Large-Scale Knowledge Processing #1 Guidance

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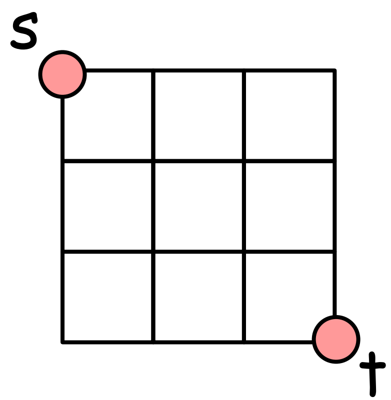
Large-Scale Knowledge Processing

- Course objectives
  - This lecture aims to learn the techniques of knowledge processing, which are essential to intellectual information processing, such as editing, classifying, analyzing, and indexing of knowledge.
- Topics on large-scale knowledge processing: (Lectures are given in parallel or sequentially.)
  - Optimization techniques
  - Fundamentals of Boolean functions and computational complexity
  - Exact algorithms and approximation algorithms
  - Manupulation of discrete structure by BDDs/ZDDs
- Report assignments will be assigned.

Quiz : s-t path (shortest path)

Q : Enumerate (or count) all **shortest paths** from s to t



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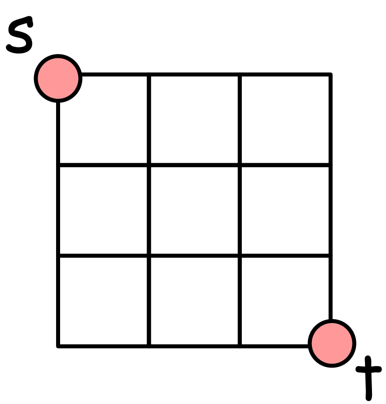


Any combination of ↓ ↓ ↓ → → →

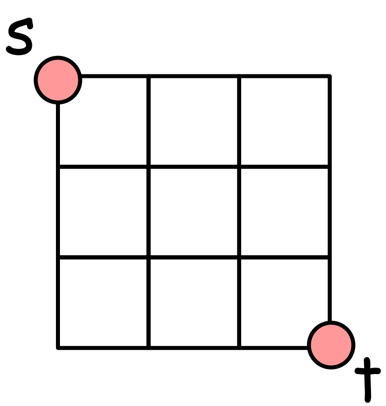
gives a shortest path

#(shortest path) is $_6C_3 = \frac{6\cdot5\cdot4}{3\cdot2\cdot1} = 20$

Quiz： s-t path ~~(shortest path)~~

Q： Enumerate (or count) all ~~shortest~~ **paths** from s to t

- **Detours** are **allowed**
- Self avoiding： Any path **cannot** go through the **same vertex twice** (or more)



- There is no formula for counting the number of paths
(The answer of the above problem is 184)

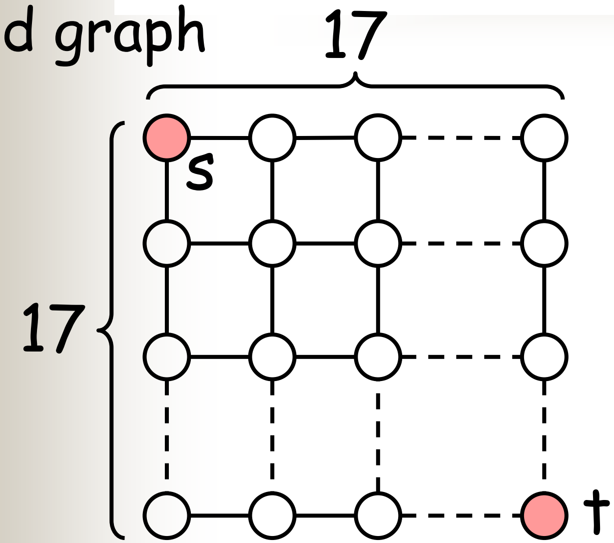
Enumeration:

- Find all solutions satisfying the given conditions

- What is required
  - Enumerate **efficiently** (Time complexity)
  - Store the solutions **compactly** (Space complexity)
  - Use the solutions **easily**
    - How many ? / Sampling
    - Retrieve the solutions by various queries

Ex.) s-t path (Self-avoiding path)

