

Linear

Programming

Announcements

Hwk due Saturday

My Offes: Wednesdays 11am
Soda 683

LP Recap

objective value = 9

(1, 4)

$$x + y = 5$$

$$x = 3$$

$$x + y \leq 5$$

$$y - 3x \leq 1$$

Feasible set

(3, 2)

(0, 1)

$$x \leq 3$$

(3, 0)

$$\begin{array}{l} \text{LP: } \max \quad x + 2y \\ \text{subject to} \quad x \leq 3 \\ \quad \quad \quad x + y \leq 5 \\ \quad \quad \quad -3x + y \leq 1 \\ \quad \quad \quad x \geq 0 \\ \quad \quad \quad y \geq 0 \end{array} \left. \vphantom{\begin{array}{l} \max \\ \text{subject to} \end{array}} \right\} \begin{array}{l} n \text{ vars} \\ m \\ \text{constraints} \end{array}$$

Fact: For all LPs, there is an optimal solution at a **vertex**

Def: A vertex is a point x in the polytope ($x \in$ feasible set) which lies at the intersection of n hyperplanes in n dimensions.

Fact: If $n = \# \text{ vars}$, $m = \# \text{ constraints}$
 $\# \text{ of vertices} \leq \underline{\underline{\binom{m}{n} \leq m^n}}$

Linear Programming Alg 1: "Try all vertices"

Given m constraints $C = \{ \sum a_{ij} x_j \leq b_j \}$

For each subset $S \subseteq C$ of size n :

1. Solve for the point of intersection x^*
(solving linear system / Gaussian elimination)
2. Check if x^* is feasible (satisfies all constraints)
3. If so, compute value of x^*

Output **best** vertex found

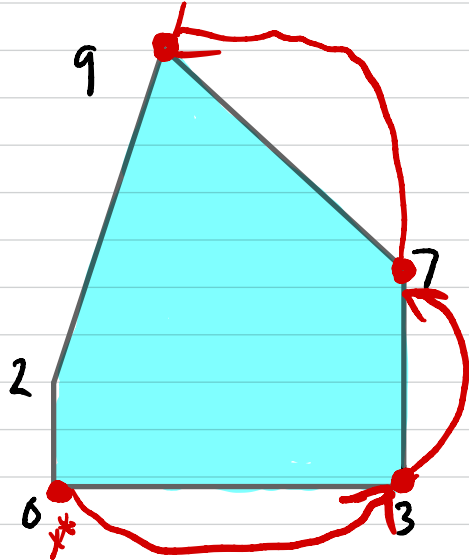
Time complexity $\geq \binom{m}{n} \approx m^n = \text{exponentially large in } n$

LP alg 2: Simplex

1. Start at a vertex x^*
2. Look at all "neighboring" vertices
3. Find neighbor y^* with best value
4. If y^* has a better val than x^* , move to y^* . Repeat.

$n=2$:

$n=3$: Constraints $\{A, B, C, D, E\}$



Vertex: (ABC)

Neighbors: ABD, ABE, ACD,
ACE, BCD, BCE

Fact: Suppose n vars, m constraints

of neighbors $\leq \frac{(m-n) \cdot n}{2} \leq m \cdot n$

sad fact: Simplex still exponential time
(in the worst case)

Thm: Linear Programs can be solved
in polynomial time.

[Khachiyan 1979]: Ellipsoid algorithm

[Karmarkar 1984]: Interior points
algorithm

"All the News That's Fit to Print"

The New York Times

NEW YORK, WEDNESDAY, NOVEMBER 7, 1979

LATE CITY EDITION

Winter: Many news, not today. Also, on page 10. Business: Many news, not today. Also, on page 10. Sports: Many news, not today. Also, on page 10. Deaths: on page A20.

VZJ-CXJXJ - No. 6136

Similar Transportation Bond Issues Are Passed in New York and Jersey

Con Ed Takeover Action Fails in Westchester — Simon Wins in Bronx

By FRANK LYNCH
New York and New Jersey voters yesterday in New York and New Jersey, while voting on an issue that was not on the ballot in New Jersey, but in New York, passed similar transportation bond issues. In Westchester County, voters rejected a measure to raise the county's debt ceiling to \$1 billion. In the Bronx, voters approved a similar measure to raise the county's debt ceiling to \$1 billion.

