Hancock: A Language for Extracting Signatures from Data Streams

Kathleen Fisher

Karin Högstedt

Anne Rogers

Fred Smith

AT&T

AT&T Infolab

Networks:

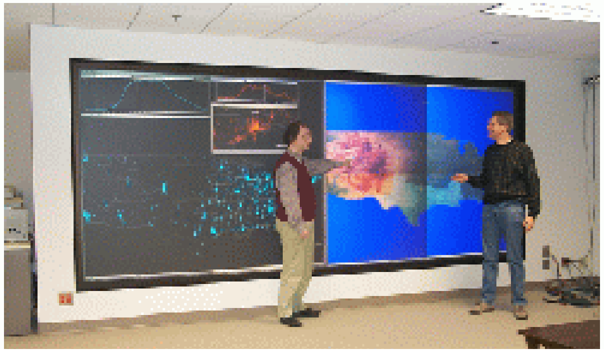
- Long distance
- Frame Relay
- ATM
- IP

Applications:

- Manage Network
- Prevent/Detect Fraud
- Understand Customers

Challenge:

To convert this data into useful information.



Whole data analysis

Individualized analysis: Signatures

- Anomaly detection: fraud, access arbitrage, etc.
- Classification problems: target marketing, biz/res, etc.

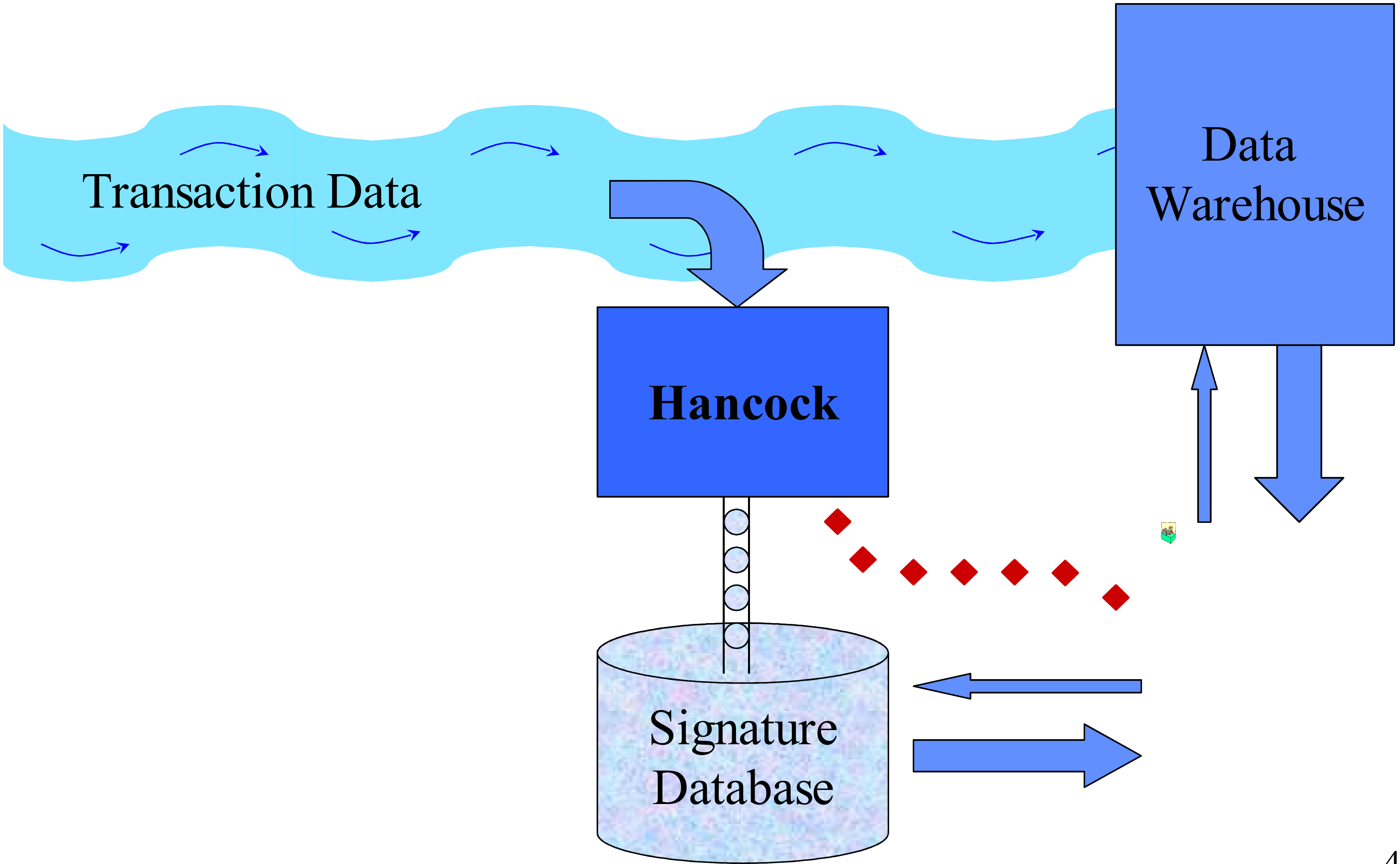
Technical challenge:

- Massive data sets and real-time queries $\Rightarrow$
  Hard I/O and storage requirements $\Rightarrow$
  Complex programs (hard to read, write, and maintain).

Solution:

- A system that reduces the complexity of signature programs.

Processing transactions



Evolution of fraud detection

Country-based thresholds:

- Aggregate calls in 1/4/24 hour windows.
- Compare aggregates to fixed thresholds.
- Exclude common false positives.

