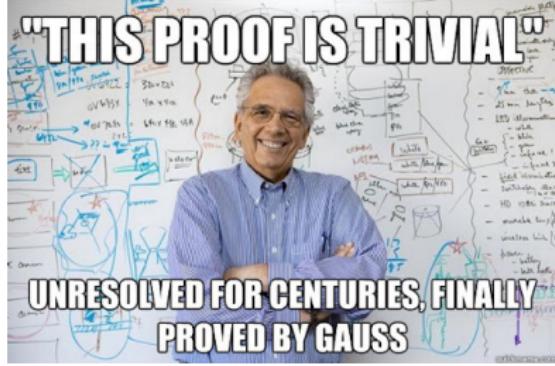
将计算机（离散）数学看作一门语言，一套工具

培养形式化描述问题的能力

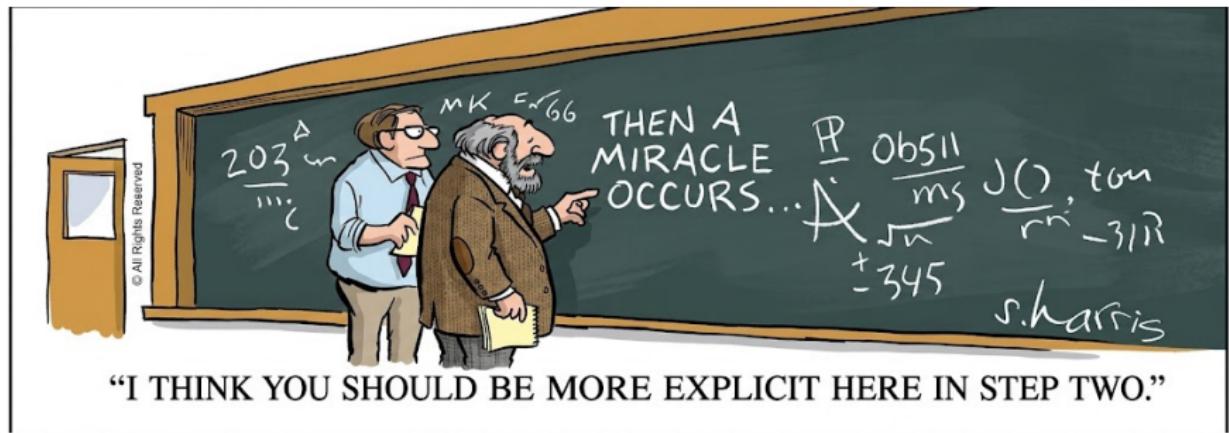
培养做严格证明的能力

# 本课程最重要的主题: 证明





凡是“跳步”的证明，一律默认是错的!!!



## Theorem ((第一) 数学归纳法)

设  $P(n)$  是关于自然数的一个性质。如果

(i)  $P(0)$  成立；

(ii) 对任意自然数  $n$ , 如果  $P(n)$  成立, 则  $P(n + 1)$  成立。

那么,  $P(n)$  对所有自然数  $n$  都成立。

Definition (良序原理 (The Well-Ordering Principle))

自然数集的任意非空子集都有一个最小元。

Theorem

良序原理与 (第一) 数学归纳法等价。

## Lemma

(第一) 数学归纳法蕴含良序原理。

Proof.

By mathematical induction on the size  $n$  of non-empty subsets of  $\mathbb{N}$ .

$P(n)$  : All subsets of size  $n$  contain a minimum.

Basis Step:  $P(1)$

Inductive Hypothesis:  $P(n)$

Inductive Step:  $P(n) \rightarrow P(n + 1)$

- ▶  $A' \leftarrow A \setminus a$
- ▶  $x \leftarrow \min A'$
- ▶ Compare  $x$  with  $a$

$\forall n \in \mathbb{N} : P(n) \quad vs. \quad P(\infty)$

## Lemma

(第一) 数学归纳法蕴含良序原理。

By contradiction.

