

Are Financial Networks Highly Complex?



Roger Wattenhofer

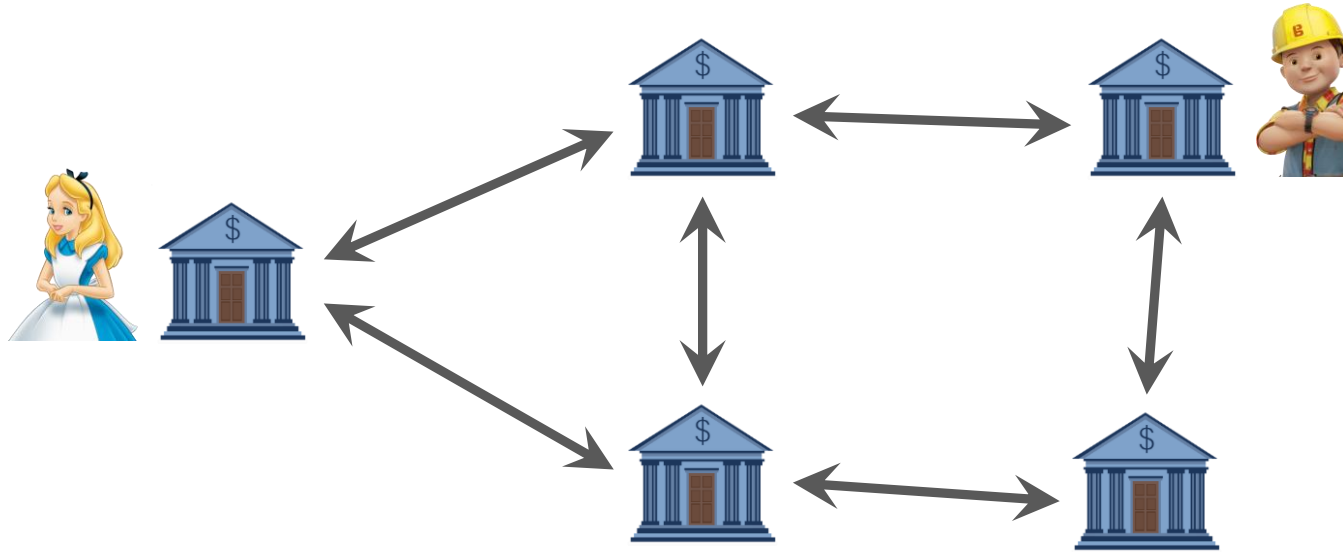
FINANCIAL TIMES

Are financial markets too complex?

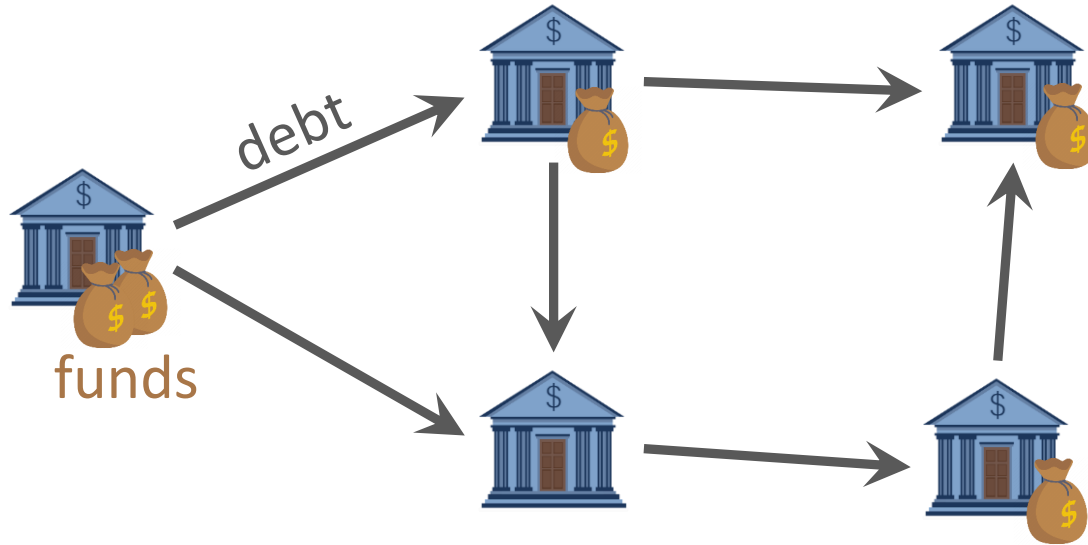
The global credit market has plummeted and the collapse of various hedge funds has raised fears that the credit market conflagration could become a true economic crisis.

Richard Bookstaber, a former academic, who went on to head risk management for Morgan Stanley, and now runs a large hedge fund at FrontPoint Partners, argues in his book *A Demon of Our Own*

