Towards secure mobile computation for (astronomical) data centres

James Cheney (with Bob Mann)

University of Edinburgh

The problem

- Historically, scientists have managed data in ad hoc ways.
- In astronomy (and many other disciplines), databases are now necessary for managing scientific datasets
- Conversely, database technology is enabling *new science*
- Moreover, the way science is performed is also changing

The problem

- Astronomical sky surveys (such as WFCAM) are under way
- Already producing around 10s-100s of TBs of data per year
- Individual astronomers do not have the resources to manage such datasets locally.
- Instead, they are to be managed by astronomical data centres (e.g. ROE)
- Similar situations in other sciences (e.g. bioinformatics)
- How to provide individual scientists with the ability to analyze this data?

Traditional model

- Traditional research model:
  - Scientist visits observatory
  - Scientist makes/records observations (in ad hoc/text formats)
  - Scientist takes data back to home institution
  - Scientist does analysis locally
  - Scientist publishes a paper
  - Scientist puts data in a box under desk.
- Data moves to code

New model

- New research model:
  - Observatory makes a large number of observations on behalf of community
  - Observatory stores results in DBMS
  - Scientist analyzes the data
  - Scientist publishes paper
  - Scientist makes the results of the analyses available to other scientists
- Code moves to data

Security issues

- Providing remote shared access to any resource on a network introduces many risks.
  - Loss or (silent) modification of irreplaceable observations
  - Misuse for illegal or non-research purposes
  - Theft or damage of IP (plagiarism, sabotage, accident)
  - Crashes, denial of service, resource hogging

Security issues

- Standard security techniques suffice for many of the risks
- For example, non-networked archival backups help ensure the integrity of irreplaceable data
- Grid-based credential systems being developed to manage authentication
- Access control systems help protect users of shared resources from each other
- Existing Grid security infrastructure is in place/in development for many of these issues
- However, security issues relating to *mobile code* (moving code to data) are still an active research area.

Key requirement

- The ability to run data analyses on remote data center machines is a key requirement
- We want to provide users flexibility/efficiency comparable to having *their own copy* of the database
- while minimizing expenses related to administrative overhead and security risks.
- These capabilities go *far beyond* the ability to query the data.

First-class access to data

- If users had their own copy of the DB, they could:
  - Write customized applications that interact with the database
  - Install *stored procedures* for moving processing inside the database
  - Create new tables for temporary results or to share the results of analyses with others
  - Develop customized indexing schemes for the data
- Providing all these abilities to legitimate users while maintaining an acceptable level of risk and management overhead is a significant challenge.

Mobile code is a huge security risk

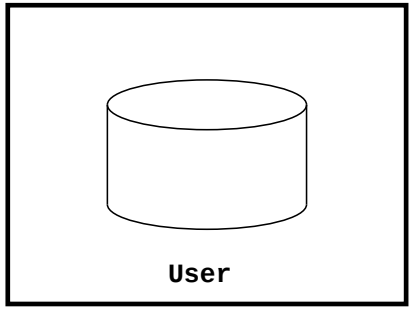
- Gaining the ability to run code on a remote machine is a big step towards gaining control of it.
- So, it would be very risky to give unknown users the ability to run arbitrary code
- Even authorized users may accidentally submit programs that hog resources or crash the server
- Or authorized users' accounts could be compromised.
- Even though the DB is archived, restoring from backups can take hours, denying service to legitimate users.
- (Imagine this happening right before a paper deadline!)

What can we do now?

- Obviously, safely sharing access to networked computers is a well-studied problem.
- What can we do now?
- Is it enough?