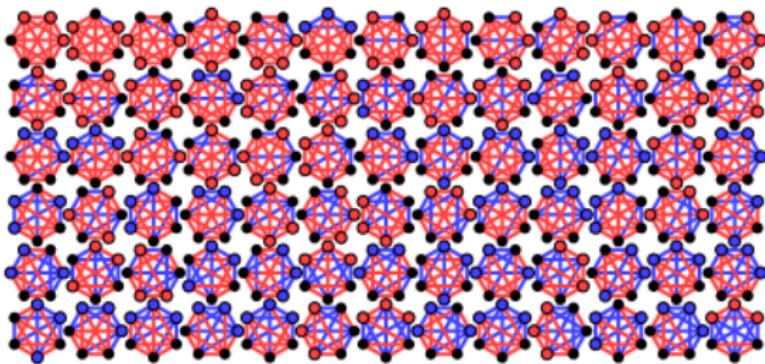
Suppose that there exists  $S \neq \emptyset : S$  has no minimum element.

$$A \triangleq \mathbb{N} \setminus S$$

We claim that  $A = \mathbb{N}$  by induction, and thus  $S = \emptyset$ , a contradiction.

## Theorem on Friends and Strangers

At any party with at least 6 people, there are 3 people who are all either mutual acquaintances or mutual strangers.



In Terms of **Graph Theory**.

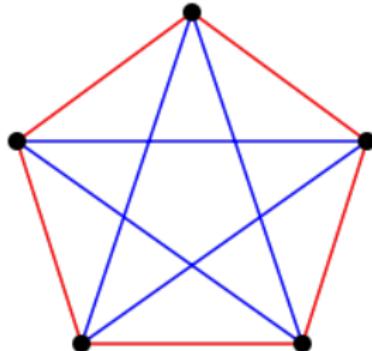
(Is there a **monochromatic** triangle in any 2-coloring of  $K_6$ ?)

## Theorem on Friends and Strangers

Is there a **monochromatic** triangle in any 2-coloring of  $K_6$ ?

## Theorem on Friends and Strangers

Is there a **monochromatic** triangle in any 2-coloring of  $K_5$ ?

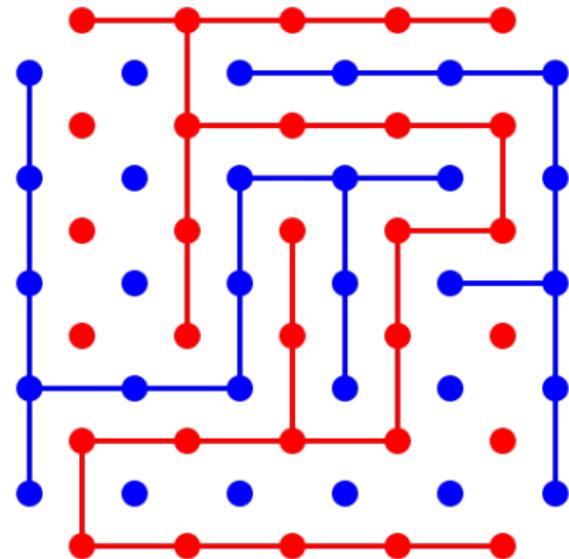
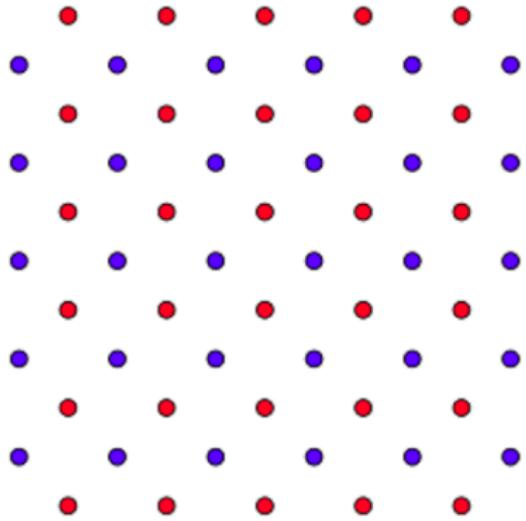


## Ramsey theory

How **big** must the **structure** be  
to ensure that it has a given interesting **property**?