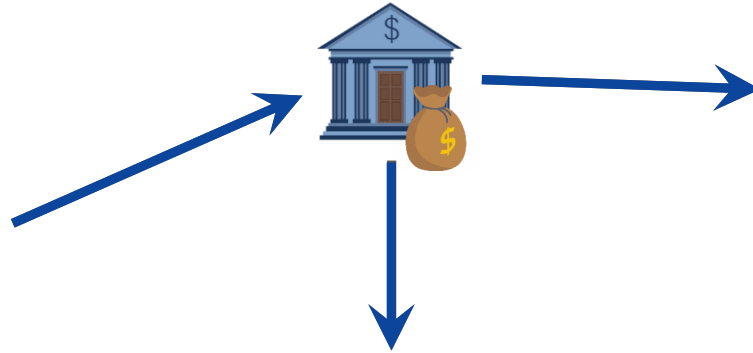
Financial Network



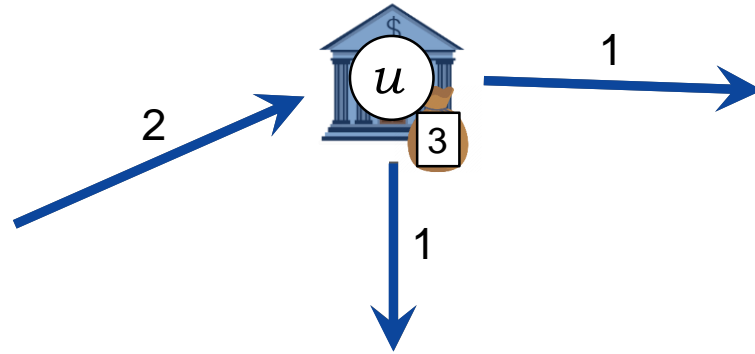
Financial Network



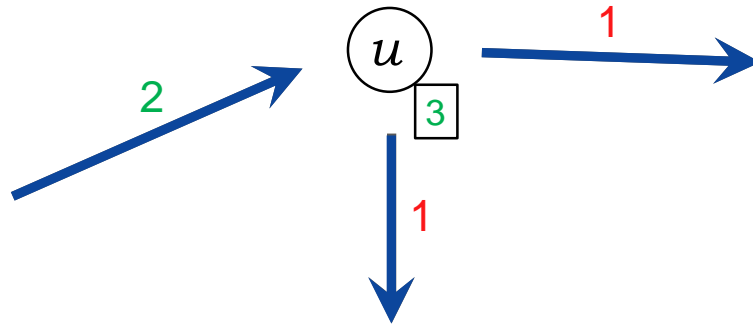
Assets, Liabilities, Default, and Recovery Rate



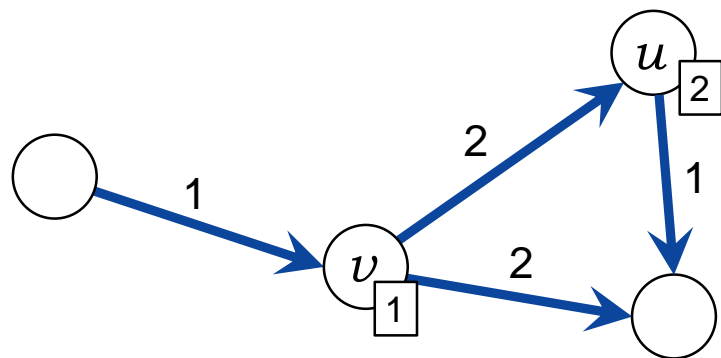
Assets, Liabilities, Default, and Recovery Rate



Assets, Liabilities, Default, and Recovery Rate

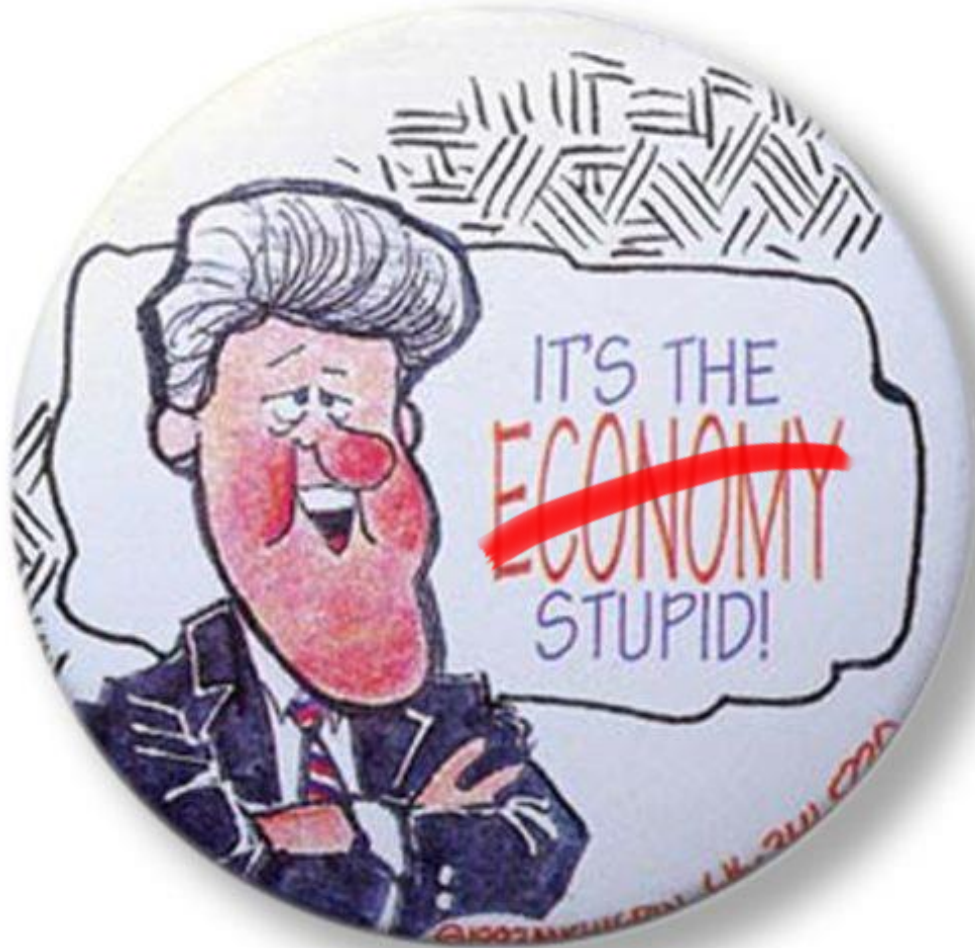


Assets, Liabilities, Default, and Recovery Rate



$$a_u \geq l_u \Rightarrow r_u = 1$$

$$a_v < l_v \Rightarrow r_v = \frac{a_v}{l_v} = \frac{2}{4} = \frac{1}{2}$$



NETWORK

economic crisis (2008)