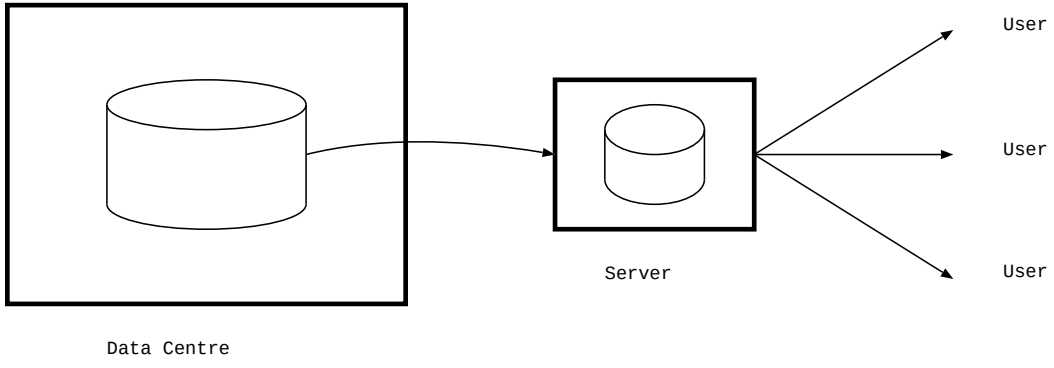
Scientist moves to data

- No remote access: require users to visit the data centre personally
- Expensive! Defeats purpose of networking
- But minimal risk.



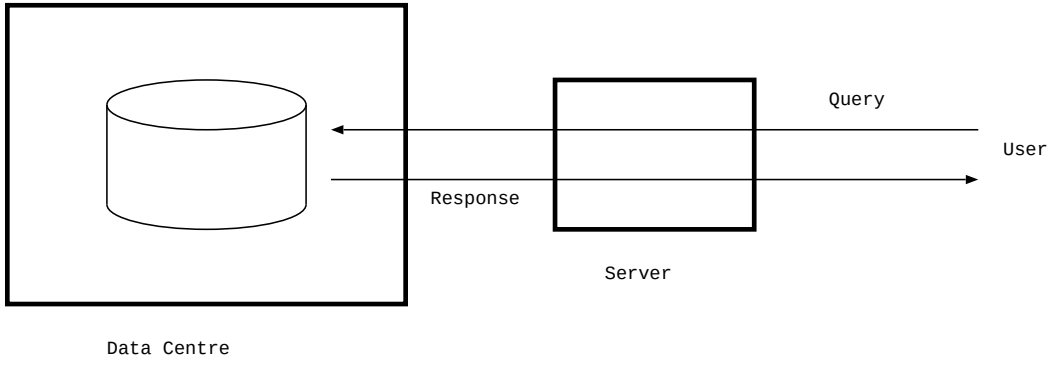
Data moves to code

- Require users to download data (or send out tapes)
- Still expensive! Users have to maintain DB locally, which requires expensive expertise.
- Alternatively, maintain multiple data centres, so that each user can visit a local one
- Also too expensive.
- But risks still low.



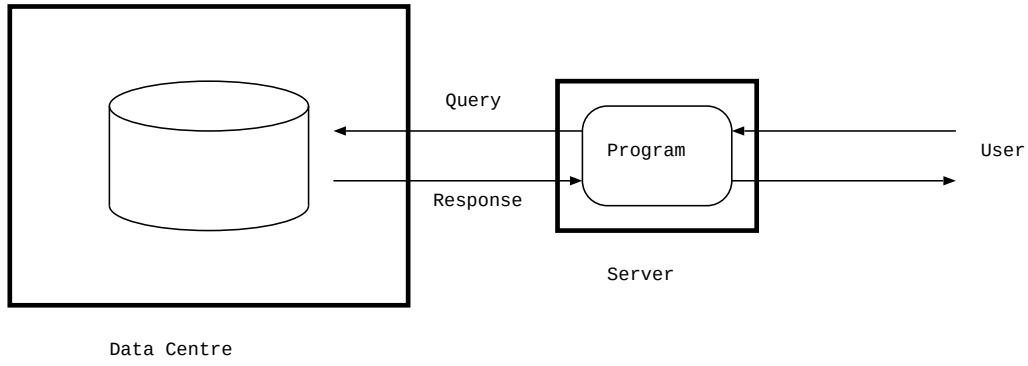
Query interface

- Allow users to send DB queries, download results, run further analysis locally
- Several systems already allow this.
- Inexpensive, low risk.
- But provides limited analysis capability.