## Bridg-It Game (David Gale, 1958)



$5 \times 6$  vs.  $6 \times 5$

Play with it here!



Does **Player 1** have a **winning strategy**?

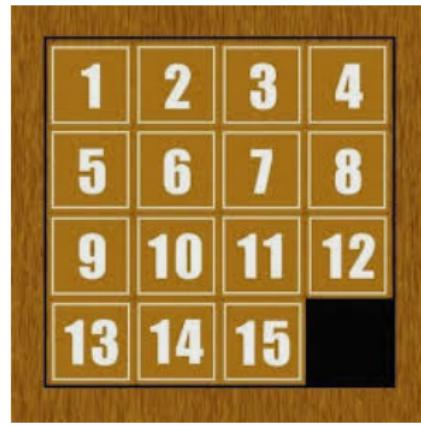
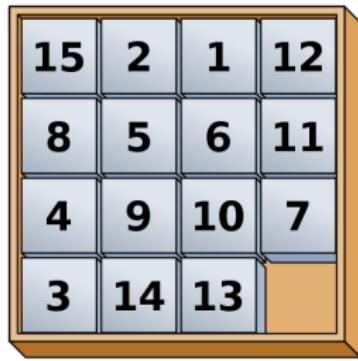
(先手是否有必胜策略?)

Yes! It uses **spanning trees** in **graph theory**.



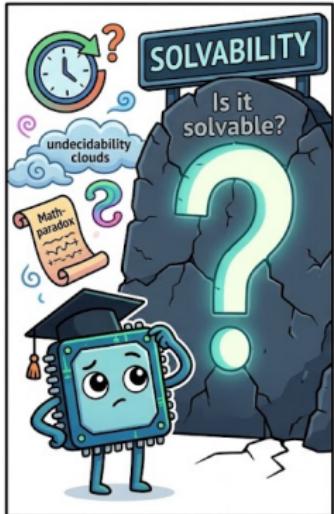
STAY TUNED

## 15 Puzzle (数字华容道)

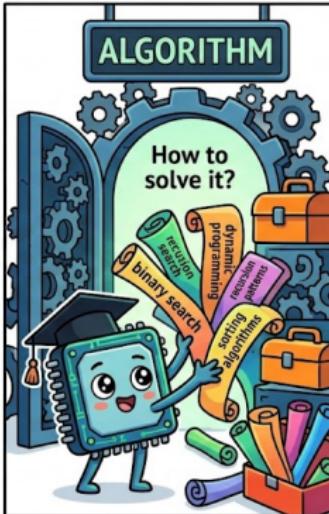


Is it solvable?    How to solve it?    How fast can we solve it?

Panel 1: SOLVABILITY



Panel 2: ALGORITHM



Panel 3: EFFICIENCY



计算机科学的“灵魂三问：可解性、算法设计、算法效率

It uses **permutation groups** in **group theory**.

## A Modern Treatment of the 15 Puzzle

Aaron F. Archer

**1. INTRODUCTION.** In the 1870's the impish puzzlemaker Sam Loyd caused quite a stir in the United States, Britain, and Europe with his now-famous 15-puzzle. In its original form, the puzzle consists of fifteen square blocks numbered 1 through 15 but otherwise identical and a square tray large enough to accommodate 16 blocks. The 15 blocks are placed in the tray as shown in Figure 1, with the lower right corner left empty. A legal move consists of sliding a block adjacent to the empty space into the empty space. Thus, from the starting placement, block 12 or 15 may be slid into the empty space. The object of the puzzle is to use a sequence of legal moves to switch the positions of blocks 14 and 15 while returning all other blocks to their original positions.

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	

Figure 1. The starting position for the 15-puzzle. The shaded square is left empty.