Grid graph



#(s-t paths) 6,344,814, 611,237,963,971,310,297,540, 795,524,400,449,443,986,866, 480,693,646,369,387,855,336

Approx. 6.3 x 10^{61} (63 那由他)

"Sufficiently large number" in Sanskrit

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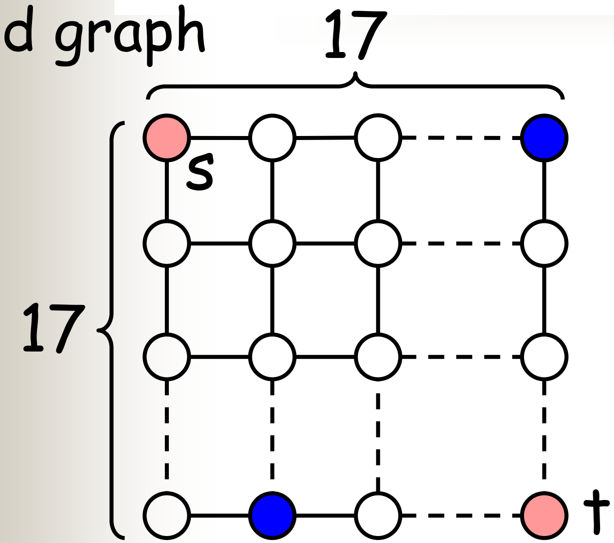

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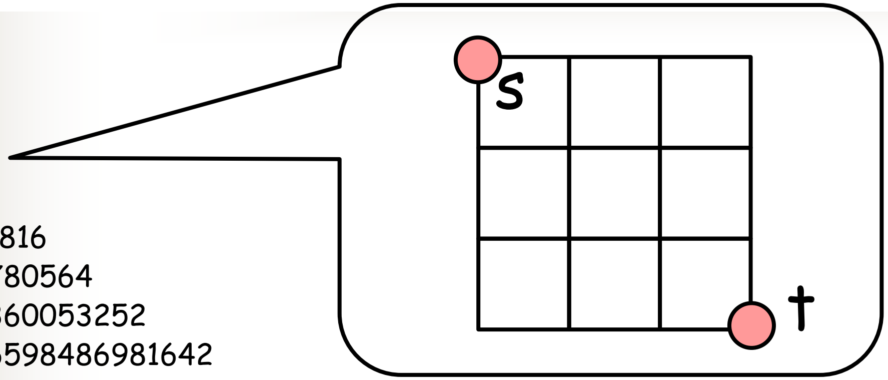
The number of paths of length at most 50 ?

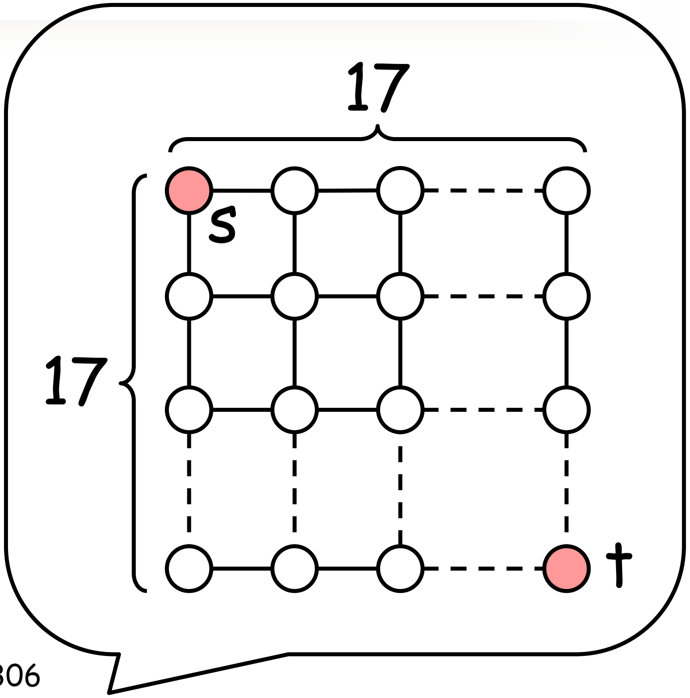
Longest path ?

Paths going through both of two ●s ?