Simon Getting 50-50
Westchester County voters yesterday were split 50-50 on the issue of raising the county's debt ceiling to \$1 billion. In the Bronx, voters approved a similar measure to raise the county's debt ceiling to \$1 billion. The Bronx measure was approved by a 50-50 vote.

CARTER SAID TO ASK FOR LOYALTY CHECK OF AIDES ON POLITICS

Outer Implicated for Those Unwilling to Help Him Now — Strides to Head the Election '80

By FRANK LYNCH
President Jimmy Carter yesterday said he would ask for a loyalty check of his aides on politics. The president said he would ask for a loyalty check of his aides on politics. The president said he would ask for a loyalty check of his aides on politics.

Government's Role
The president's aides were asked to provide a list of their political activities. The president's aides were asked to provide a list of their political activities. The president's aides were asked to provide a list of their political activities.

IRAN'S CIVIL GOVERNMENT OUT; HOSTAGES FACE DEATH THREAT; OIL EXPORTS BELIEVED HALTED

STUDENTS WARN U.S. Ayatollah Instructs Council to Form a Cabinet



In Tehran, a demonstrator held up pictures with the faces of President Carter and the Shah of Iran superimposed on faces of victims of the firing squad.

Main Iran Oil Port Reported Closed And Prices of Spot Petroleum Soar

By ANTHONY FARRIS
Iranian demonstrators yesterday closed the United States' main oil port in the Persian Gulf, the Strait of Hormuz. The closure of the port is expected to cause a sharp rise in the price of oil. The price of oil is expected to rise sharply.

Oil Prices Soar
The price of oil is expected to rise sharply. The price of oil is expected to rise sharply. The price of oil is expected to rise sharply.

President Carter after announcing that Robert S. Strauss, right, would become his energy secretary. At left is the Secretary of State.

F.A.A. Seeks Fine of \$1.5 Million For 'Unairworthy' Braniff Flights

By RICHARD WITKIN
The Federal Aviation Administration yesterday announced it would seek a \$1.5 million fine from Braniff Airways for conducting hazardous flights. The FAA is seeking a \$1.5 million fine from Braniff Airways for conducting hazardous flights.

Agony Aids
The FAA is seeking a \$1.5 million fine from Braniff Airways for conducting hazardous flights. The FAA is seeking a \$1.5 million fine from Braniff Airways for conducting hazardous flights.

Interior Dept. Assaulted On Missing a Deadline For Species Protection

By PHILIP HENNING
The Interior Department yesterday was accused of missing a deadline for species protection. The Interior Department was accused of missing a deadline for species protection.

President Carter after announcing that Robert S. Strauss, right, would become his energy secretary. At left is the Secretary of State.

Soviet Discovery Rocks World of Mathematics

By MALCOLM W. BROWNE
A Soviet mathematician yesterday announced a discovery that rocks the world of mathematics. The Soviet mathematician announced a discovery that rocks the world of mathematics.

Energy Dept. Accuses 9 Refiners Of \$1.18 Billion Oil Overcharges

By RICHARD M. LYONS
The Energy Department yesterday accused nine oil refiners of overcharging. The Energy Department accused nine oil refiners of overcharging.

INSIDE

\$25,000 Scoops Oil Chief
A new report says that the oil industry has paid a \$25,000 bribe to an oil industry official. The oil industry has paid a \$25,000 bribe to an oil industry official.

A Soviet Discovery Rocks World of Mathematics

By MALCOLM W. BROWNE

A surprise discovery by an obscure Soviet mathematician has rocked the world of mathematics and computer analysis, and experts have begun exploring its practical applications.

Mathematicians describe the discovery by L.G. Khachiyan as a method by which computers can find guaranteed solutions to a class of very difficult problems that have hitherto been tackled on a kind of hit-or-miss basis.

Apart from its profound theoretical interest, the discovery may be applicable

in weather prediction, complicated industrial processes, petroleum refining, the scheduling of workers at large factories, secret codes and many other things.

"I have been deluged with calls from virtually every department of government for an interpretation of the significance of this," a leading expert on computer methods, Dr. George B. Dantzig of Stanford University, said in an interview.

The solution of mathematical problems by computer must be broken down into a series of steps. One class of problem sometimes involves so many steps that it

could take billions of years to compute.

The Russian discovery offers a way by which the number of steps in a solution can be dramatically reduced. It also offers the mathematician a way of learning quickly whether a problem has a solution or not, without having to complete the entire immense computation that may be required.