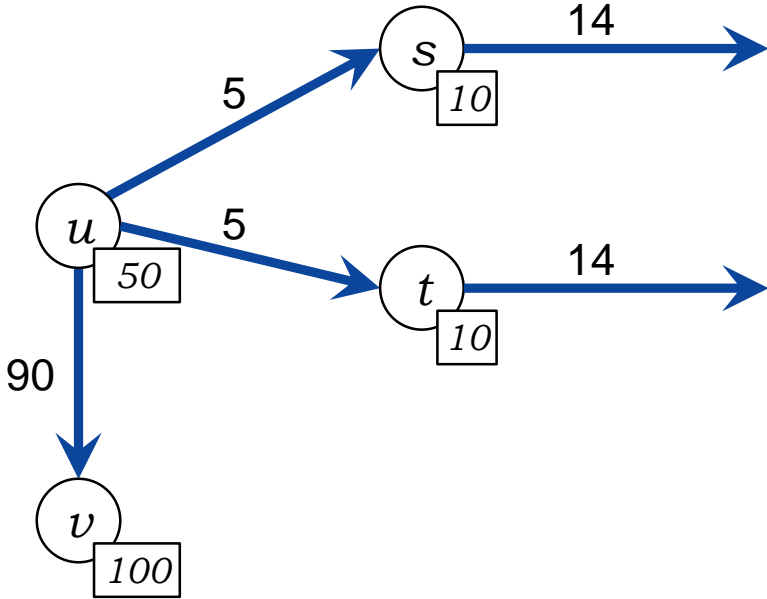
=

many companies involved

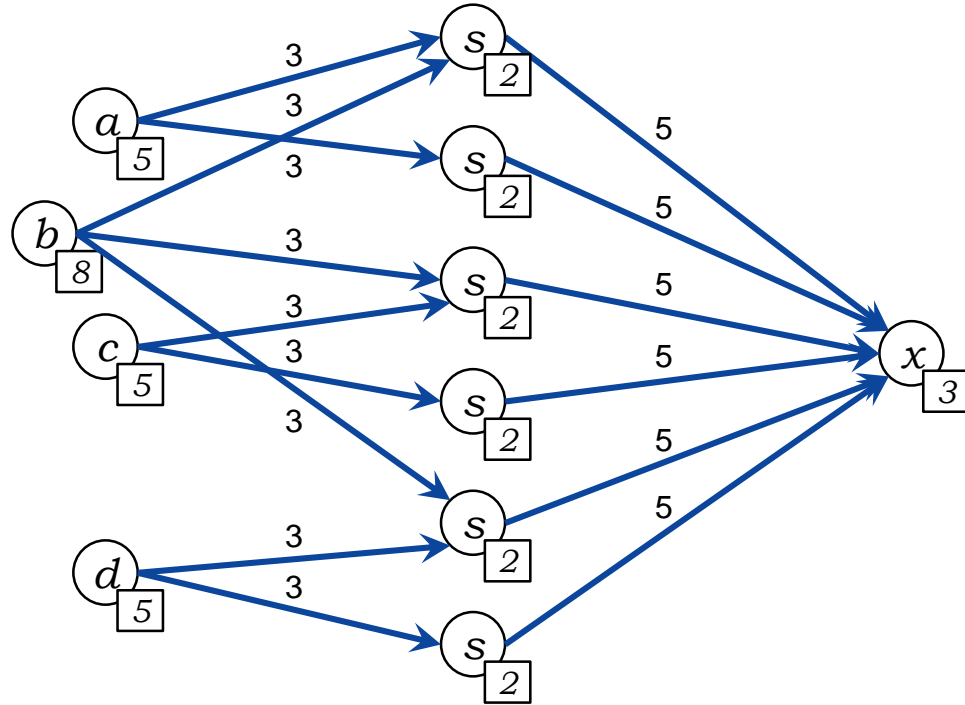
=

network

Too Big to Fail?



Bailouts on a Budget (of 3)



Bailouts are NP hard.*

*in some models.

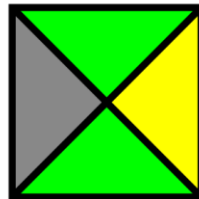
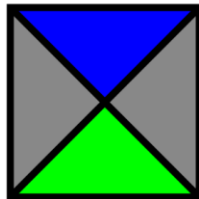
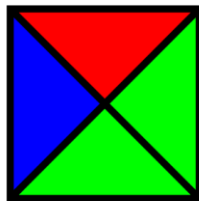
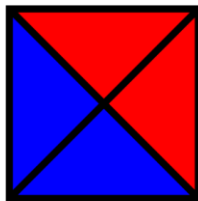
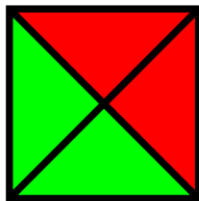
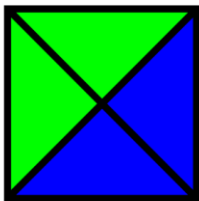
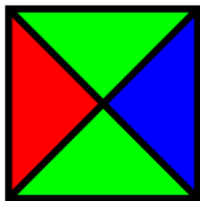
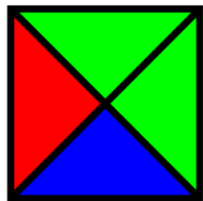
The image shows a detailed architectural floor plan drawn on blue paper. The plan includes several rooms: a Family Room at the top, a Kitchen on the left, a Bathroom in the center, a Bedroom at the bottom, and a Walk-in Closet. The drawing is filled with technical annotations, including dimensions (e.g., 13'-4", 7'-0", 45'-8", 6'-0", 3'-2x4), material notes (e.g., 'EXIST. BRICK WALL TO BE DEMOLISHED'), and structural references (e.g., 'EXIST. JOISTS', 'EXIST. W/MS'). There are also notes about existing conditions and proposed changes, such as 'EXIST. BI-MATERIAL' and 'EXIST. GUARD'. The word 'Complexity' is written in a large, white, sans-serif font across the middle of the plan, highlighting the intricate nature of the design. The overall style is that of a professional architectural drawing, with clear lines and legible text.