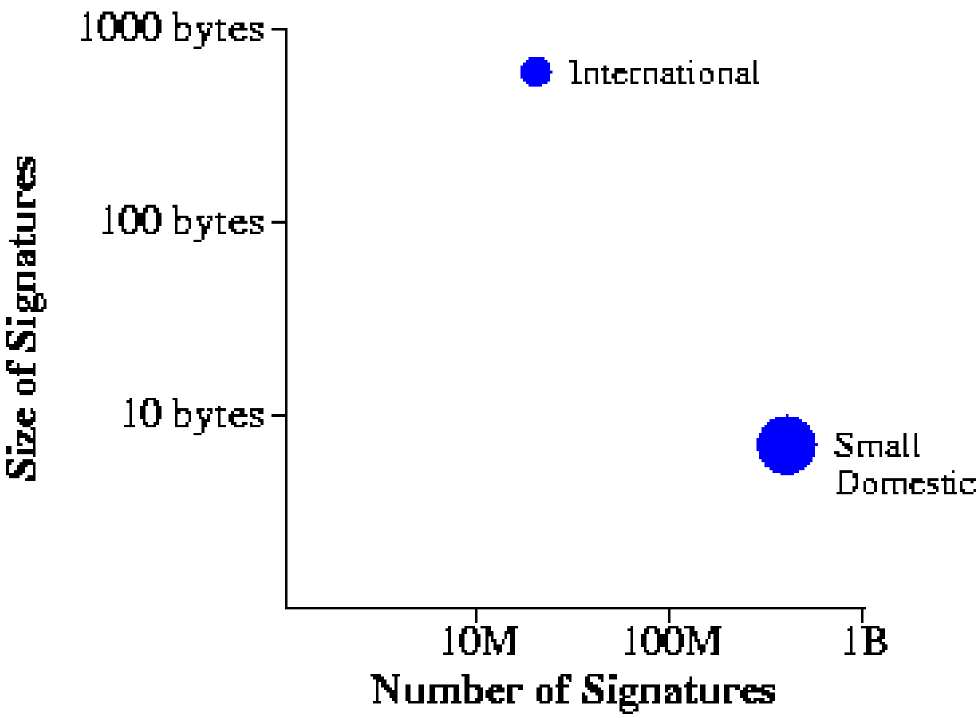
International signatures:

- Signature is an evolving profile.
- Match calls against the customer's and known fraud signatures.

Domestic signatures?

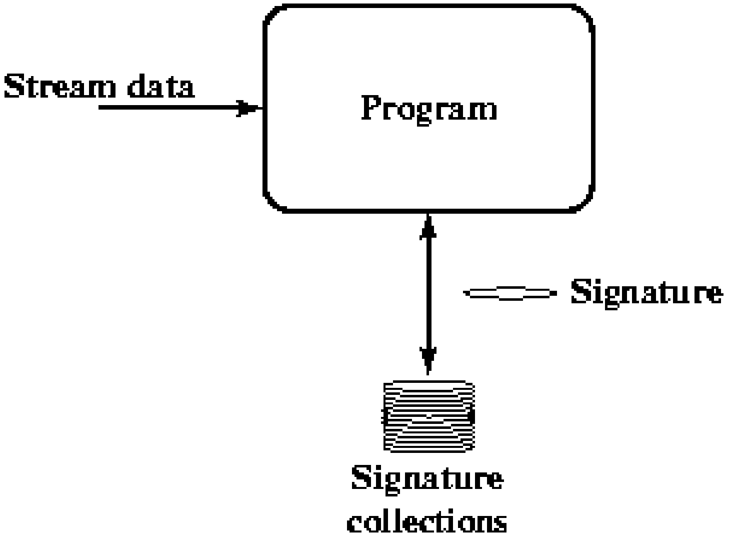
- Much larger scale…

Problem scale



Computational issues

Efficiently managing communications-scale data requires substantial programming expertise.

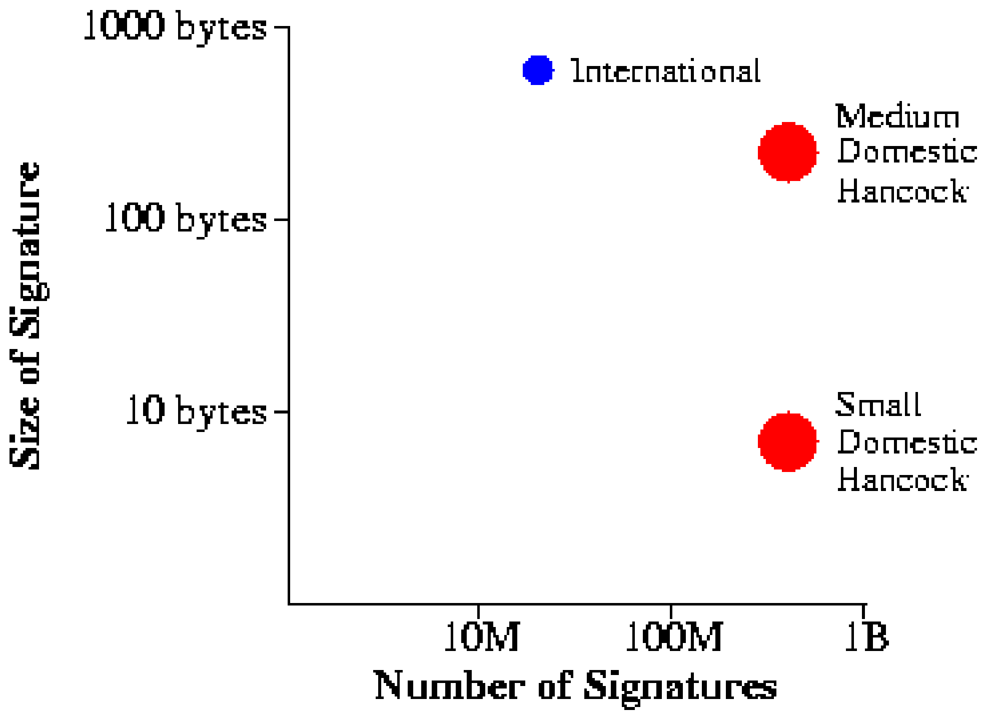


Locality, locality, locality!