STAY TUNED

Why is this 15-Puzzle Impossible? - Numberphile

## The Stable Marriage Problem (SMP)

Given  $n$  men and  $n$  women, where each person has a preference list, to establish a stable marriage.

Men $\{x, y, z, w\}$	Women $\{a, b, c, d\}$
$x : a > b > c > d$	$a : z > x > y > w$
$y : a > c > b > d$	$b : y > w > x > z$
$z : c > d > a > b$	$c : w > x > y > z$
$w : c > b > a > d$	$d : x > y > z > w$

$\{xb, yc, zd, wa\}$  is an unstable matching

$(x, a)$  is a (dangerous) unstable unmatched pair

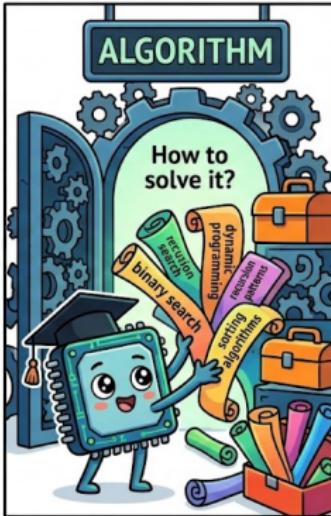
## Definition (Stable Matching)

A matching is stable when there does not exist any pair  $(A, B)$  which both prefer each other to their current partner under the matching.

Panel 1: SOLVABILITY



Panel 2: ALGORITHM



Panel 3: EFFICIENCY



计算机科学的“灵魂三问：可解性、算法设计、算法效率

$$\{xa, yb, zd, wc\}$$

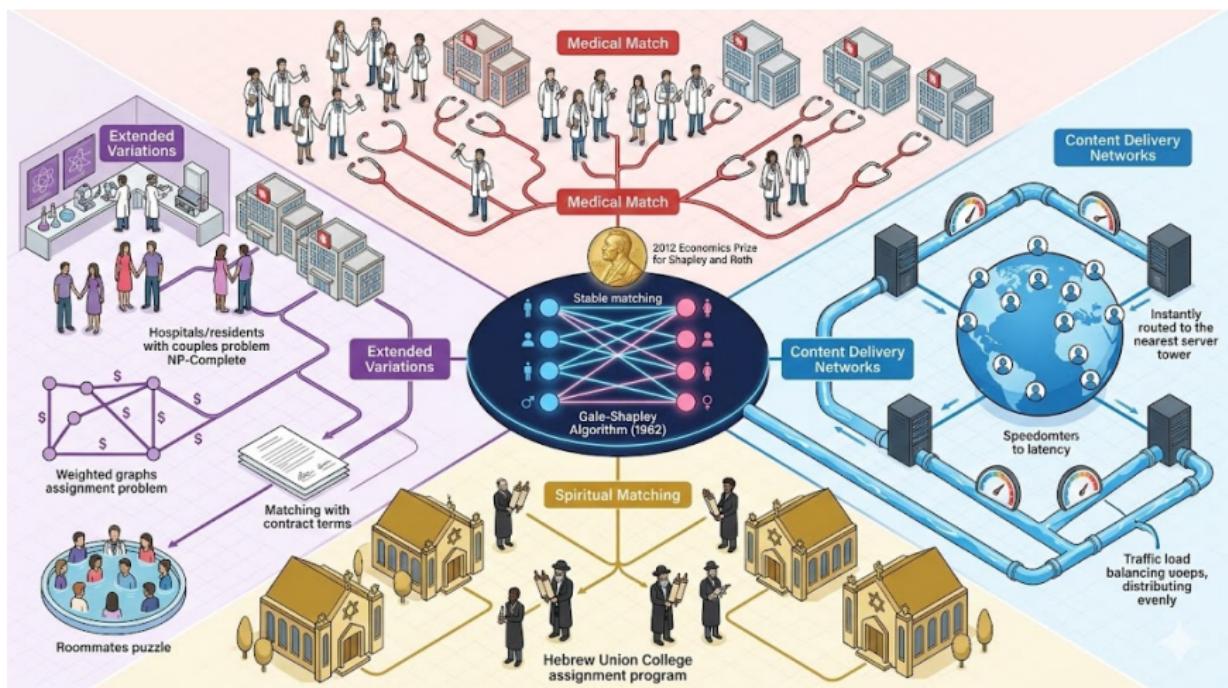
Men $\{x, y, z, w\}$	Women $\{a, b, c, d\}$
$x : a > b > c > d$	$a : z > x > y > w$
$y : a > c > b > d$	$b : y > w > x > z$
$z : c > d > a > b$	$c : w > x > y > z$
$w : c > b > a > d$	$d : x > y > z > w$