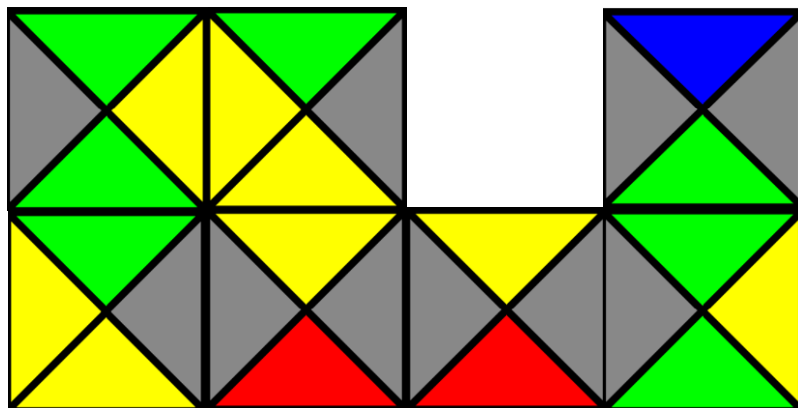
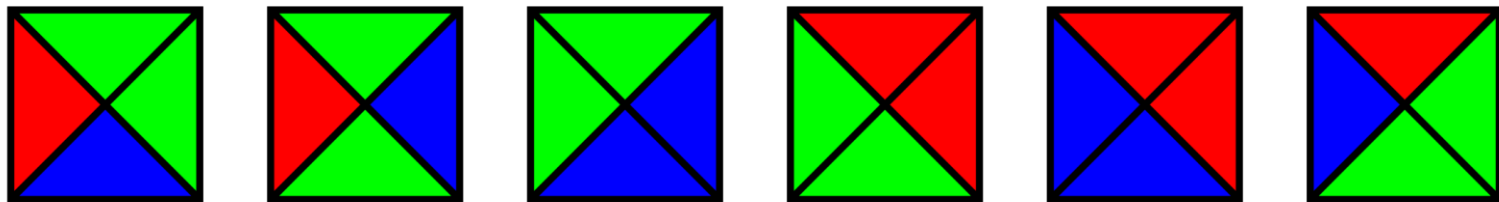


David Hilbert



Kurt Gödel





Bank of England

50

AA44 699671

£50

Final
m-config. Symbol Operations m-config.

q_i	S_j	PS_k, L	q_m	(N_1)
q_i	S_j	PS_k, R	q_m	(N_2)
q_i	S_j	PS_k	q_m	(N_3)

$q_1 S_0 S_1 R q_2; q_2 S_0 S_0 R q_3; q_3 S_0 S_2 R q_4; q_4 S_0 S_0 R q_1;$

100100011110000111101111

SPECIMEN

Alan Turing

Fifty Pounds

This is only a foretaste of what is to come
and only the shadow of what is going to be

Alan Turing 1912-1954



AA44 699671

The image shows a detailed architectural floor plan of a house, drawn in white lines on a blue background. The plan includes several rooms: a Family Room at the top, a Living Room (L.V.) in the center, a Kitchen (K) on the right, a Bathroom, a Bedroom, and a Hallway. There are also various closets, including a 'WALK-IN CLOSET' and a 'PROVIDE VENTILATION' area. The drawing is filled with technical annotations such as 'EXIST. BRICK WALL TO BE DEMOLISHED', 'EXIST. JOISTS', 'EXIST. WIND BRACKET', and 'EXIST. GUARD'. Dimensions are provided throughout, such as '13'-4"', '7'-0"', '7'-2"', '45'-8"', '6'-0"', '3'-2x4', '2x4 @ 16" O.C. (C.I.B.)', and '47'-0"'. The word 'Background' is written in a large, white, sans-serif font across the center of the image, partially obscuring the architectural details.

Sorting





Partition

Sorting

vs.

Partition

<0.01s

22 Players

<0.01s

Sorting

vs.

Partition

<0.01s

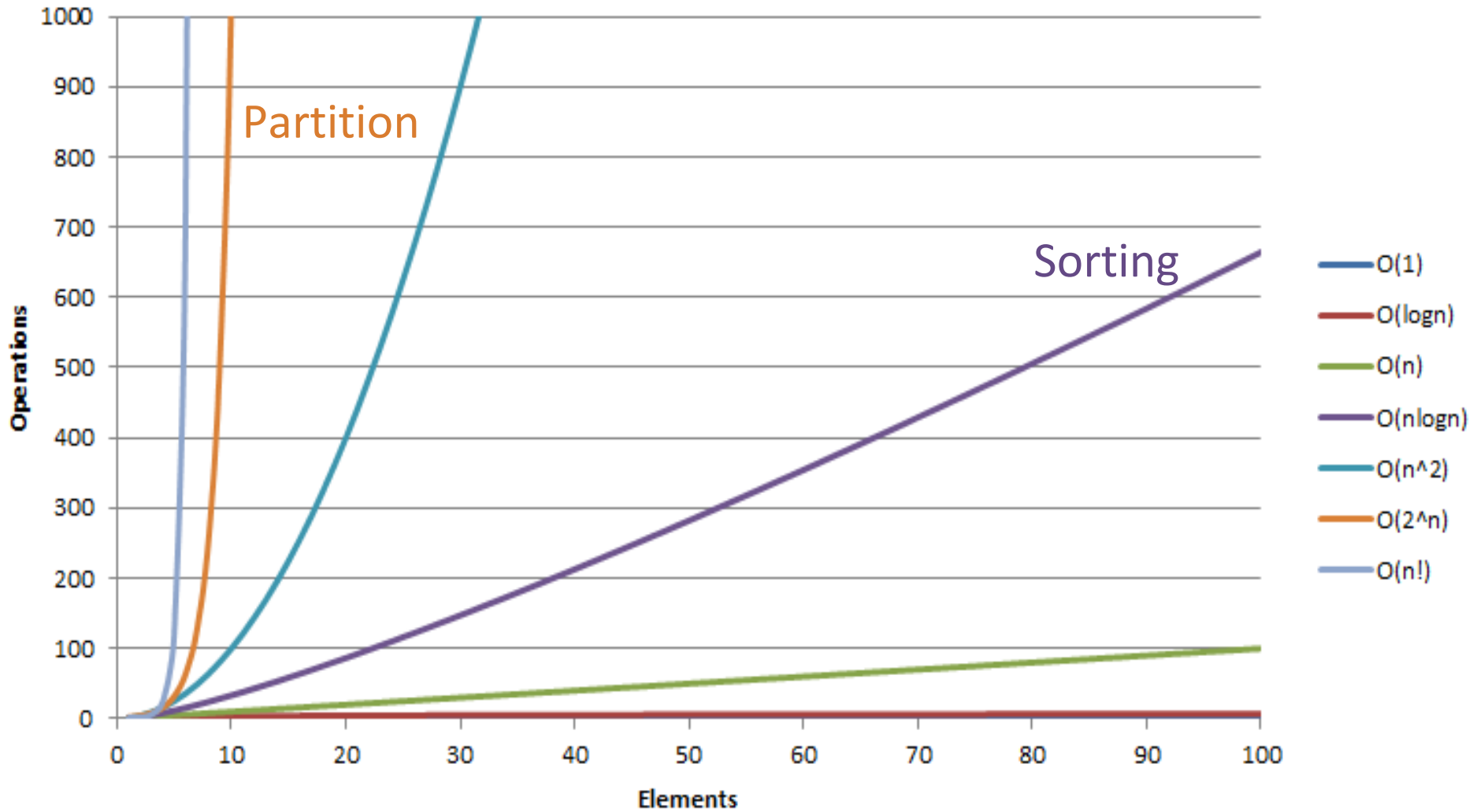
22 Players

<0.01s

<0.01s

222 Players

...



