This is my once-in-a-lifetime chance to write a paper and its corresponding talk without being subject to the whims of the reviewers....
1970: E. F. Codd writes pioneering CACM paper

- All data should be in stored relations (tables - the simplest possible data structure)

- And accessed in a high level language (now SQL)

1970’s: System R (IBM) and Ingres (Berkeley) are full function Data Base Management System (DBMS) prototypes embodying Codd’s idea
The Land Sharks are on the Squawk Box

(Why Riding a Bicycle Across America and Building Postgres Have a Lot in Common)
Kennebago, ME: Summer 1993
Part 1: Off to a Great Start

- Cascades & Rockies
  Berkeley 1984-1986

- Minnesota to Pennsylvania
  Berkeley 1991-1993

- New York to Massachusetts
  Berkeley 1995

- North Dakota
  Berkeley 1986-1989

- Allegheny Mountains
  Berkeley 1994-1995

- Berkeley 1995

- The End

- The End
Anacortes, WA: Day 1 - June 4, 1988
Berkeley, CA: 1984

- Commercial Ingres is 4 years old
  - And much better code than academic Ingres
- Makes no sense to continue prototyping on our code line
- We push the code off a cliff, and start something new
- So what is Postgres to be?
Berkeley, CA: 1984

- Abstract Data Types (ADTs)
  
  - Ingres, System R were focused on business data processing (competing against IMS and Codasyl)
  
  - Motivated by a large collection of papers of the form:
    
    - “we tried RDBMS on X; it didn’t work, so we added Y to the relational model”
**Example from GIS**

<table>
<thead>
<tr>
<th>name</th>
<th>age</th>
<th>xmin</th>
<th>xmax</th>
<th>ymin</th>
<th>ymax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sam</td>
<td>38</td>
<td>100</td>
<td>220</td>
<td>46</td>
<td>87</td>
</tr>
</tbody>
</table>

Find me all employees who overlap a specific (14, 17, 0, 16) rectangle?

Select name where
xmin < 17 and xmax > 14 and
ymin < 16 and ymax > 0

*Messy and very difficult to optimize!!!
## Better Solution

<table>
<thead>
<tr>
<th>name</th>
<th>age</th>
<th>location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sam</td>
<td>38</td>
<td>Internal representation for a box</td>
</tr>
</tbody>
</table>

Select name where location Overlaps MakeBox (14, 17, 0, 16)
In General

User-defined data types (Rectangle)
User-defined operators (Overlaps)
User-defined functions (MakeBox)

Requires adding functions to DBMS engine and calling them at appropriate times during query execution…
The Devil is in the Details

- Using new types in indexes (B-trees, hashing)
- New indexes (e.g. R-trees)
- Teaching the query optimizer about new types
- Specifying commutativity rules
- Optimization of “not”
- And others
Winthrop, WA: Day 3
Rainy Pass, WA: Day 3
Washington Pass, WA: Day 3
Berkeley, CA: 1985-86

- Chris Date wrote a pioneering paper on referential integrity
- Basically what to do with foreign-key-primary-key constraints
What happens if you delete the Candy department?
Date’s Solution

- Cascade the delete
- Replace dept by “null”
- Refuse the delete

- Plus three corresponding actions on inserts
My Idea: A Single Mechanism

- Referential integrity
- Triggers (make sure a salary update to Sam gets cascaded to Bill)
- Integrity constraints (salaries must be non-negative)
My Solution

- Update ALWAYS command
- Make sure Bill has the same salary as Sam

  - Update ALWAYS (set salary = E.salary)
    where E.name = “Sam” and
    name = “Bill”

  - Semantics: the command appears to be perpetually running

- Somewhat cleaner than an if-then rules system....
Traditional DBMS Crash Recovery

Two data stores with different access engines, which must be carefully synchronized!!

Log code is complicated and ugly!
Postgres Picture: No Overwrite

DBMS

Data + Log

Gets rid of crash recovery code!
Provides “time travel” in addition
The Devil is in the Details

- Log is “write optimized”
- Data is “read optimized”
- No overwrite must be competitive - tricky placement problem
Postgres Game Plan

- ADTs
- Rules using an “always” command
- No overwrite storage

- There was other (less important) stuff...
  - Complex objects
  - Inheritance
Part 2: Things Aren’t Going Well

Cascades & Rockies
Berkeley
1984-1986

Minnesota to Pennsylvania
Berkeley
1991-1993

New York to Massachusetts
Berkeley
1995

North Dakota
Berkeley
1986-1989

Allegheny Mountains
Berkeley
1994-1995

The End
Berkeley
1995

The End
Drake, ND: Day 26
Berkeley, CA: 1986-87
Reality Sets In

• Lisp is a disaster
  – Lots of code over the cliff
• ADT system works well
  – Multiple semantics for time
• Time travel has promise, but is a tricky to tune
• “Always” doesn’t work
  – Lots of code over the cliff
  – And we go back to a exploring a conventional rule system
Berkeley, CA: 1986-90
Reality Sets In

• The “Wine Connoisseur” and I spend a lot of time on:
  – How complex can complex objects be
  – What to do about time travel, rules, ...

