Graph Analytics in Big Data

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A changing World

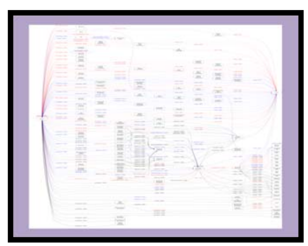
- The breadth of problems requiring graph analytics is growing rapidly

Large Network Systems

Social Networks

Packet Inspection

Natural Language Understanding



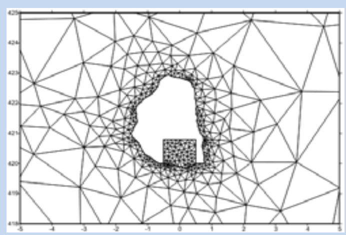
Semantic Search and Knowledge Discovery

CyberSecurity

Graphs are not grids

- Graphs arising in informatics are very different from the grids used in scientific computing

Scientific Grids



Static or slowly involving

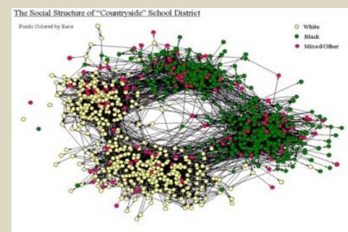
Planar

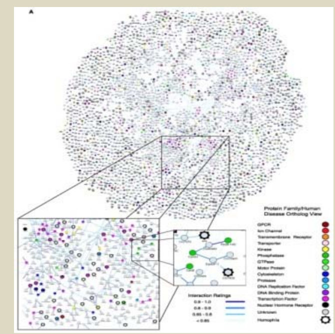
Nearest neighbor communication

Work performed per cell or node

Work modifies local data

Graphs for Data Informatics





Dynamic

Non-planar

Communications are non-local and dynamic

Work performed by crawlers or autonomous agents

Work modifies data in many places

Challenges

- Problem size
  - Ton of bytes, not ton of flops
- Little data locality
  - Have only parallelism to tolerate latencies
- Low computation to communication ratio
  - Single word access
  - Threads limited by loads and stores
- Frequent synchronization
  - Node, edge, record
- Work tends to be dynamic and imbalanced
  - Let any processor execute any thread

System requirements

- Global shared memory
  - No simple data partitions
  - Local storage for thread private data
- Network support for single word accesses
  - Transfer multiple words when locality exists
- Multi-threaded processors
  - Hide latency with parallelism
  - Single cycle context switching
  - Multiple outstanding loads and stores per thread
- Full-and-empty bits
  - Efficient synchronization
  - Wait in memory
- Message driven operations
  - Dynamic work queues
  - Hardware support for thread migration