Bailouts are NP hard.*

*in some models.

The image shows a detailed architectural blueprint of a house, rendered in white lines on a blue background. The blueprint includes various rooms such as a Family Room, Kitchen, Bathroom, and Bedroom. It features numerous annotations, dimensions, and notes, such as 'EXIST. BRICK WIP TO BE DEMOLISHED', 'EXIST. JOISTS', and 'EXIST. GUARD'. The text 'Conditional Debt' is prominently displayed in the center in a large, white, sans-serif font. The overall style is that of a professional architectural drawing.

Conditional Debt

Debt = “Long” Position (Positive)



Conditional Debt = “Short” (Negative)

Short Positions

ABS: Asset-Backed Securities

CDO: Collateralized Debt Obligations

CDS: Credit Default Swaps

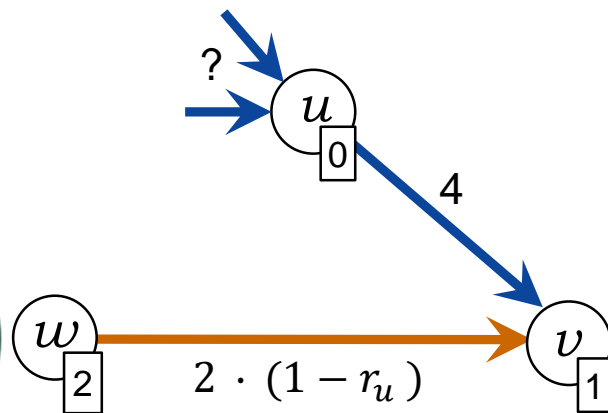
CLS: Collateralized Loan Obligations

MBS: Mortgage-Backed Securities

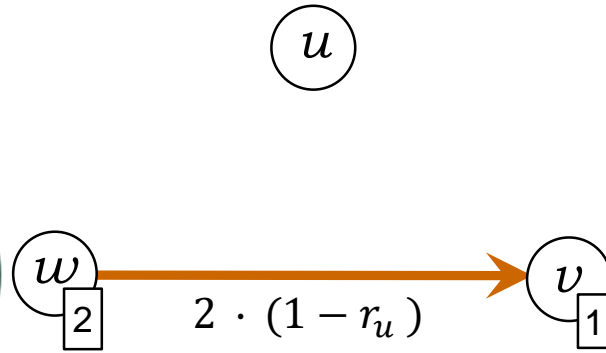
...

“Financial Weapons of Mass Destruction” (Warren Buffet)

Conditional Debt Contracts



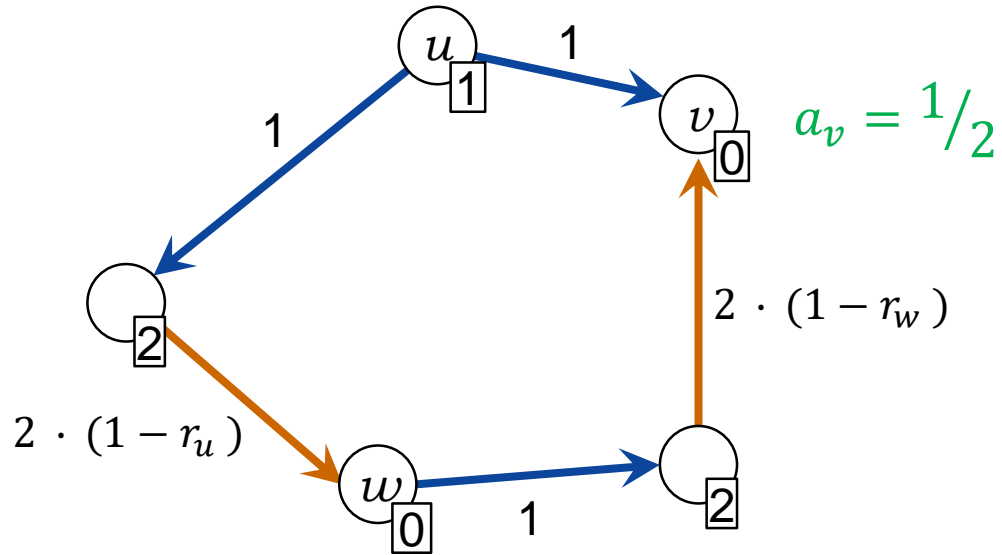
Conditional Debt Contracts



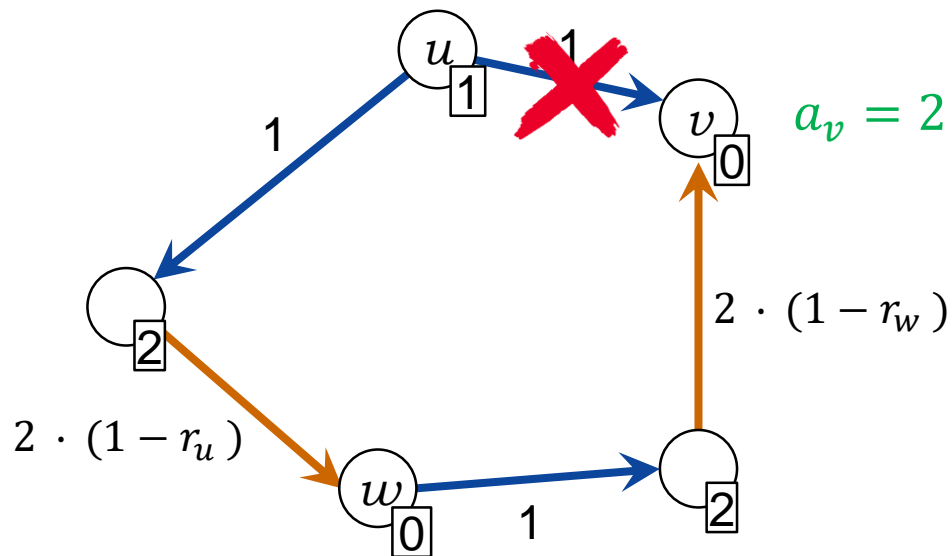
The image shows a detailed architectural blueprint of a house renovation project, rendered in white lines on a dark blue background. The blueprint includes various rooms such as a Family Room, Bathroom, and Bedroom, along with structural elements like beams (BM 2, BM 4) and joists. Annotations include dimensions, material specifications like 'EXIST. BRICK RIPUP TO BE DEMOLISHED', and notes about existing conditions like 'EXIST. JOISTS' and 'EXIST. GUARD'. A central white text overlay reads 'Improve Situation'.