According to the American journal Science

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"All the News That's Fit to Print"

The New York Times

VOL. CXXIV... No. 46,232 Copyright © 1984 by The New York Times Company NEW YORK, MONDAY, NOVEMBER 19, 1984 39 CENTS



SOVIETS HELP TO DELIVER U.S. FARMER SUPPLIES In Romania, a Romanian soldier from the United States is loaded onto a Soviet helicopter to help deliver emergency grain.

Cocaine Traffickers Kill 17 in Peru Raid On Antidrug Team

LIMA, Peru, Nov. 18 — A band of cocaine traffickers last night in a surprise raid on a Peruvian antidrug team, killing at least 17 and capturing 10, according to a United States second program director on arrival in the port city here.

The raid on the team, which took place early Saturday, was reportedly the first of a series of operations aimed at the eradication of cocaine along the Peruvian coast.

Vote Comes to a 'Homeland' But African Problems Linger

BY ANAN COWELL
Special to the New York Times

WASHINGTON, Nov. 18 — A band of cocaine traffickers last night in a surprise raid on a Peruvian antidrug team, killing at least 17 and capturing 10, according to a United States second program director on arrival in the port city here.

AMERICANS IN POLL VIEW GOVERNMENT MORE CONFIDENTLY

But Postelection Inquiry Also Finds Most Think Reagan Will Ask Rise in Taxes

BY ADAM CULVER
The American public, on a level of confidence, has been more confident in the government since the election of Ronald Reagan than it has been in any other year since the end of World War II, according to a new survey by the Pew Research Center.

But the poll also found that most Americans believe that the government will ask for a raise in taxes in the next year.

Breakthrough in Problem Solving

BY JAMES GLEICK
A 21-year-old mathematician at A.T. Bell Laboratories has made a breakthrough in the study of complex systems.

Homeless Spend Nights in City Welfare Office

BY SARAH RIMMER
For the last 10 weeks, homeless families, mostly mothers and young children, have been sleeping in the city welfare office.

TREASURY MAY ASK INCREASES IN TAXES OF SOME CONCERNS

OTHERS COULD PAY LESS Unprecise Setup Would be Challenged — Little Support in Congress Expected

By DAVID E. ROSENBLUM
WASHINGTON, Nov. 18 — The Treasury will ask for a 10 percent increase in the top marginal rate of the income tax in 1985, according to a report by the Congressional Budget Office.

Albany Leaders Predicting a Cut In Income Taxes

By JOHN BARRELL
The Democratic and Democratic-in-Albany political community here is in a personal income tax battle that has been going on for some time.

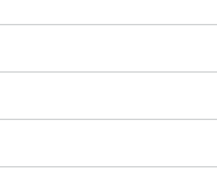
U.S. Grant Hits Aymaras

U.S. Grant hits Aymaras in the highlands of Bolivia, according to a report from the United States.

INSIDE

The With 6 Award Missing
A report with a shock and a surprise: the With 6 award is missing.

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The With 6 Award Missing
A report with a shock and a surprise: the With 6 award is missing.



Senator Bill Dole Predicting a Cut In Income Taxes

Senator Bill Dole, Republican of Kansas, predicts a cut in income taxes in the next year.

U.S. Grant Hits Aymaras

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Homeless people waiting at the Emergency Assistance Desk at 81 Charles Street in city welfare workers wait in line temporary space for them.

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NOVETS HELP DELIVER U.S. FARMER SUPPLIES IN Somalia. Helicopters from the United States are loaded onto a Soviet helicopter to help deliver emergency 'Aid'.

Cocaine Traffickers Kill 17 in Peru Raid On Antirug Team

LIMA, Peru, Nov. 18—A band of cocaine traffickers used a jungle of mountains to ambush a United States antirug team in a surprise raid on a Peruvian town, killing at least 17 people and capturing 10. The team was on its way to a meeting with a Peruvian official to discuss the drug trade...

Peru's defense forces half of the world's cocaine, the drug is sold in the United States. The traffickers are now being hunted down by the United States and Peru. The raid was a surprise attack on a Peruvian town...

High Cuban Defector Speaks Out, Denouncing Castro as 'Impulsive'

By LESLIE MATLAND WEBSTER. A Cuban defector who speaks in Cuba's largest newspaper says he has seen the Cuban leader, Fidel Castro, in a "highly impulsive" mood. He says he has seen Castro in a "highly impulsive" mood...