Hancock

- Identified abstractions for computing with large data streams.
- Embedded these abstractions in Hancock, a C-based domain-specific programming language.
- Built experimental and production signatures using a number of different data streams.
- Intended as an experiment in practical language design.

Concrete results



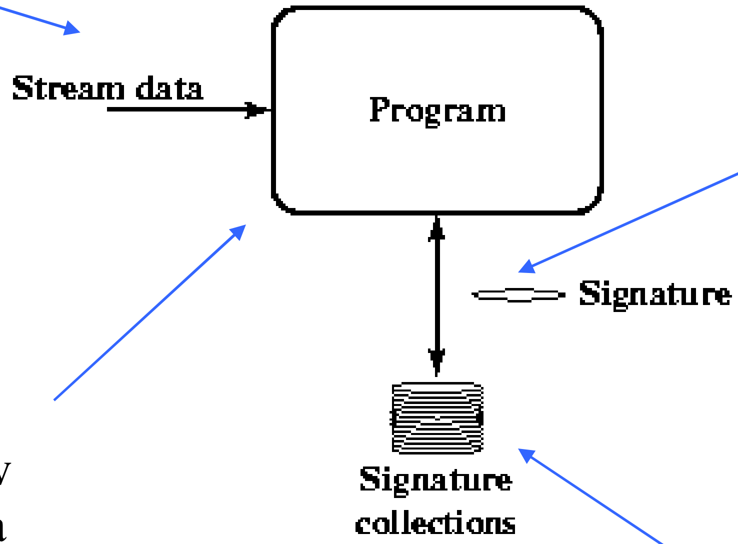
Outline

- Introduction
- Language overview
- Implementation overview
- Conclusions

Abstraction overview

Streams. The transactional data to be consumed "daily."

Views. The information to store for each "customer."



Iterate statement. How to combine today's data with historic signatures and other data.

Maps. The collection of customer signatures.

Hancock maps

- Persistently associate data with keys.
- Support direct addressing, programmable defaults, and a customized, compressed format.

```
map sig_m {
   key 1999999999LL .. 9999999999LL;
   split (10000, 100);
   value sig_t;
   default SIG_DEFAULT;
   compress sig_compress;
   uncompress sig_uncompress;
};
```

Map operations

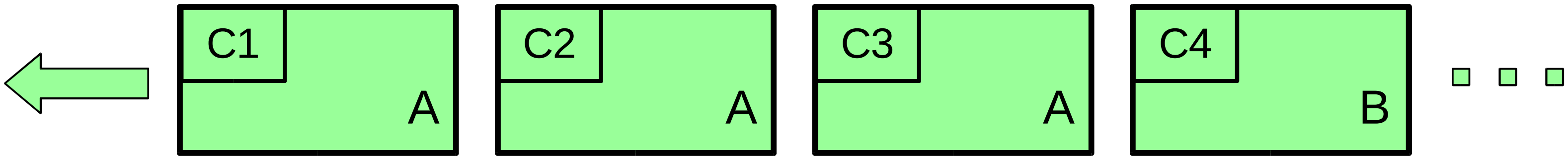
- Supported: read, write, test, remove, iteration, and copy.

```
sig_m  myMap = “data/myMap”;
long long      id1, id2;
sig_t    oldS, newS;

oldS = myMap<:id1:>;          /* read id1’s old data     */
                 ⋮
myMap<:id1:> = newS;        /* write id1’s new data    */

if (myMap@<:id2:>)           /* test if id2 is in myMap */
    myMap\<:id2:>;            /* remove id2’s data       */
```

- Unsupported: atomic transactions, locking, secondary indices, declarative queries.

Computation model

- Detect “events of interest” in transactional stream; respond to those events.



begin_line(A)
call(C1)

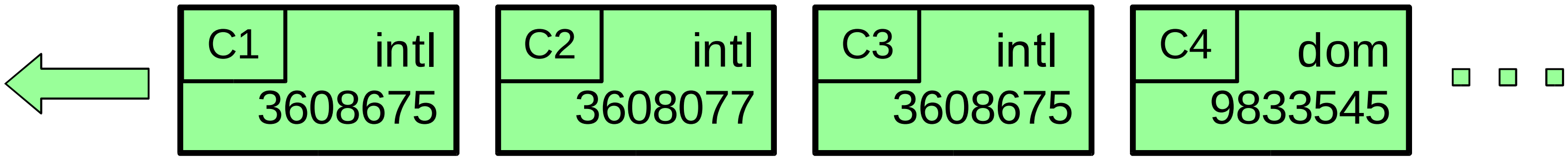
call(C2)

call(C3)
end_line(A)

begin_line(B)
call(C4)
end_line(B)