Improve Situation

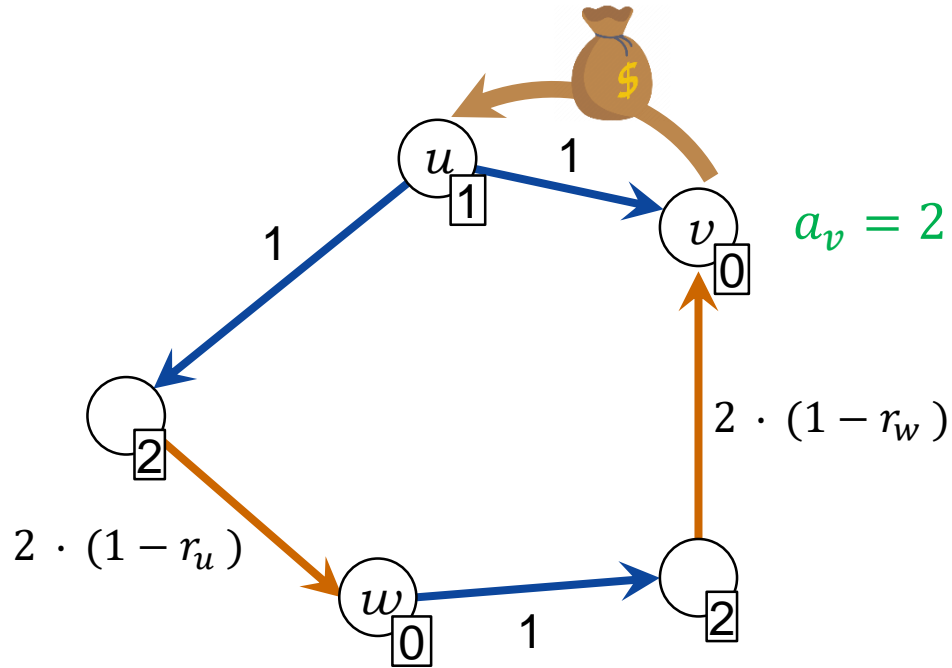
Can Bank v Improve?



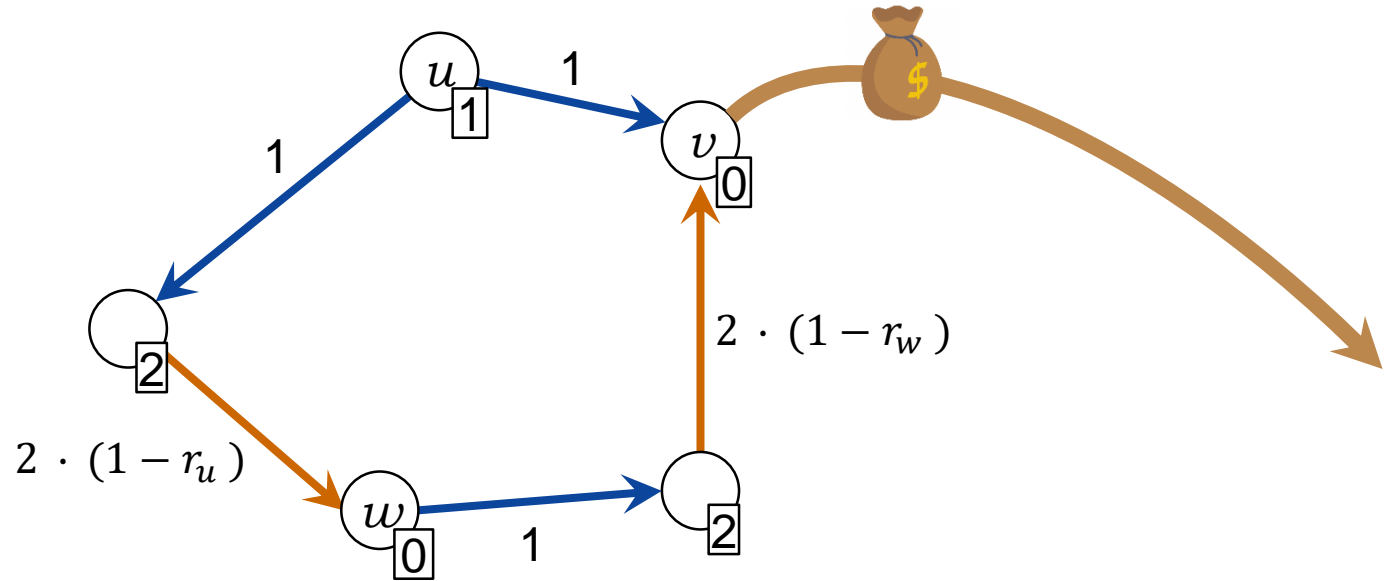
Can Bank v Improve?



Can Bank v Improve?



Can Bank v Improve?



A Loss Can Be a Win.

BUSINESS

How to Make Money for Nothing Like Wall Street

Credit default swaps might not be financial WMDs anymore, but Wall Street can still game them to make guaranteed profits.