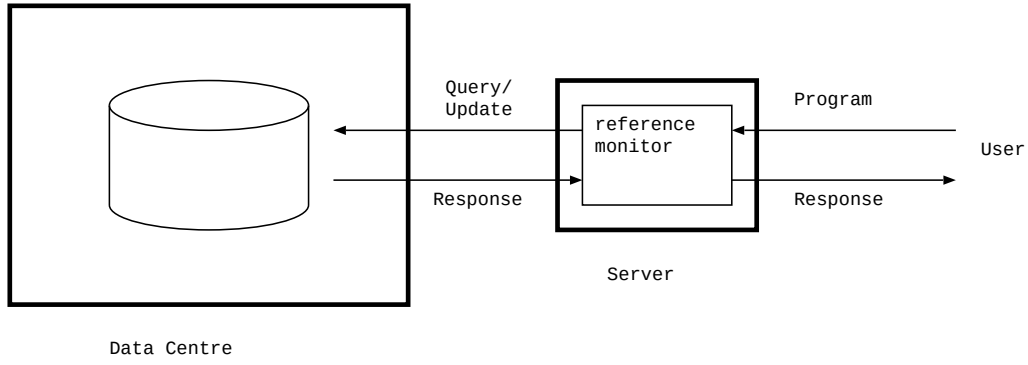
User accounts

- Give each user an account at the data centre; use traditional OS security or “virtualization”
- Users log in and develop/run programs locally
- Less expensive, but administrator still needs to manage accounts, monitor server, kill runaway processes/queries



Reference monitoring

- Idea: Wrap DB server with a *reference monitor* that provides illusion of full DB access: “MyDB” (Szalay, Gray, et al.)
- Users can create local tables, add stored procedures for their own use
- Amounts to re-implementing OS access control system inside DB



Is it enough?

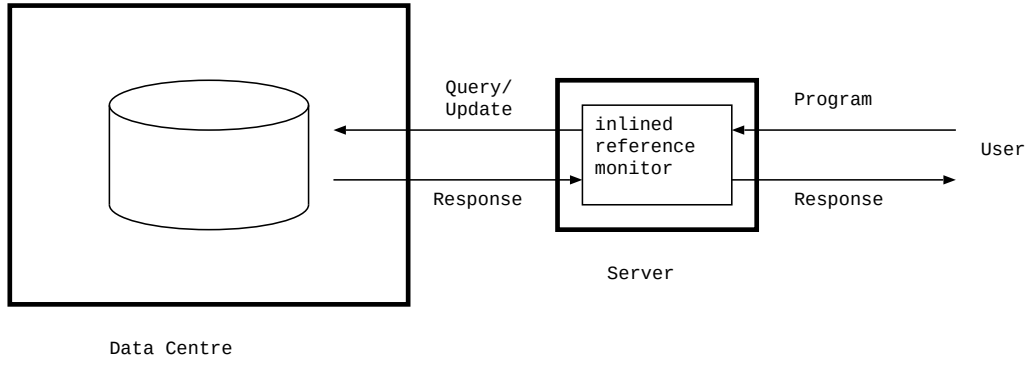
- None of the approaches comes close to providing “first-class” access to the database to legitimate users for a reasonable cost.
- The first two approaches provide full access, but very expensively
- the third provides limited access cheaply
- the fourth provides greater (but still limited) access but still expensive
- the fifth is reasonable, but still under development
- Conclusion: Still some work to do.

Recent research directions

- Mobile code security has received a lot of attention (e.g., Java, C#)
- *Reference monitoring* is a common approach to security
- Idea: All accesses to resource are controlled by system layer (e.g. OS, DBMS)
- which tracks uses and decides whether to allow access
- Recent improvement: *inlined reference monitoring*, which rewrites mobile code so that it *cannot* violate the security policy

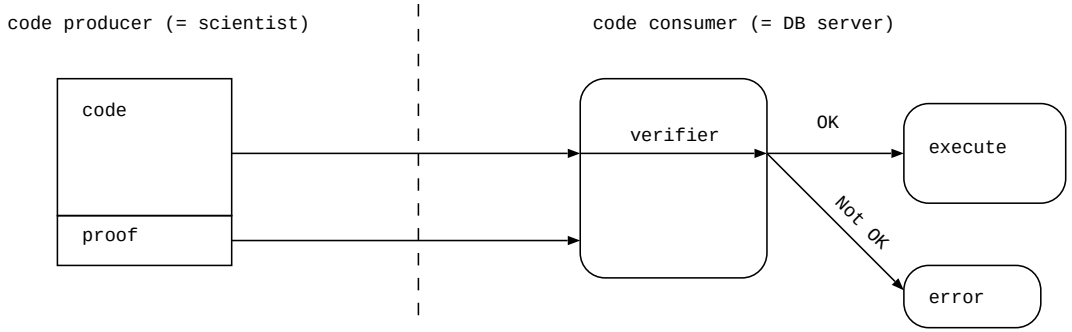
An idea

- Users submit programs to the DB server
- Server uses IRM to rewrite each program so that it is guaranteed to obey security policy
- Advantage: Unlike MyDB, don't need to modify underlying DBMS
- Disadvantage: Dynamic checks slow down programs



