Full statistical analyses with secure multi-party computation

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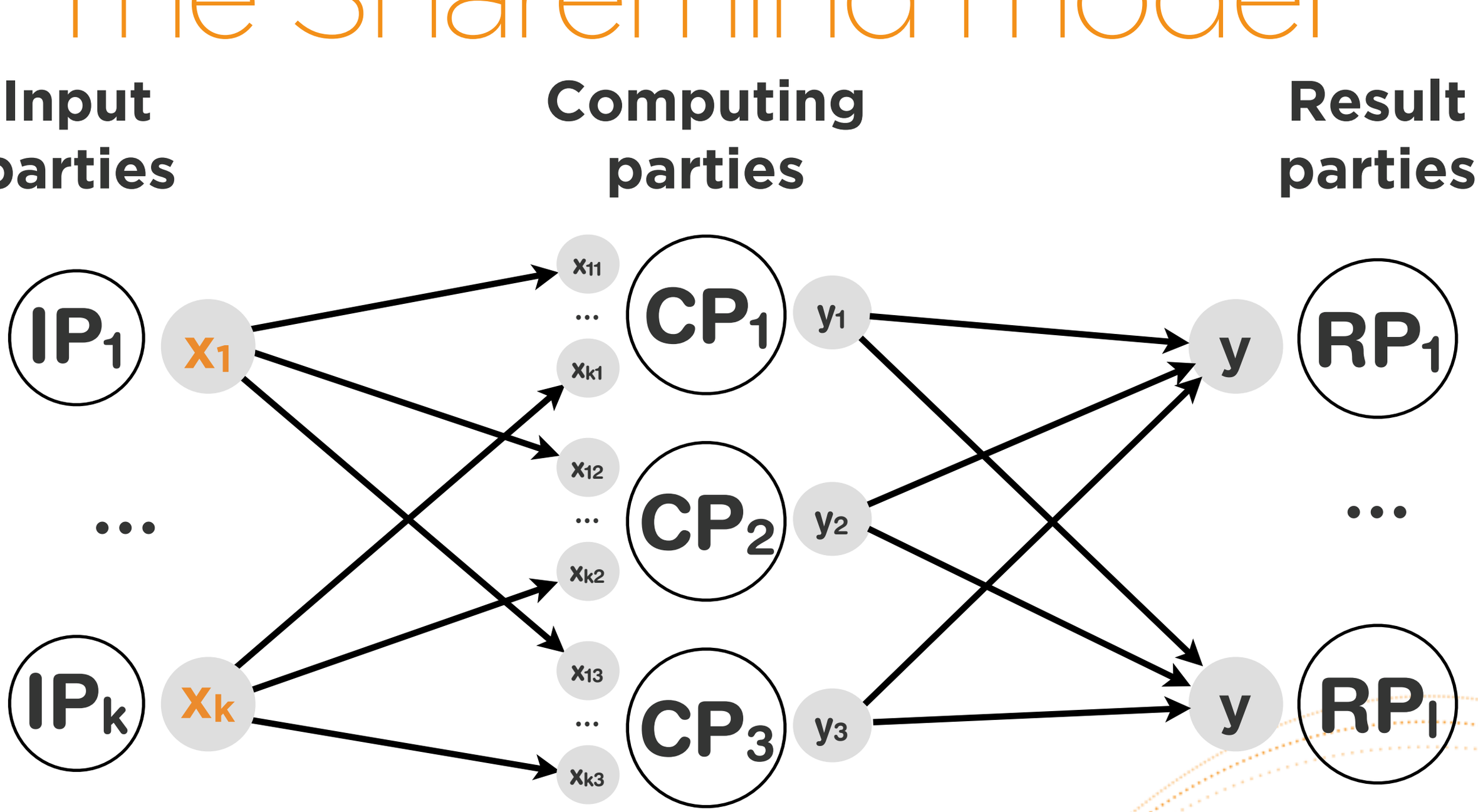
The Sharemind model