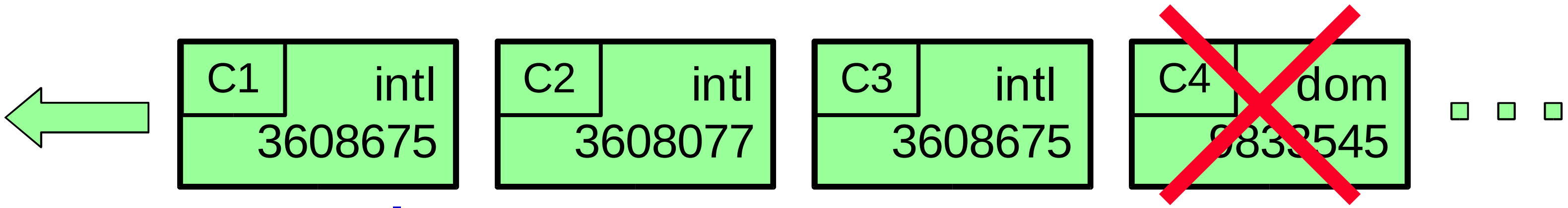
- Hancock’s iterate statement
  – prepares stream for computation,
  – separates event detection from event response, and
  – generates scaffolding code.

Iterate statement




```
Iterate
  over          calls
  filteredby    onlyInternational
  sortedby      origin
  withevents    detectCalls
{
    event  line_begin (pn_t pn) { … }
    event  call (callRec_t c)
{ … }
    event  line_end (pn_t pn)    { … }
 }
```

Iterate statement

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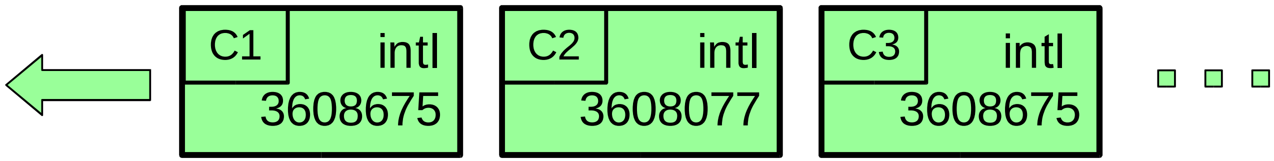


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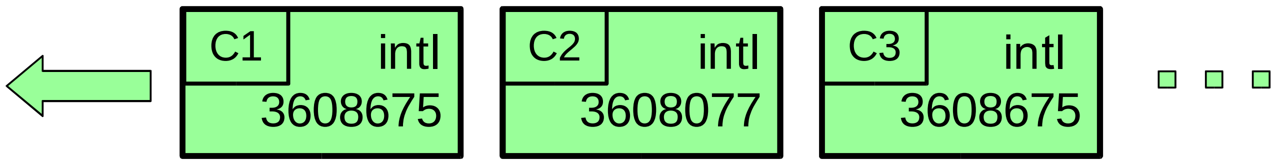


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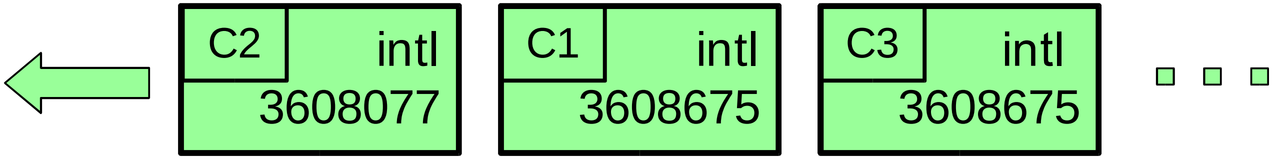


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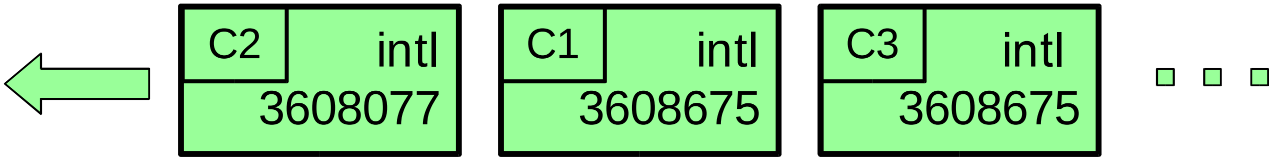
Iterate statement

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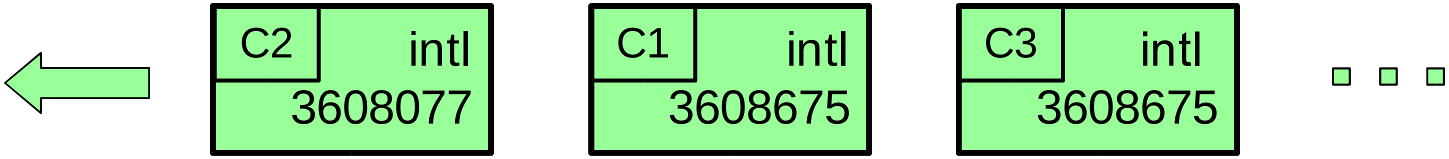

line_begin(...)
call(C2)
line_end(...)