• Next 3 years was a lot of “repair”
  – Think of this as a “slog through the swamp”
Part 3: Another High Point

- Cascades & Rockies
  Berkeley
  1984-1986

- Minnesota to Pennsylvania
  Berkeley
  1991-1993

- New York to Massachusetts
  Berkeley
  1995

- The End
  Berkeley
  1995

- North Dakota
  Berkeley
  1986-1989

- Allegheny Mountains
  Berkeley
  1994-1995

- The End
Carrington, ND: The Next Afternoon
Serendipity
In the DBMS field, the ultimate arbiter of good ideas is the commercial marketplace.

In my opinion, technology transfer is best done through a startup:
  – Large companies have their own agenda
  – Read “The Innovators Dilemma” by Clayton Christensen
Recruited “Mom” and her husband “Short One”
“EMP1” and “Quiet One” came over from the academic team, joined shortly thereafter by “Triple Rock”
With the “Tall Shark” as interim CEO and lead investor
We were off and running – converting the query language from QUEL to SQL, hardening the code and improving performance
Luddington, MI: Day 38
Berkeley, CA: 1993-94

- After a couple of miscues, we are named Illustra
- Got the first few customers
- Raised more money (see slide 1)
- Hired “Voice of Experience”, “Uptone” and “Smooth” -- a real management team
- The future is looking up....
Part 4: Another Low

- Cascades & Rockies
  Berkeley
  1984-1986

- Minnesota to Pennsylvania
  Berkeley
  1991-1993

- New York to Massachusetts
  Berkeley
  1995

- Allegheny Mountains
  Berkeley
  1994-1995

- North Dakota
  Berkeley
  1986-1989

- The End
  Berkeley
  1995

- The End

Database Group
MIT Computer Science and Artificial Intelligence Lab
Ellicottville, NY: Day 49
Reality Sets In

• Catch-22 between customers and ADT providers
  – Customers wanted ADTs from the large app vendors
  – App vendors wanted a distribution channel

• The dreaded “down round”
  – “a fate worse than death”
Troy, NY: Day 56
The Last Hill
Berkeley, CA: 1995
Serendipity

• The internet is taking off
• “Uptone” turns the company on a dime and we become “the database for cyberspace”
• Get a lot of buzz
• Maybe we have turned the corner
Part 6: More Challenges

- Cascades & Rockies
  Berkeley 1984-1986

- Minnesota to Pennsylvania
  Berkeley 1991-1993

- New York to Massachusetts
  Berkeley 1995

- North Dakota
  Berkeley 1986-1989

- Allegheny Mountains
  Berkeley 1994-1995

- Berkeley 1995

The End
Berkeley, CA: 1995
Reality Sets In (Again)

• The internet bake off

• On business data processing data!!!!
  – Transaction processing is not in our “wheelhouse”
Part 7: The Ending

Cascades & Rockies
Berkeley
1984-1986

Minnesota to Pennsylvania
Berkeley
1991-1993

New York to Massachusetts
Berkeley
1995

North Dakota
Berkeley
1986-1989

Allegheny Mountains
Berkeley
1994-1995

Berkeley
1995
Wollaston Beach, MA: Day 59
Berkeley, CA: February 1996  
Serendipity

• Illustra is purchased by one of the elephants
  – Solves the Catch-22 on ADTs
  – Solves the transaction processing problem

• We set about putting Illustra features into their system
Why Tell a Bicycle Story?

Algorithm for a cross-country bike trip:

Until (ocean) {
    get up in the morning;
    ride east;
    persevere and overcome any obstacles that arise;
}
A Bit of Abstraction...

Until (GOAL) {
    get up in the morning;
    ACTION;
    persevere and overcome any obstacles that arise;
}
And a Macro

Make It Happen
Why Would Anybody Want to Ride Across America?

• Long and hard
• Periods of depression and elation
• Lots of monotony (slogging through the swamp)
My Career

Make It Happen (PhD) – 5 years
Make It Happen (tenure) – 5 years
Make It Happen (bike ride) – 2 months
Building Postgres Required
Make It Happen

Have a good idea (or 2 or 3)
Make it Happen (prototype)
Start a company
Hire superb implementers
Hire talented execs
Make It Happen (product)

(Have a good idea then
Make It Happen for 10 years)
Summary

What Do Riding Across America and Building Postgres Have in Common?

Make It Happen

Serendipity
The Following 39 Berkeley Students and Staff Wrote Postgres
(with data model collaboration from Larry Rowe)

Jeff Anton, Paul Aoki, James Bell, Jennifer Caetta, Philip Chang, Jolly Chen, Ron Choi, Matt Dillon, Zelaine Fong, Adam Glass, Jeffrey Goh, Steven Grady, Serge Granik, Marti Hearst, Joey Hellerstein, Michael Hirohama, Chin-heng Hong, Wei Hong, Anant Jhingren, Greg Kemnitz, Marcel Kornacker, Case Larsen, Boris Livshitz, Jeff Meredith, Ginger Ogle, Mike Olson, Nels Olsen, Lay-Peng Ong, Carol Paxson, Avi Pfeffer, Spyros Potamianos, Sunita Surawagi, David Muir Sharnoff, Mark Sullivan, Cimarron Taylor, Marc Teitelbaum, Yongdong Wang, Kristen Wright, and Andrew Yu