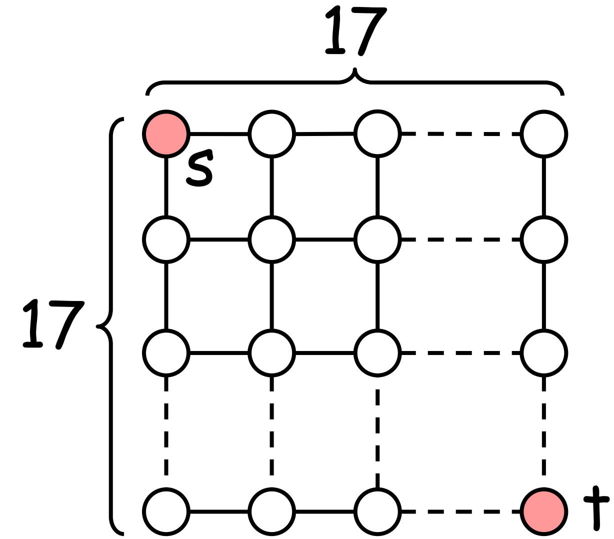
#(s-t paths)

- 1 2
- 2 12
- 3 184
- 4 8512
- 5 1262816
- 6 575780564
- 7 789360053252
- 8 3266598486981642
- 9 41044208702632496804
- 10 1568758030464750013214100
- 11 182413291514248049241470885236
- 12 64528039343270018963357185158482118
- 13 69450664761521361664274701548907358996488
- 14 227449714676812739631826459327989863387613323440
- 15 2266745568862672746374567396713098934866324885408319028
- 16 68745445609149931587631563132489232824587945968099457285419306
- 17 6344814611237963971310297540795524400449443986866480693646369387855336
- 18 178211284084206512989338494665232527516783806570476765593145247460582669278253 2
- 19 15233449717048799930807428103192296908994542553232945557760298667373550605928775692558 44
- 20 396289219982303756020729951713336250210633970573946377151523711337701068236403570670447206494039 8





#(s-t paths)



- 21
  3137475105013710272042053813738221451310331219369872365306135199134643337938938579396557699224602131646
  3868
- 22
  7559702866673453396615191233152226193531037320724094811673914104795179257927436312349870388833176349872
  71171404439792
- 23
  5543542935523747700991431848906143793069037997096433133255695864648400840733488554456638692402087571
  1242060085408513482933945720
- 24
  123717122312070647583387448626735708323730419890129435396787270804849516955159304856413945507921530371
  91858028212512280926600304581386791094
- 25
  84029748578811334710070837454368091272960542937753835498247426239370284978982152569291785770839709601
  21625602506027316549718402106494049978375604247408
- 26
  173699315862792729311754404212364989003722295882881406046637037209103424132761347627892181934980061070
  82296223143380491348290026721931129627708738890853908108906396

Algorithms for large-scale knowledge processing

- **How to solve the problems** (= strategies)
- Why algorithms are **important** ?
  - Improve **implementations**: **2x or 3x** speed-up
    Improve **algorithms**: **1000x** speed-up
    → We can handle larger/practical problems
  - **Basic theory** can connect to various **applications**

Ex.)
- "Electoral district" and "disaster evacuation site"
- "Developments" and "origami by cells"
- …