line_begin(…)
call(C1)

call(C3)
line_end(...)

```
Iterate
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{ … }
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 }
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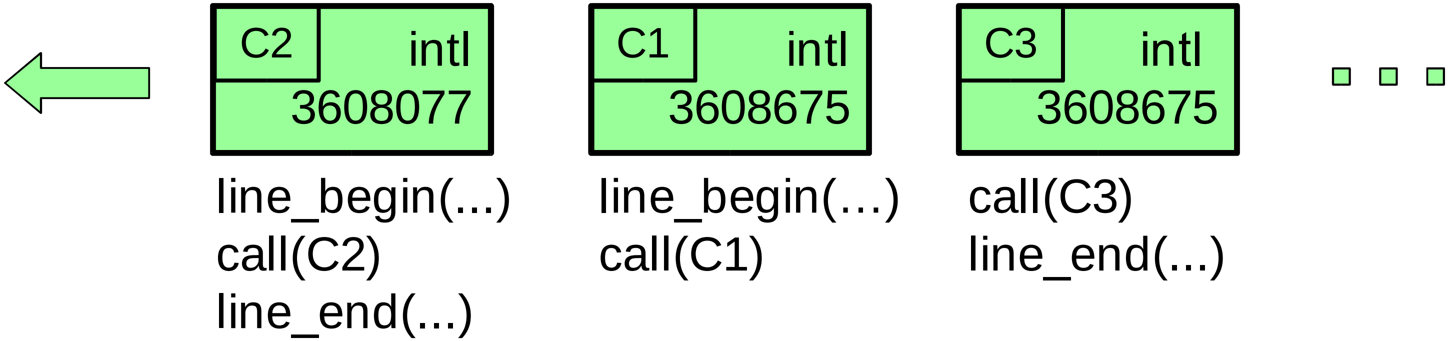


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```
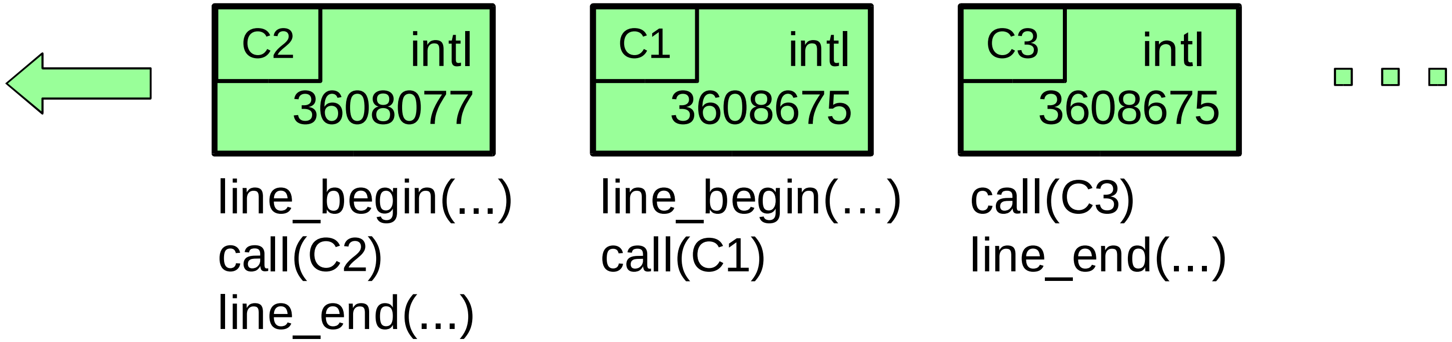
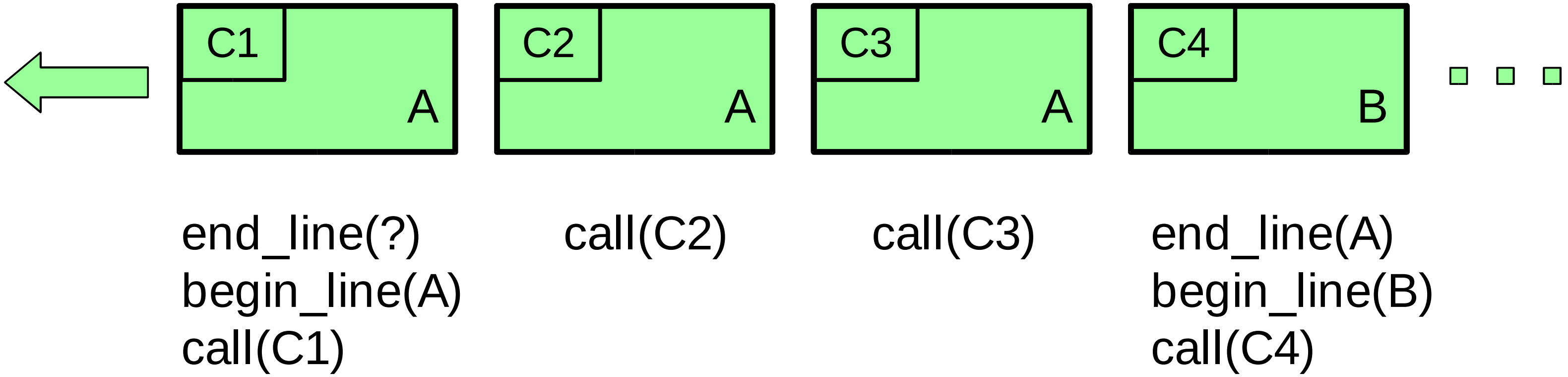

Iterate statement