U.S. Grand Jury Asks. A grand jury in Washington subpoenaed the late Sen. Frank Lautenberg to testify before it on the activities of the late Sen. Frank Lautenberg. The grand jury is investigating the activities of the late Sen. Frank Lautenberg...

AMERICANS IN POLL VIEW GOVERNMENT MORE CONFIDENTLY

But Postelection Inquiry Also Finds Most Think Reagan Will Ask Rise in Taxes

By ADAM CLYMER. The American public, in a new survey, views the government more favorably than it did in a similar survey last year. The survey also found that most Americans believe that President Reagan will ask for a raise in taxes...

'Major Realignment' Seen. The survey also found that most Americans believe that there will be a major realignment of the political parties in the next election. The survey also found that most Americans believe that there will be a major realignment of the political parties...

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TREASURY MAY ASK INCREASES IN TAXES OF SOME CONCERNS

OTHERS COULD PAY LESS

Unpreparation Setup Would be Changed—Little Support in Congress Explored

By DAVID E. ROSENBLUM. WASHINGTON, Nov. 18—The Treasury department is studying proposals to raise the rates of some taxes and to reduce the rates of others...

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Senator Bob Dole

Albany Leads Predicting a Cut In Income Taxes

By JOHN BARANELL. The Republican caucus in the Albany Legislature has predicted a cut in income taxes. The caucus also predicted a cut in income taxes...

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Breakthrough in Problem Solving

By JAMES GLEICK. A 28-year-old mathematician at A.T. & T. Bell Laboratories has made a startling theoretical breakthrough in the solving of systems of equations that often grow too vast and complex for the most powerful computers.

Homeless Sleep Nights in City Welfare Office

By SARA RIMER. For the last 10 weeks, homeless families, mostly mothers and young children, have been spending weekend nights on plastic chairs, on countertops or on the floor in New York City's emergency welfare office because the city's welfare agency has run out of beds.



Homeless people waiting at the Emergency Assistance Center in New York City. Hundreds of city welfare workers try to find temporary space for them.

INSIDE

The With 6 Aboard Missing. A report with a aboard a missing plane was dropped on the floor of the New York City Police Department.

Musicals for City Opera. The New York City Opera has announced that it will be producing a series of musicals for the city opera.

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Breakthrough in Problem Solving

By JAMES GLEICK

A 28-year-old mathematician at A.T. & T. Bell Laboratories has made a startling theoretical breakthrough in the solving of systems of equations that often grow too vast and complex for the most powerful computers.

The discovery, which is to be formally published next month, is already circulating rapidly through the mathematical world. It has also set off a deluge of inquiries from brokerage houses, oil companies and airlines, industries with millions of dollars at stake in problems known as linear programming.

These problems are fiendishly complicated systems, often with thousands of variables. They arise in a variety of commercial and government applications, ranging from allocating time on a communications satellite to routing millions of telephone calls over long distances. Linear programming is particularly useful whenever a limited, expensive resource must be spread most efficiently among competing users. And investment companies use the approach in creating portfolios with the best mix of stocks and bonds.

Faster Solutions Seen

The Bell Labs mathematician, Dr. Narendra Karmarkar, has devised a radically new procedure that may speed the routine handling of such problems by businesses and Government agencies and also make it possible to tackle problems that are now far out of reach.

"This is a path-breaking result," said Dr. Ronald L. Graham, director of mathematical sciences for Bell Labs in Murray Hill, N.J. "Science has its mo-

ments of great progress, and this may well be one of them."

Because problems in linear programming can have billions or more possible answers, even high-speed computers cannot check every one. So computers must use a special procedure, an algorithm, to examine as few answers as possible before finding the best one—typically the one that minimizes cost or maximizes efficiency.

A procedure devised in 1947, the simplex method, is now used for such prob-

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Homeless Spent

By SARA RIMER

For the last 10 weeks, homeless families, mostly mothers and young children, have been spending weekend nights on plastic chairs, on countertops or on the floor in New York City's emergency welfare office because the city's welfare agency has run out of beds.

Other families have been waiting almost through the night while city welfare workers try to find temporary space for them in any of the 51 hotels scattered throughout Manhattan, the Bronx, Brooklyn and Queens that accept homeless families.

In some cases, the families leave the Manhattan office at 4 or even 5 A.M. for an hour's trip on the subway to hotels in the other boroughs that will require them to check out as early as 11 A.M. that same morning.