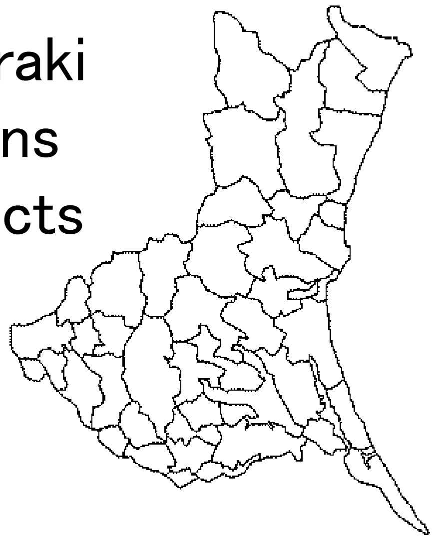
Electoral district

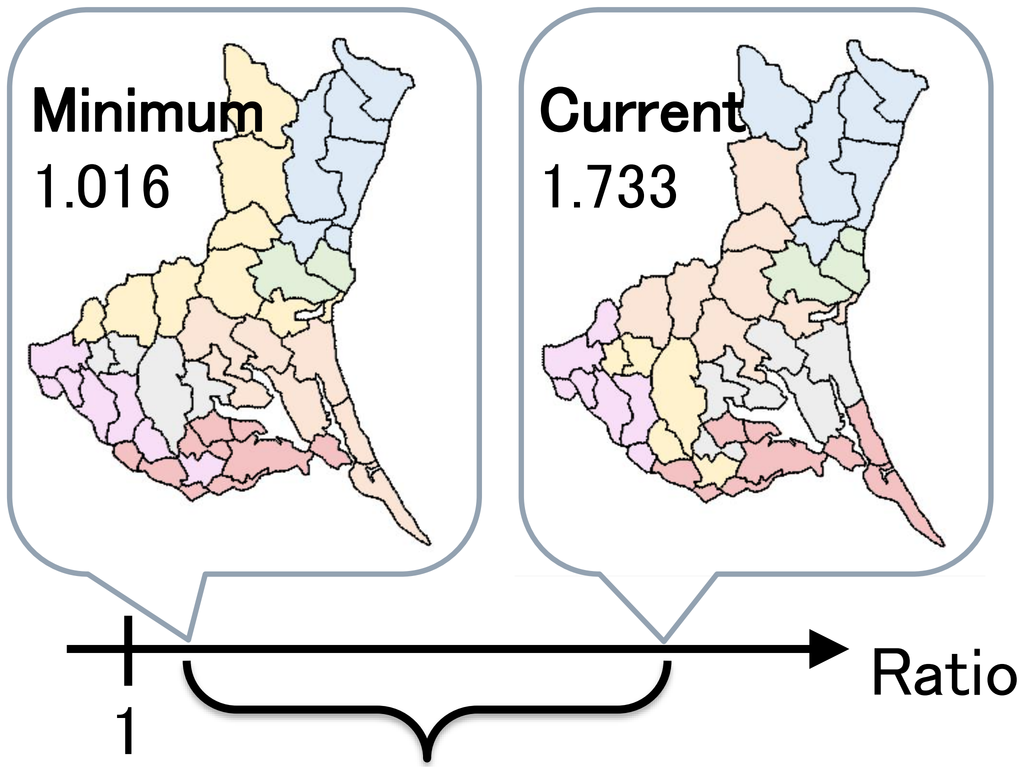
4,893,281,393,039,250,022,519,012,101,206
ways for partitioning Osaka prefecture
(We cannot store them in the usual way)
We can find all of them in 0.34 seconds.

- **Political equality**

Partition into districts with almost equal populations according to the census results

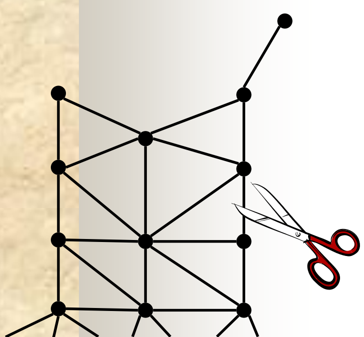
Ex.: Ibaraki
41 regions
7 districts





We are interested in the gap.
Many ways for partitioning or not ?

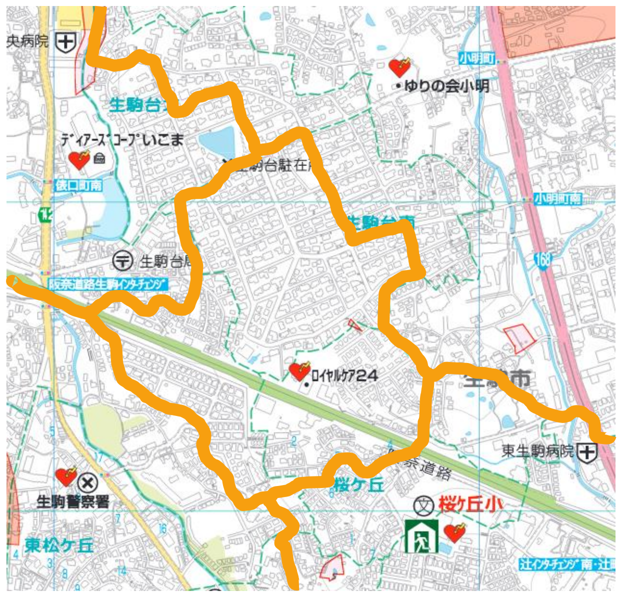
How to tackle problems
- Not all at once
- Step-by-step approach