```
Iterate ...
 {
   event line_begin(pn_t pn)  { numToday = 0; }
   event call(callRec_t c)         { numToday++; }
   event line_end(pn_t pn)       { numCalls<:pn:> =
                                             0.8 * numCalls<:pn:> + 0.2 * numToday;
}
 }
```

Result: Cleaner code

- Hand-coding results in complex event detection code that obscures simple event response code:



Representing events

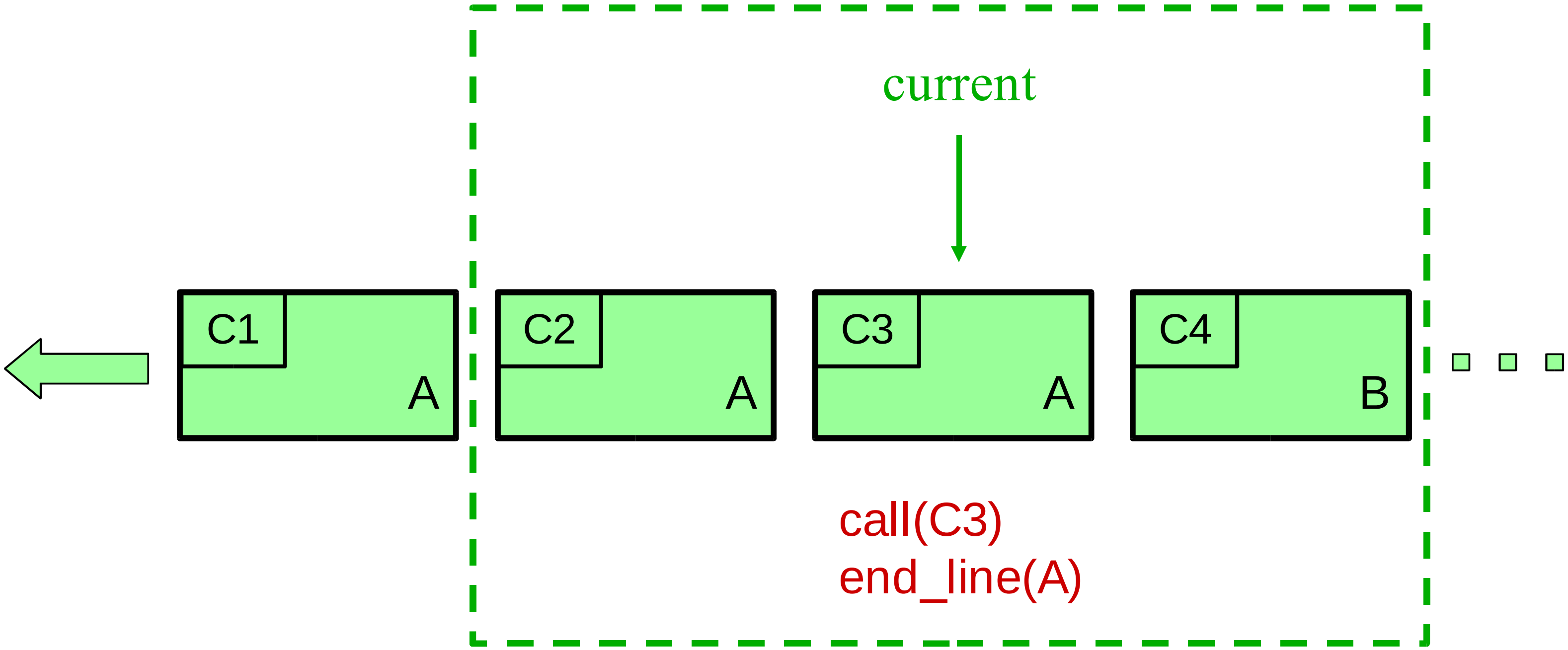
- Hancock's multi-union (munion): A set of labels and associated values.

```
munion line_e {:
   pn_t          begin_line,
   callRec_t     call,
   pn_t          end_line,
:};
```

- Supported operations: value construction, right-dominant union, test for label, access value, difference, and remove.

Detecting events

- An event detection function:
  - takes a window onto a stream
  - returns a munion that describes the detected events.



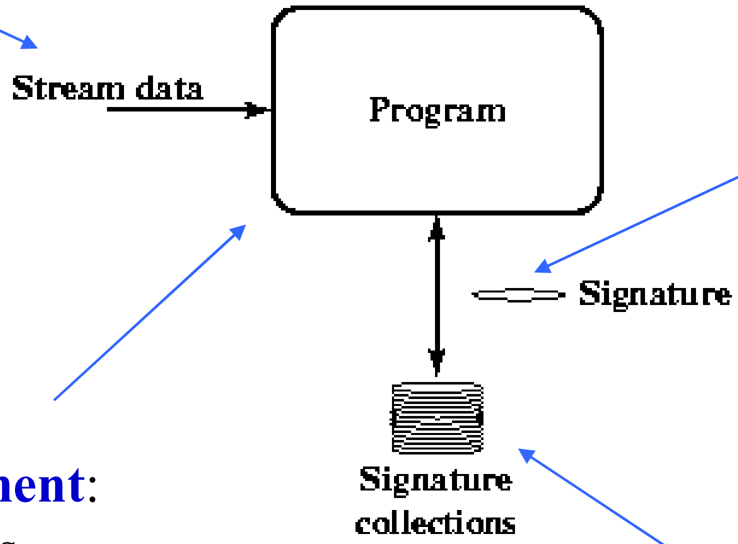
Event detection example