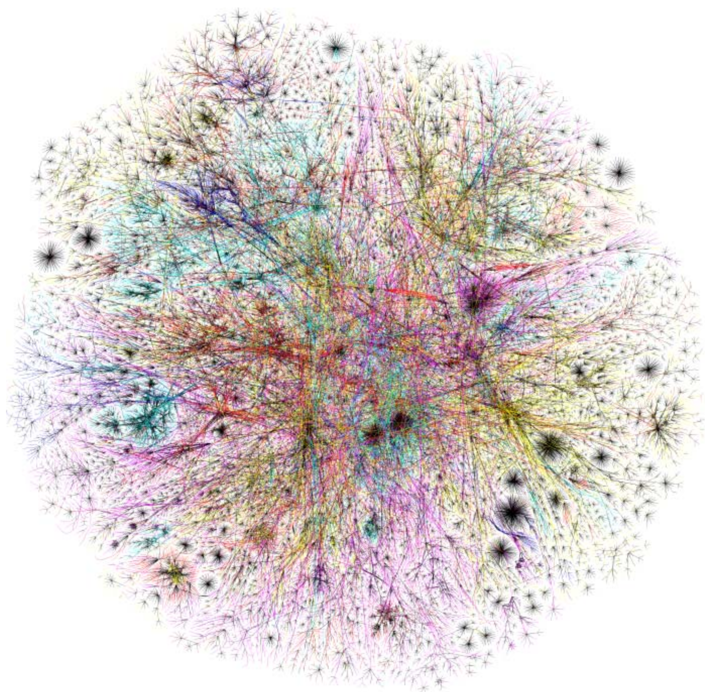
Cray XMT

Our type of problems

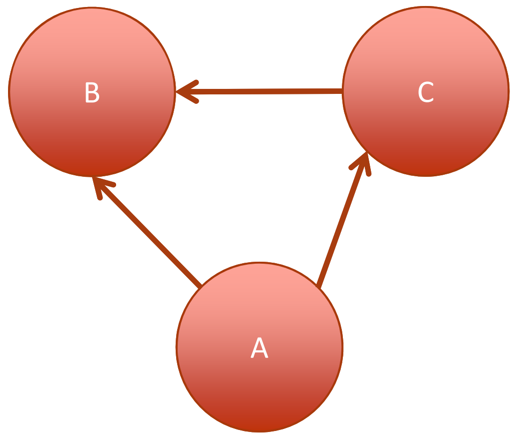
- Return all triads such that
  (A ➔ B), (A ➔ C), (C ➔ B)

- Return all three paths with link types {T_1, T_2, T_3} such that the timestamps of consecutive links overlap by at least 0.5 seconds.

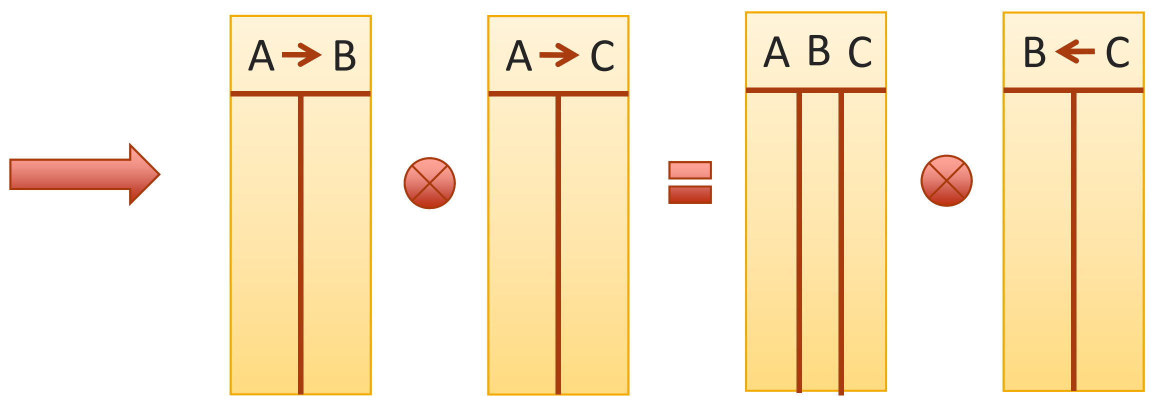
- From Facebook, return the connected subgraph **G**(V, E) such that **G** includes all the friends of John, the cardinality of V is minimum, and Σ NetWorth(v_i ε V) is maximum.



Triads




```
SELECT ?A ?B ?C
WHERE {  ?A ?a ?B .
         ?A ?b ?C .
         ?C ?c ?B.
}
```



Simple C code !?!?!

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Proudly Operated by **Battelle** *Since 1965*

```
for each node A {
   for each out_edge I of A {
   for each out_edge J of A {
      B = tail of I;
      C = tail of J;

      for each out_edge K of C
         if tail of K == B {… write answer …}
} } }
```