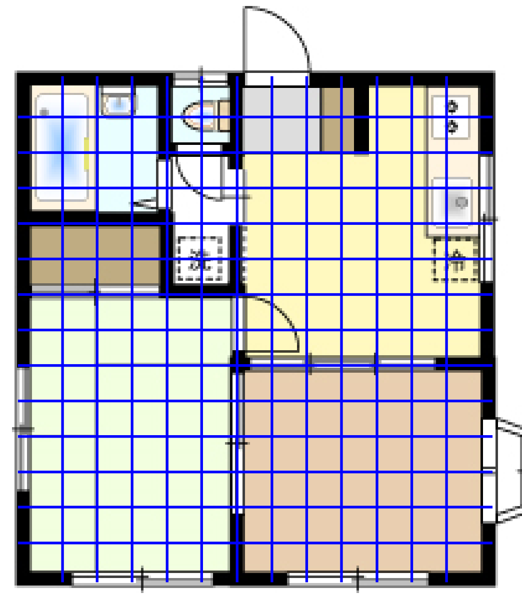
Ex.: model the problem as a partition of a graph

Other applications

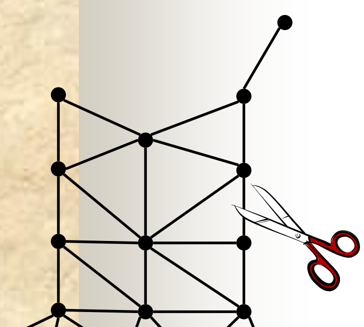
- Similar ideas can be **applied to other areas**



Evacuation plan (Allocation of evacuation sites)



Floor plan



Ex.: model the problem as a partition of a graph

Folding Mechanism

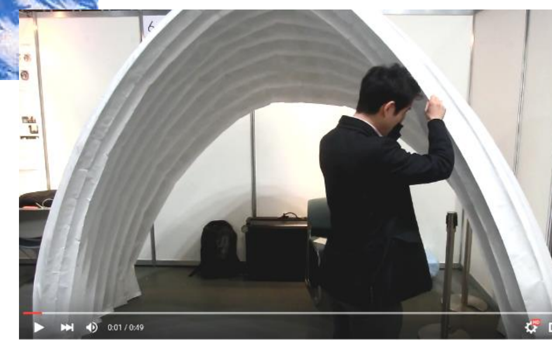
Packages

Folding Mechanism

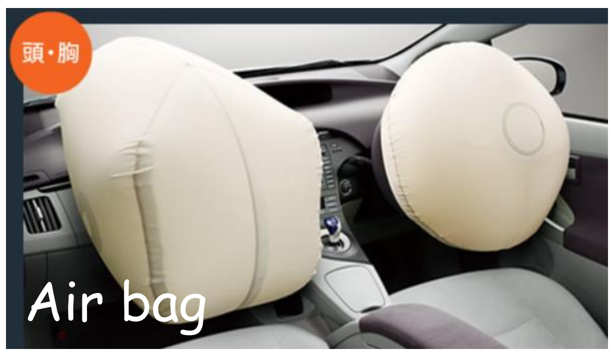
Packages

Satellite panel
(Miura fold)

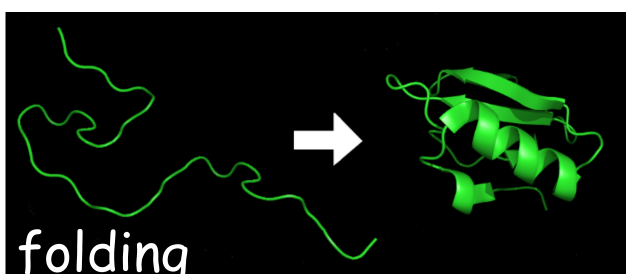
Architecture



Canned beverage
(Yoshimura pattern)