```
line_e originDetect(callRec_t *w[3:1]){
        line_e b, e;
         callRec_t *prev, *current, *next;
        prev = w[0];
        current = w[1];
         next = w[2];
        b = beginLineDetect(prev, current);
        e = endLineDetect(current, next);
        return     b :+: {: call = *current :} :+:
e;
:};
```

Code sizes

Streams: 110 to 250 lines.

Views: 5 to 30 lines.



Iterate statement: 70 to 330 lines.

Maps: 5 to 200 lines.

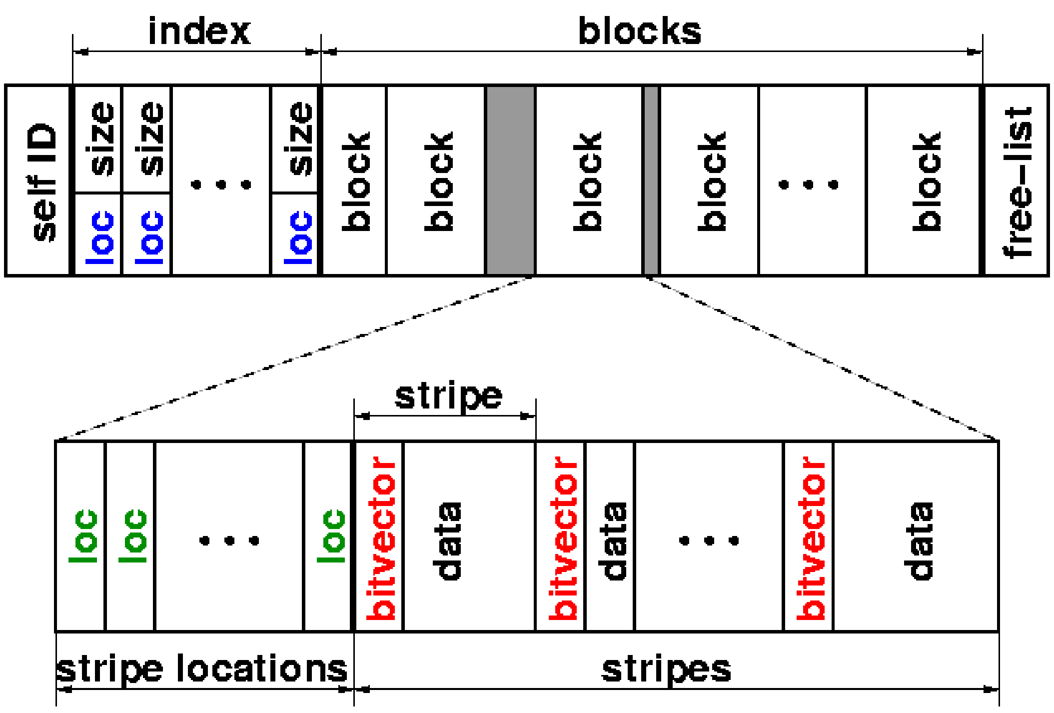
Implementation

- Compiler:
  - Based on CKIT C-to-C translator (SML/NJ).
- Runtime system:
  - Written in C.
  - Map representation is essentially a stripped-down database.
  - Goal: balance space limits against access-time requirements.

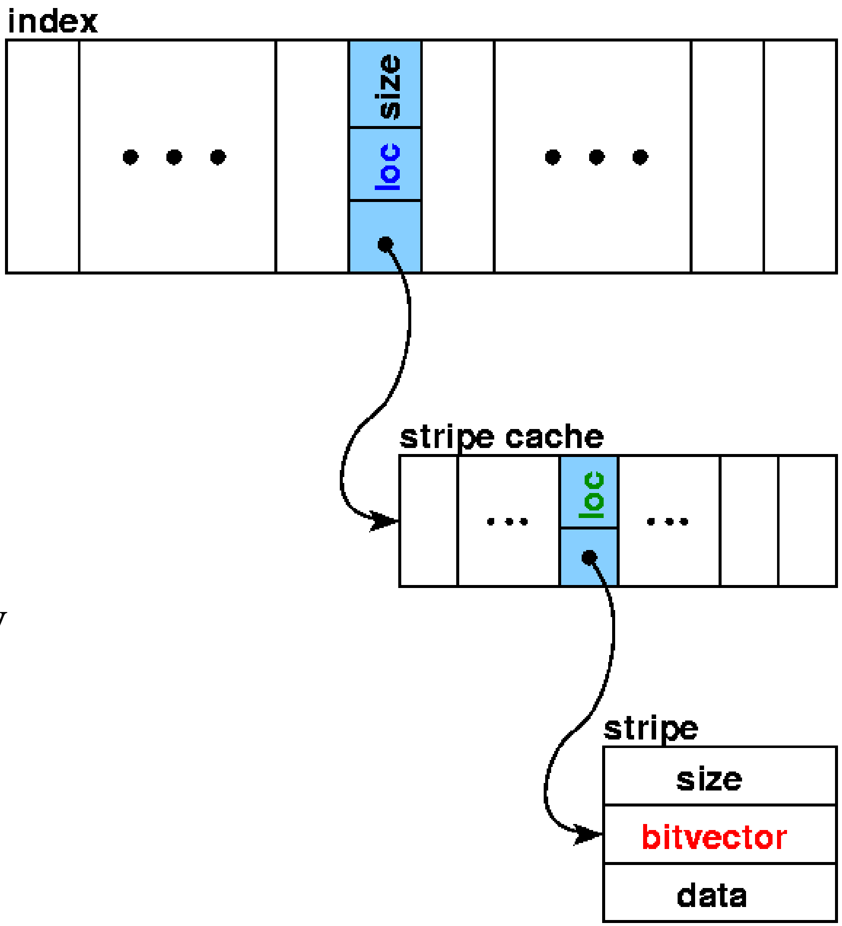
- Available for non-commercial use.

Maps: On-disk representation

Multi-level table. Key split into three pieces: block, stripe, entry.
(973360 86 75)



Maps: In-memory representation



Map index and compressed stripe cache kept in memory (973360 86 75).

Performance requirements

Process transactions:	< ½ batch window	
Select single key:	web time	(1 second)
Select worklist:	coffee break time	(5 minutes)
Touch all values:	lunch time	(1 hour)

Experimental setup

- Platform:

  R12000 processor (SGI Origin 2000).

  32-KB primary cache/8-MB secondary cache

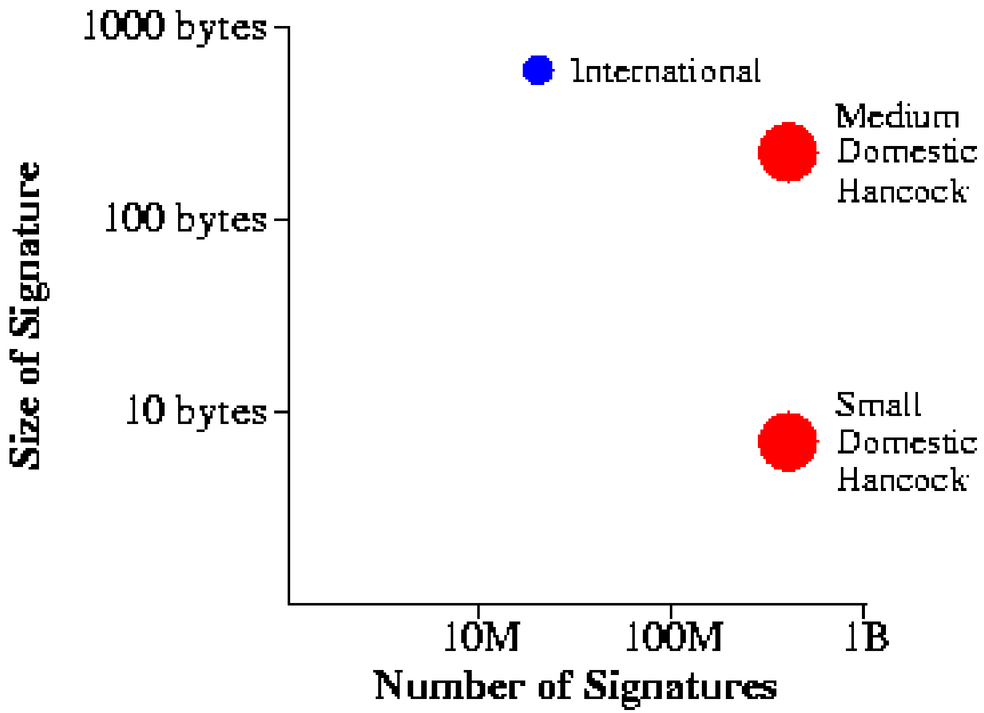
  6GB main memory

- Activity: 1.27GB on disk
  - maps phone numbers (464M) to 3-byte signatures
- Features: 1.10 GB on disk
  - maps phone numbers (163M) to 124-byte signatures

Experimental results