Theorem (The Gale-Shapley Algorithm (1962))

*It is always possible to solve SMP: Men propose + Women accept/reject.*

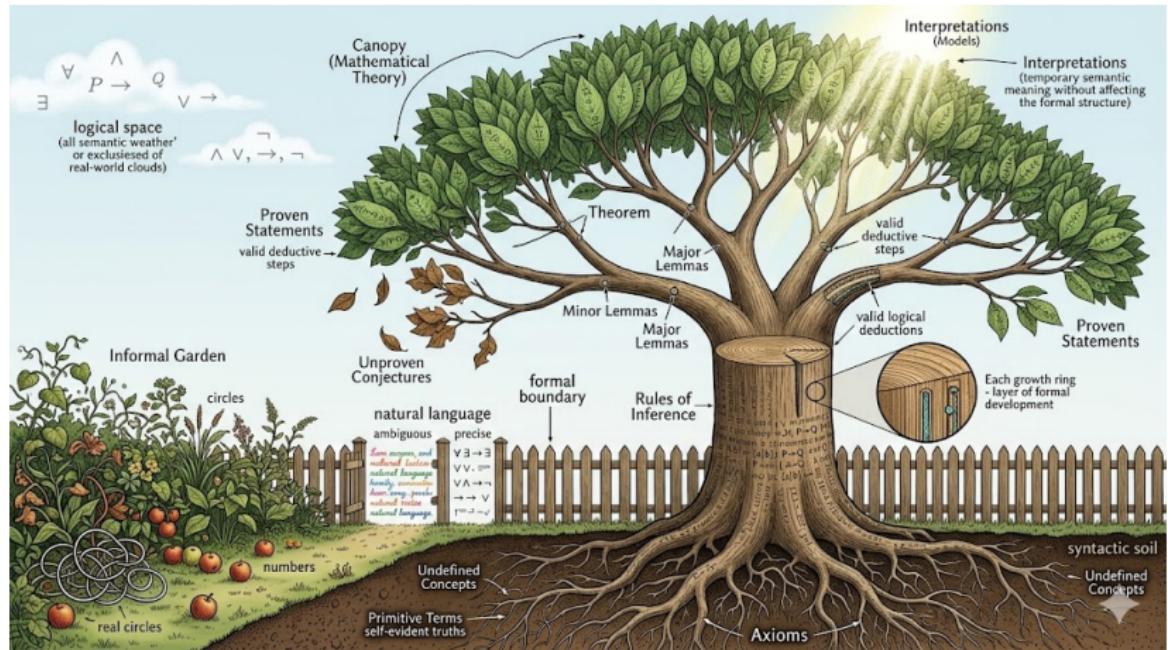


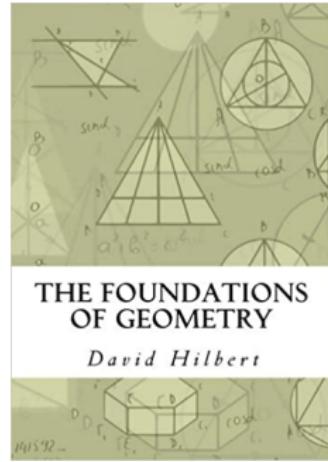
# Applications and Extensions



# Axiomatic Systems (公理系统)

Self-contained (自包含; 不假于外物); Self-consistent (自洽; 内部无矛盾)