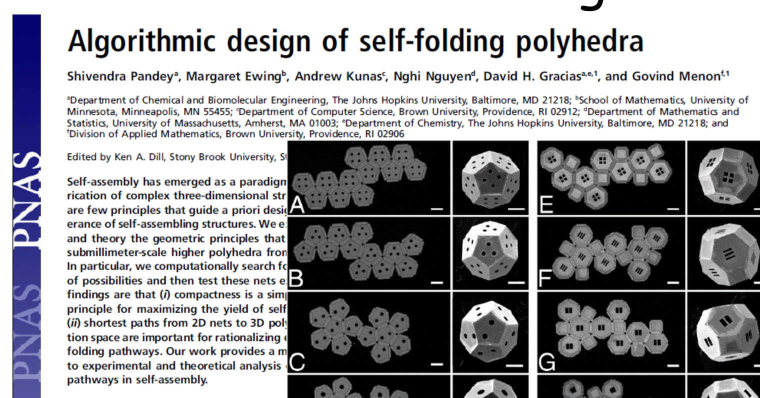


Air bag



Protein folding

Research on Origami


PNAS PNAS

Algorithmic design of self-folding polyhedra

Shivendra Pandey[a], Margaret Ewing[b], Andrew Kunas[c], Nghi Nguyen[d], David H. Gracias[a,e,1], and Govind Menon[f,1]

[a]Department of Chemical and Biomolecular Engineering, The Johns Hopkins University, Baltimore, MD 21218; [b]School of Mathematics, University of Minnesota, Minneapolis, MN 55455; [c]Department of Computer Science, Brown University, Providence, RI 02912; [d]Department of Mathematics and Statistics, University of Massachusetts, Amherst, MA 01003; [e]Department of Chemistry, The Johns Hopkins University, Baltimore, MD 21218; and [f]Division of Applied Mathematics, Brown University, Providence, RI 02906

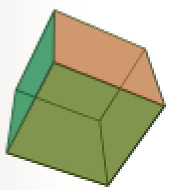
Edited by Ken A. Dill, Stony Brook University, St

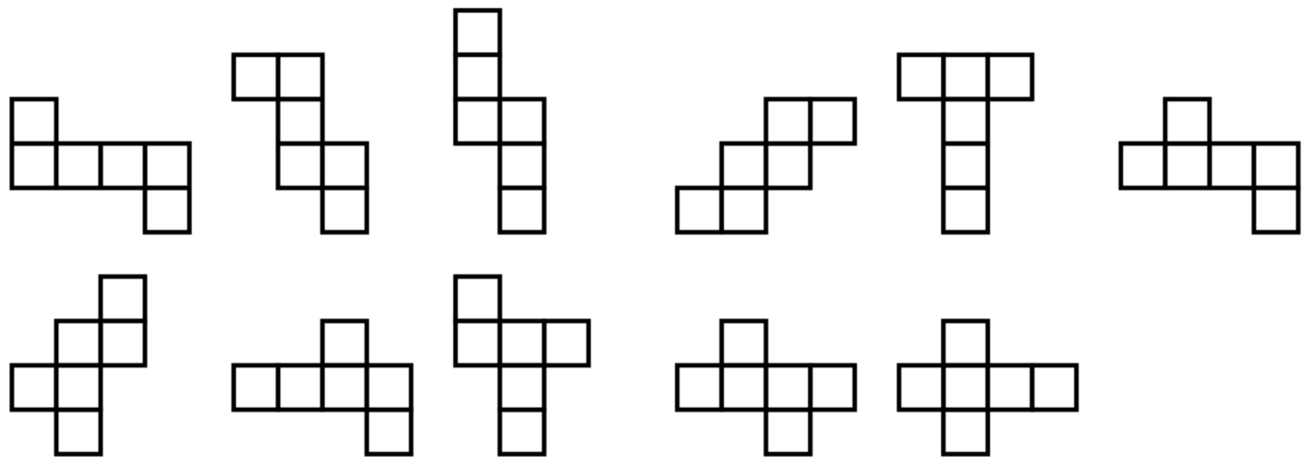
Self-assembly has emerged as a paradigm
rication of complex three-dimensional str
are few principles that guide a priori desi
erance of self-assembling structures. We e
and theory the geometric principles that
submillimeter-scale higher polyhedra fron
In particular, we computationally search fo
of possibilities and then test these nets e
findings are that (*i*) compactness is a sim
principle for maximizing the yield of self
(*ii*) shortest paths from 2D nets to 3D pol
tion space are important for rationalizing
folding pathways. Our work provides a m
to experimental and theoretical analysis
pathways in self-assembly.