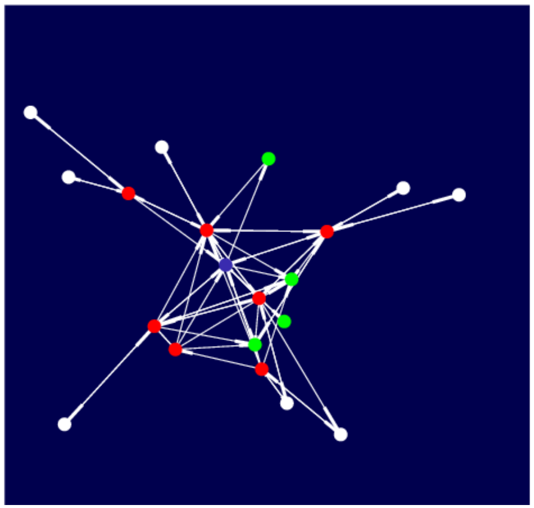
Action	Requirements	Activity	Features
Process calls (275M calls)	½ batch time	19m	30m
Select single value	web time	1.1s	1.1s
Select worklist (160,000 keys)	coffee time	3m30s	4m3s
Touch all values	lunch time	17m3s	12m18s

Concrete results



Communities of Interest

Used to detect 800 subscription fraud.



- Known fraudster
- Inbound calls
- Outbound calls

Performance: Outgoing COI

- Signature size: 120 bytes
- Active keys: 228M
- Signature collection size: 7GB
- Daily update time: 2 hours
- Neighborhood computation: 1 second to compute a neighborhood of size 2 from a seed phone number.

Why a language?

- Disadvantages:
  - Limited scope
  - New language (albeit one based on C).
  - Lack of tools, *e.g.* source-level debuggers, profilers, *etc*.
- Advantages:
  - Static type-checking
    - protects data integrity and promotes clarity of use
  - High-level and tailored abstractions
    - reduce code size, hide issues of scale, and provide a framework for structuring applications.

Further work

- Compare with database implementations (DBPL 2001)
- Allow users to specify streams declaratively (see PADS).
- Add support for variable-width data (urls).
- Improve compression mechanisms.

Try it!

Hancock is available for non-commercial use:

http://www.research.att.com/projects/hancock

Inquiries to hancock@research.att.com.

References:

- Domain Specific Languages Conference, 1999
- Knowledge Discovery and Data Mining Conference, 2000
- Databases and Programming Languages workshop, 2001
- Transactions on Programming Languages and Systems, 2004