No memory explosion

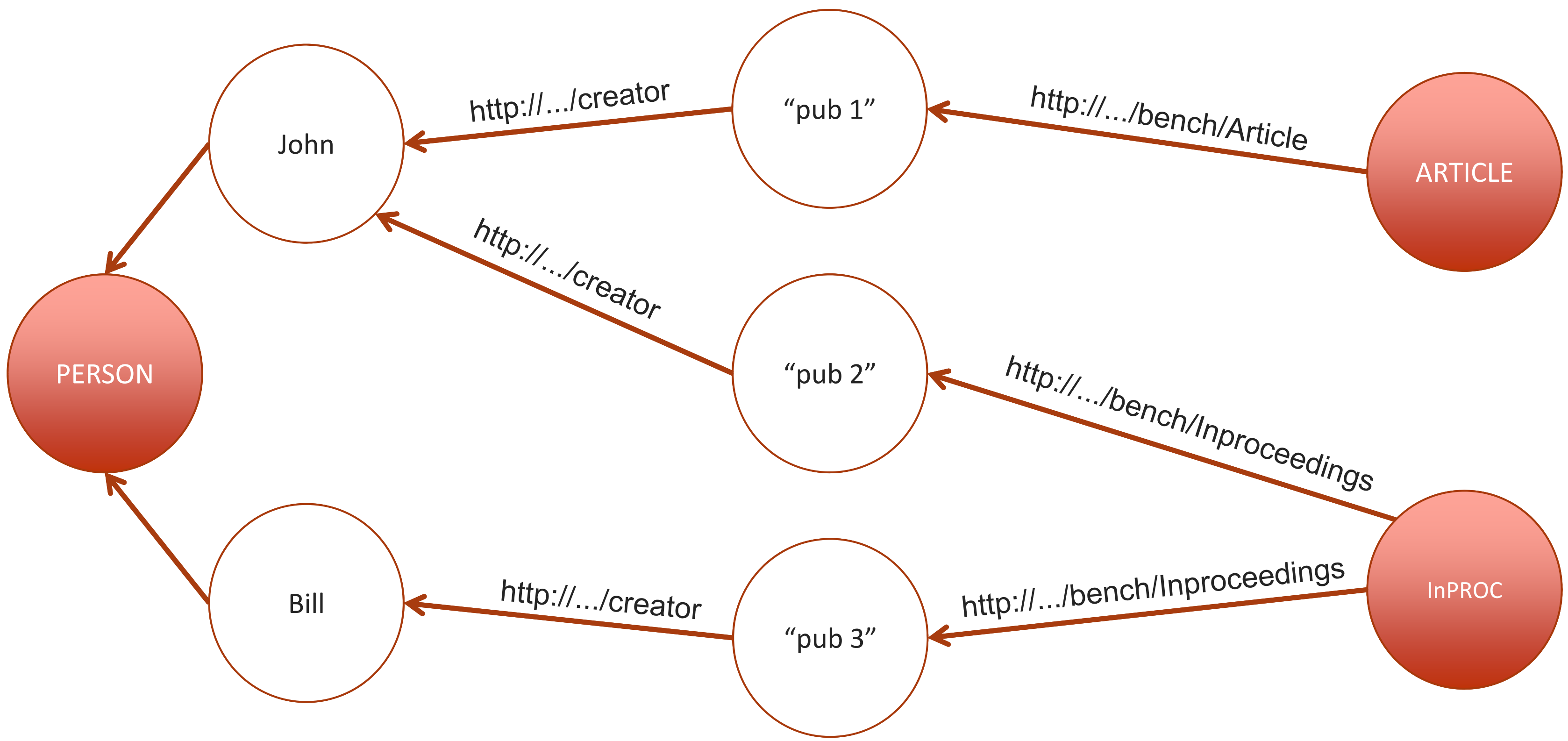
15 secs

SP2 Benchmarks

- We have written the 12 SP2B queries in C using our graph API
- Execution time on Cray XMT/2 is from one to three orders magnitude faster than Virtuoso on 3GHz Xeon server
- Now porting sdb0 to x86 server and cluster systems
- C code is simple, but
  - Can we generate it automatically from a high level query language?
  - Can we provide some other more appropriate query interface?

Query 5

- Return the names of all persons that occur as author of at least one inproceeding and at least one article



Data parallel code for Query 5

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```
int PERSON_index = get_Vertex_Index(person);
int ARTICLE_index = get_Vertex_Index(article);
int INPROC_index = get_Vertex_index(inproc);

int nmbr_Edges = inDegree(PERSON_index);
in_edge_iterator Person_edges = get_InEdges(PERSON_index);

for (i = 0; i < nmbr_Edges; i++) {
   int person = PERSON_edges[i].head;
   int nmbr_Publ = number_edges(person, creator);
   in_edge_iterator Publ_edges = get_InEdges(person, creator);

   for (j = 0; j < nmbr_Publ; j++) {
      int publ_type = edge_Head_Index(Publ_edges[j]);

      if      (publ_type == ARTICLE_index) flag |= 1;
      else if (publ_type == INPROC_index)  flag |= 2;

      if (flag == 3) {print person; break;}
}  }
```

1.29 secs   vs.   21 secs in Virtuoso

Conclusions

- Big data graph analytics is fundamentally different than big data science
  - Different algorithms
  - Different challenges
  - Different hardware requirements
- Conventional database systems based tables and join operations are insufficient
  - Data parallel graph crawls can be orders of magnitude faster
- Need new query languages capable of expressing graph analytics operations and compiling to data parallel operations