直线公设 两点决定一条直线

延伸公设 直线段可以向两端无限延伸

圆公设 以任一点为圆心、任意长为半径，可作一圆

角公设 所有直角皆相等

平行公设 过直线外一点，可作且只可作一直线与此直线平行

## Axiomatic System for a Four-point Geometry

***Undefined terms:*** point, line, is on

### ***Axioms:***

- (1) There are exactly four **points**.
- (2) It is impossible for three **points** to **be on** the same line.
- (3) For every pair of distinct **points**  $x$  and  $y$ ,  
there is a unique **line**  $l$  such that  $x$  **is on**  $l$  and  $y$  **is on**  $l$ .
- (4) Given a **line**  $l$  and a **point**  $x$  that is not **on**  $l$ , there is a unique  
**line**  $m$  such that  $x$  **is on**  $m$  and no **point** on  $l$  is also **on**  $m$ .

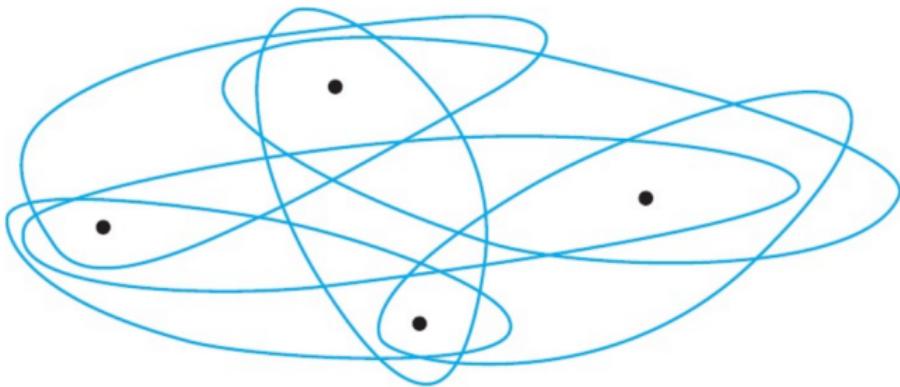
### **Theorem**

*There are at least two distinct lines.*



# Syntax      Semantics

Syntax *vs.* Semantics (语法与语义对立统一)



point : •

line : ○

is on : ⊙

你还能想到哪些公理系统？不一定是数学方面的！



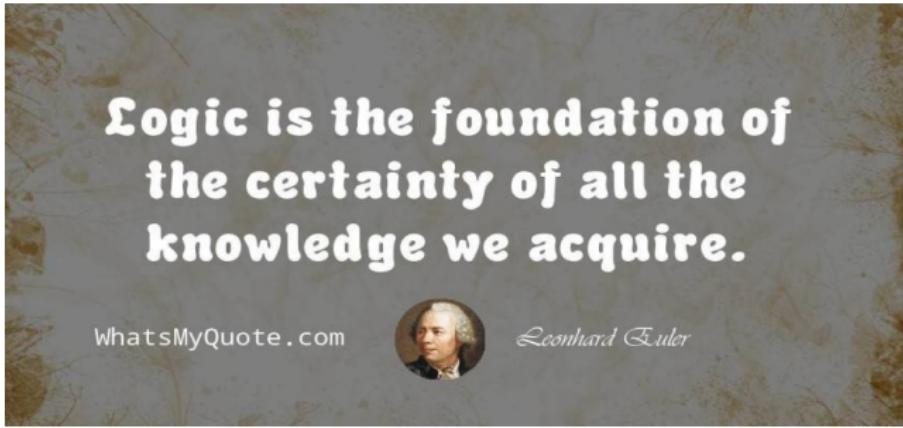
## 宇宙社会学



本课程将介绍**三个公理系统**:

逻辑、集合论、图论、群论 (抽象代数)

# 什么样的推理是正确的?







Your opinion  
Matters

hfwei@hnu.edu.cn