MATTHEW O'BRIEN OCTOBER 24, 2013



The image features a complex architectural floor plan drawn in white lines on a dark blue background. The plan includes several rooms: a 'FAMILY ROOM' at the top, a 'BATHROOM' in the middle-right, and a 'BEDROOM' at the bottom. Other areas include a 'SHOWER', a 'WALK-IN CLOSET', and a 'HALL'. The drawing is filled with technical annotations such as 'EXIST. JOISTS', 'EXIST. BRICK WALL TO BE DEMOLISHED', 'EXIST. 2x4 @ 16" O.C.', and 'EXIST. 2x6 @ 16" O.C.'. Dimensions are provided throughout, including '13'-4"', '7'-0"', '7'-2"', '45'-8"', '6'-0"', '3'-2x4', '5'-0"', '4'-0"', '3'-2x4', '2x4 @ 16" O.C. (C.I.B.)', '47'-0"', and '17'-0" T.J.'. The word 'Optimization' is written in a large, white, sans-serif font across the center of the image, partially overlapping the architectural lines. The overall style is that of a professional architectural drawing.

Optimize What?

Preferred by highest
number of banks

Worst for a
specific bank

Most representative of
the solution space

Smallest amount of
total debt unpaid

Most balanced for two
alliances of banks

Best for a
specific bank

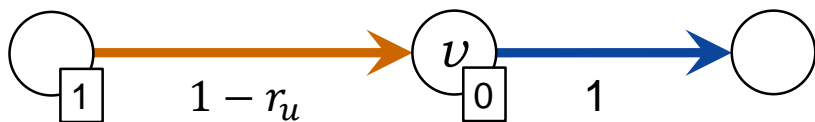
Smallest percentage
of liabilities in the
system unpaid

Smallest number
of defaults

All these (and more) are NP hard.

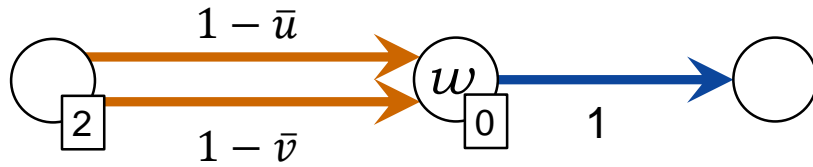
Building Circuits: NOT Gate

$$u \quad r_u \in \{0,1\}$$



$$r_v = NOT \ r_u$$

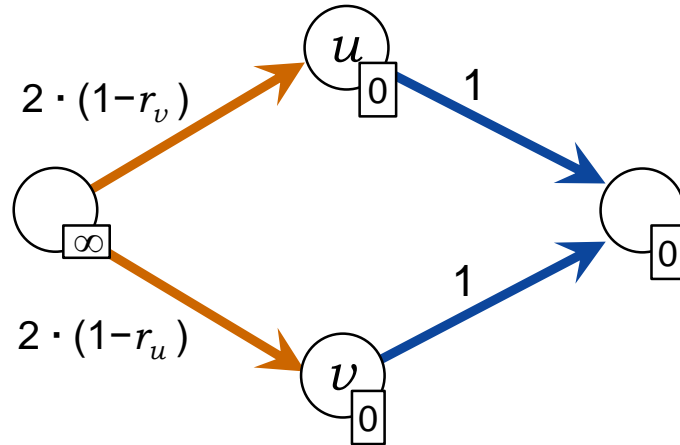
Building Circuits: OR Gate



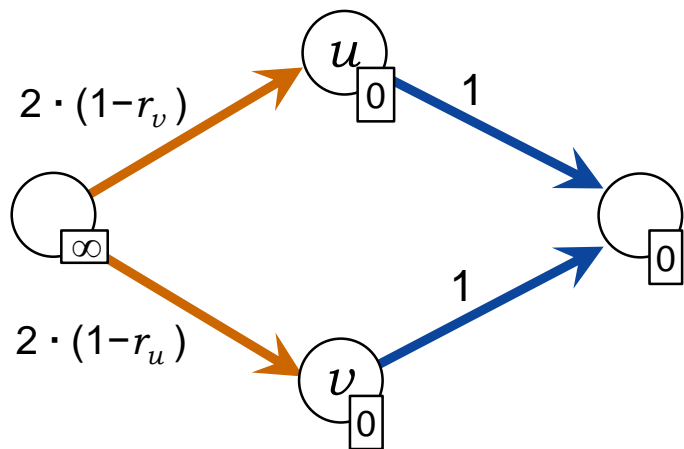
$$r_w = r_u \text{ OR } r_v$$

Financial Networks are Computers.

An Example



An Example

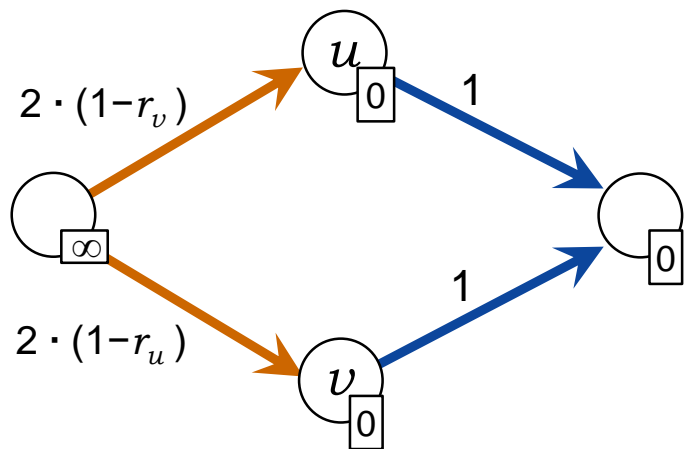


$$r_u = 0, r_v = 1$$

$$r_u = 1, r_v = 0$$

$$r_u = \frac{2}{3}, r_v = \frac{2}{3}$$

An Example



$$r_u = 0, r_v = 1$$

$$r_u = 1, r_v = 0$$

~~$$r_u = \frac{2}{3}, r_v = \frac{2}{3}$$~~

Resurrection!



Basic Properties

Defaults are reversible

Some equilibria not reachable

Might not stabilize

Depends on order of updates

Basic Properties

Defaults are reversible

Some equilibria not reachable

Might not stabilize → stabilization time?

Depends on order of updates → best order?

Basic Properties

Defaults are reversible

Some equilibria not reachable

Might not stabilize \rightarrow stabilization time? $\rightarrow \theta(2^n)$

Depends on order of updates \rightarrow best order?