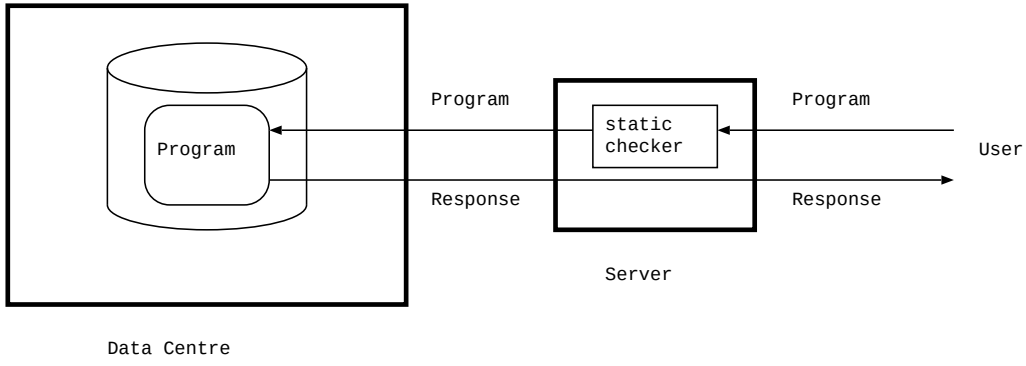
Recent research directions

- Proof-carrying code: another recent approach
- Idea: Code producer must *certify* (formally prove) that code has some *safety property*
- such as “only accesses allocated memory” (= does not crash) or memory/processing limits.
- Code consumer can *check* the proof before running the code



An idea

- Idea: Use PCC to certify “database programs”, which run inside DB as *stored procedures*.
- Power users write & submit procedures, e.g. custom indexing schemes
- Ordinary users can use the procedures in plain SQL queries.
- Stored procedures run at full speed.



MRG, Mobius, and Request

- We have a lot of local expertise on PCC!
- MRG (Mobile Resource Guarantees) is a recently completed EPSRC funded project at UoE.
- Developed extensions to proof-carrying code for certifying *resource usage*.
- Mobius and Request are recently-begun projects to implement PCC for “full” Java and apply MRG research to eScience.
- Astronomical (and other scientific) data analysis problems may be a “good fit” for PCC/MRG secure mobile code techniques.

Gotchas

- Work in progress!
- Little work on language-based security for databases
- PCC research has focused on simple, easy-to-analyze functional programming languages (that nobody else uses)
- Scaling up to full Java is still a hard research problem
- Forget about C/C++ or proprietary languages (IDL, Matlab).
- Question: Are scientists willing to learn/use slower or higher-level languages for their analyses?

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- Forget about C/C++ or proprietary languages (IDL, Matlab).
- Question: Are scientists willing to learn/use slower or higher-level languages for their analyses?
  - Even if it's the only (secure) way to allow access...?

Beyond astronomy

- We’ve focused on astronomical data analysis
- But same problems likely to appear in any discipline with large-scale data needs
- Some examples
  - Bioinformatics (human and mouse genome)
  - Social sciences (allowing remote access to demographic data): privacy/anonymity is an issue
  - Geospatial/planetary sciences

Help!

- We need examples of analyses people would like to run
- or case studies (use cases) describing what people do now vs. would *like* to be able to do
- in order to be sure we're doing something that is relevant to real situations
- Actual code would be especially helpful
- (or actual code with "interesting" algorithmic content removed...)
- Realistic examples needed at some point to build a working system

Conclusions

- Providing safe, first-class access to astronomical (and other scientific) databases is challenging
- Recent work on language-based security may be applicable
- There may be further interesting security research to do here
- Or the current state of the art may be enough
- To know for sure, need examples & use cases from potential users