microfabrication | origami | programmable mat

Developments of polyhedra

11 ways for a cube



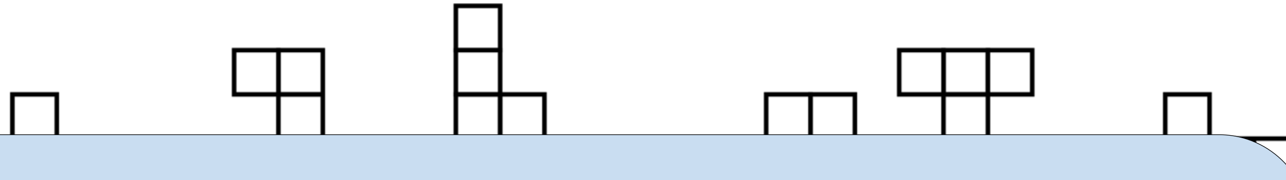


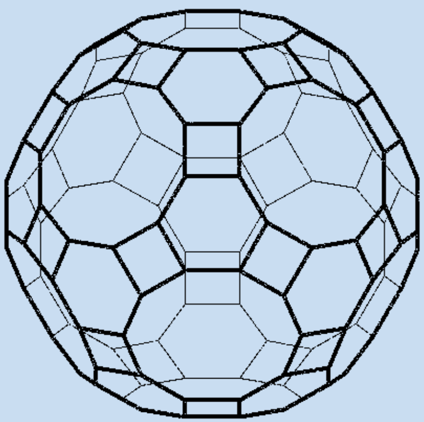
Q.2 How many ways for a soccer ball？

A. 3,127,432,220,939,473,920

Developments of polyhedra

11 ways for a cube





181,577,189,197,376,045,
928,994,520,239,942,164,480

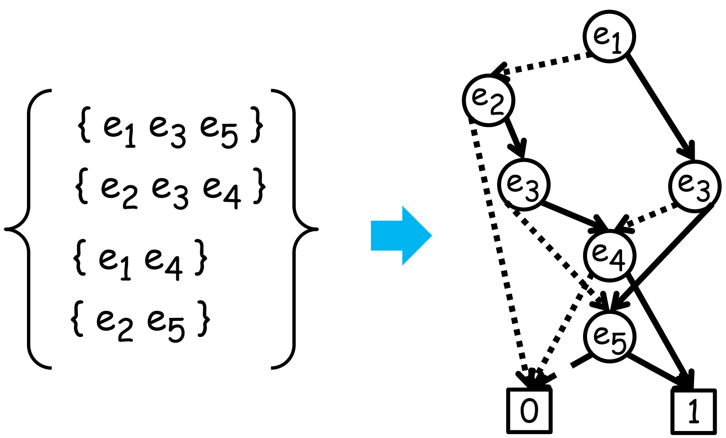
A. 3,127,432,220,939,473,920

This class: From the viewpoint of discrete structures

- Support our society **by algorithms**
  (algorithms on enumeration/optimization and their complexity)
- Various connections with our society

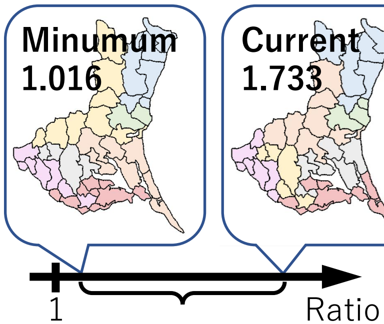
Discrete structure

How to **represent/manipulate discrete structure** (combinations, graphs, and so on)

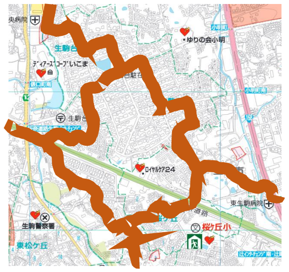


Various applications

Electoral district



Evacuation plan



Computational origami

Origami with cells