Basic Properties

Defaults are reversible

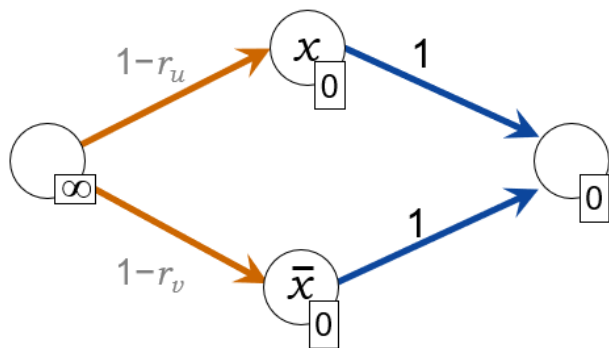
Some equilibria not reachable

Might not stabilize \rightarrow stabilization time? $\rightarrow \theta(2^n)$

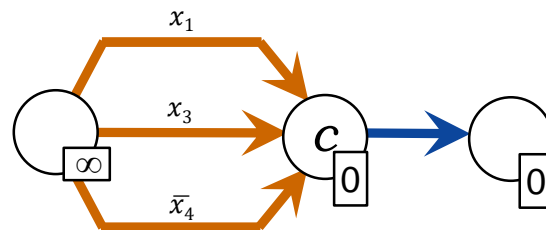
Depends on order of updates \rightarrow best order? \rightarrow NP-hard

Reduction from MAXSAT

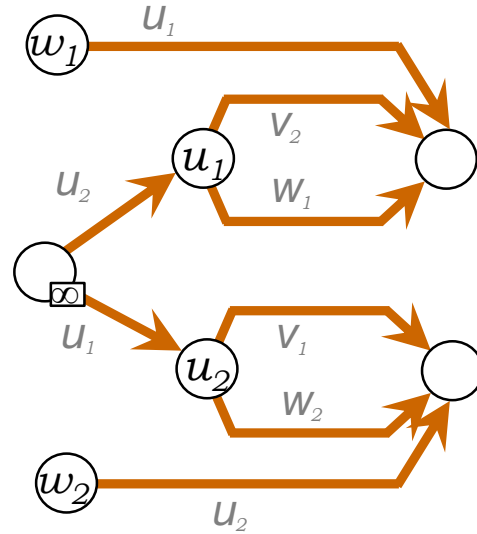
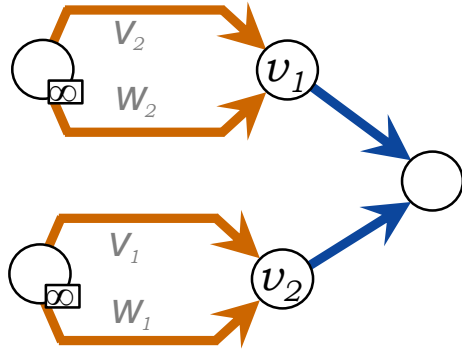
variables



clauses

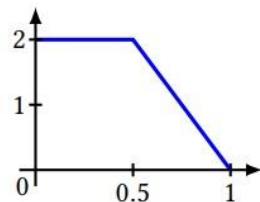
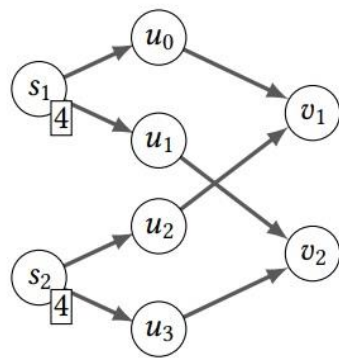
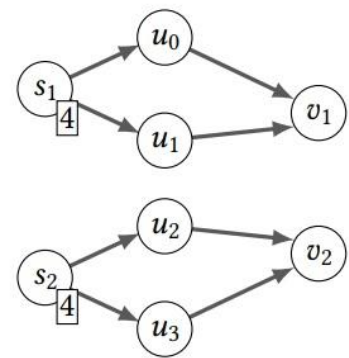


Best Order from Specific Point of View?

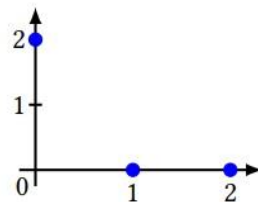


The image shows a detailed architectural blueprint of a house, rendered in white lines on a dark blue background. The blueprint includes various rooms such as a Family Room, Kitchen, Bathroom, and Bedroom. It features numerous annotations, dimensions, and notes, such as 'EXIST. BRICK WIP TO BE DEMOLISHED', 'EXIST. JOISTS', and 'EXIST. GUARD'. The text 'Reducing Risk' is prominently displayed in the center in a large, white, sans-serif font. The overall aesthetic is technical and professional, emphasizing the complexity of construction planning.

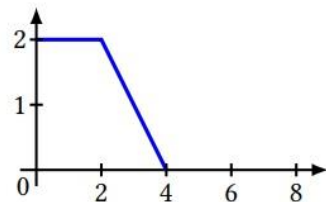
Reducing Risk



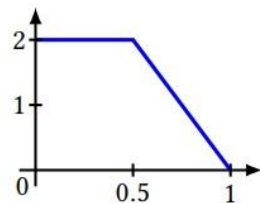
proportional



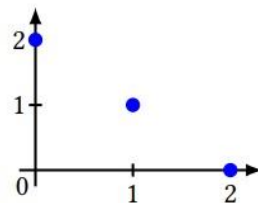
worst-set



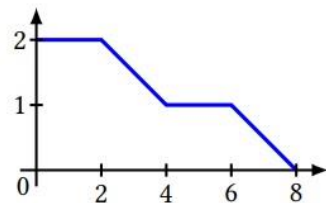
worst-sum



proportional



worst-set



worst-sum

Solution space		
	no default costs	default costs
long positions only	1 maximal solution Easy to find	1 maximal solution Easy to find
+ covered shorts	1 maximal solution Easy to find	1 maximal solution Easy to find
+ any shorts	<p>Many Pareto-optimal solutions</p> <p>Any/best one hard to find</p> <p><i>with money or cycle restrictions:</i> best one still hard to find</p> <p><i>with money+cycle restrictions:</i> unique solution, easy to find</p>	<p>Many Pareto-optimal solutions</p> <p>Any/best one hard to find</p> <p>Possibly no solution</p> <p><i>with money restrictions:</i> possibly no solution</p> <p><i>with cycle restrictions:</i> a solution always exists</p> <p><i>with money+cycle restrictions:</i> best one still hard to find</p>

In Short, What Regulators Should Do

No Uncovered Short Positions

Thank You!

Questions & Comments?