Step 1:
secret sharing and storage of inputs

Step 2:
secure multi-party computation

Step 3:
reconstruction of results

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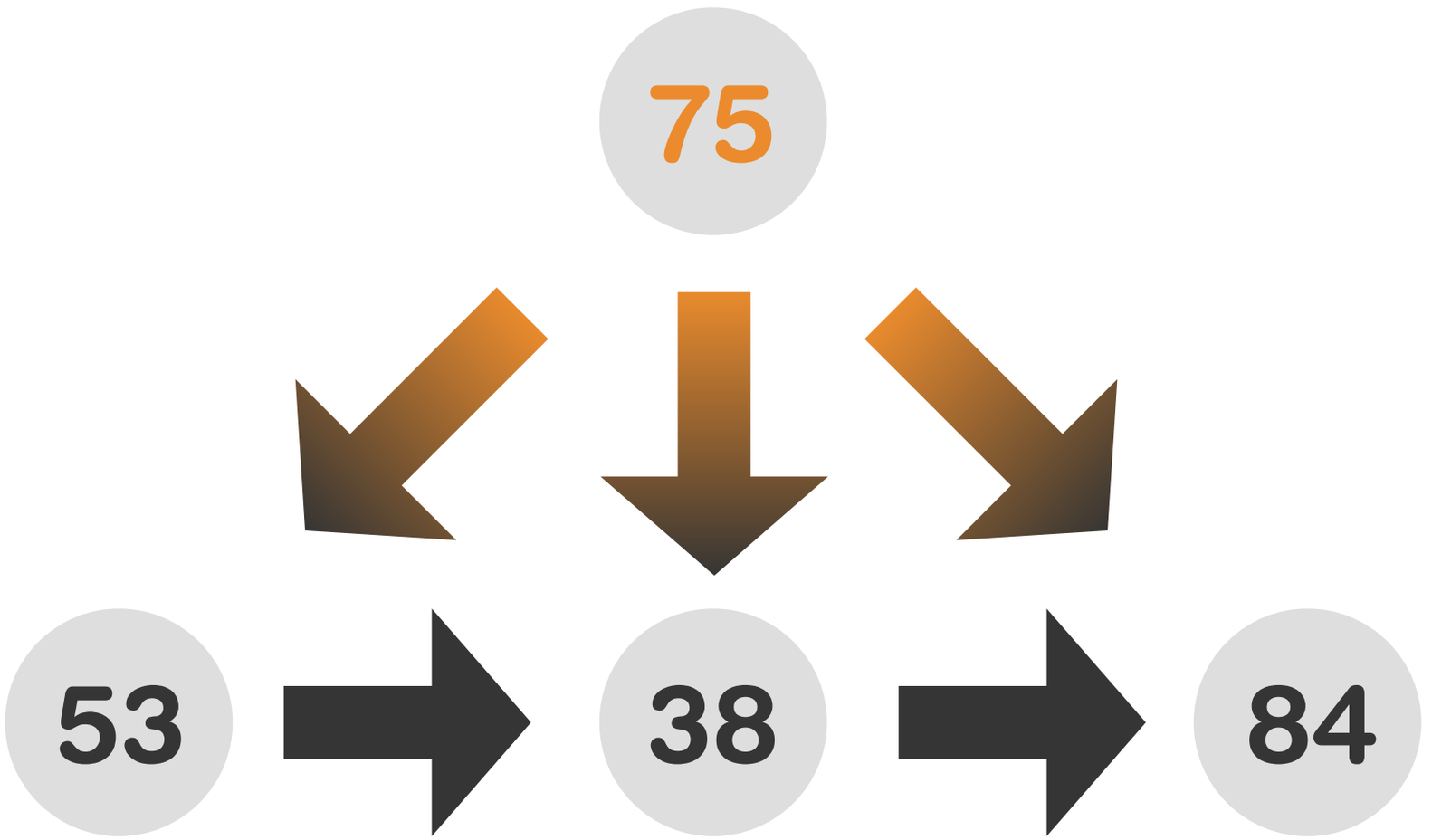
Secret sharing (simplified)



75 - 53 - 38 = 84 mod 100

Reconstruction: 53 + 38 + 84 = 75 mod 100

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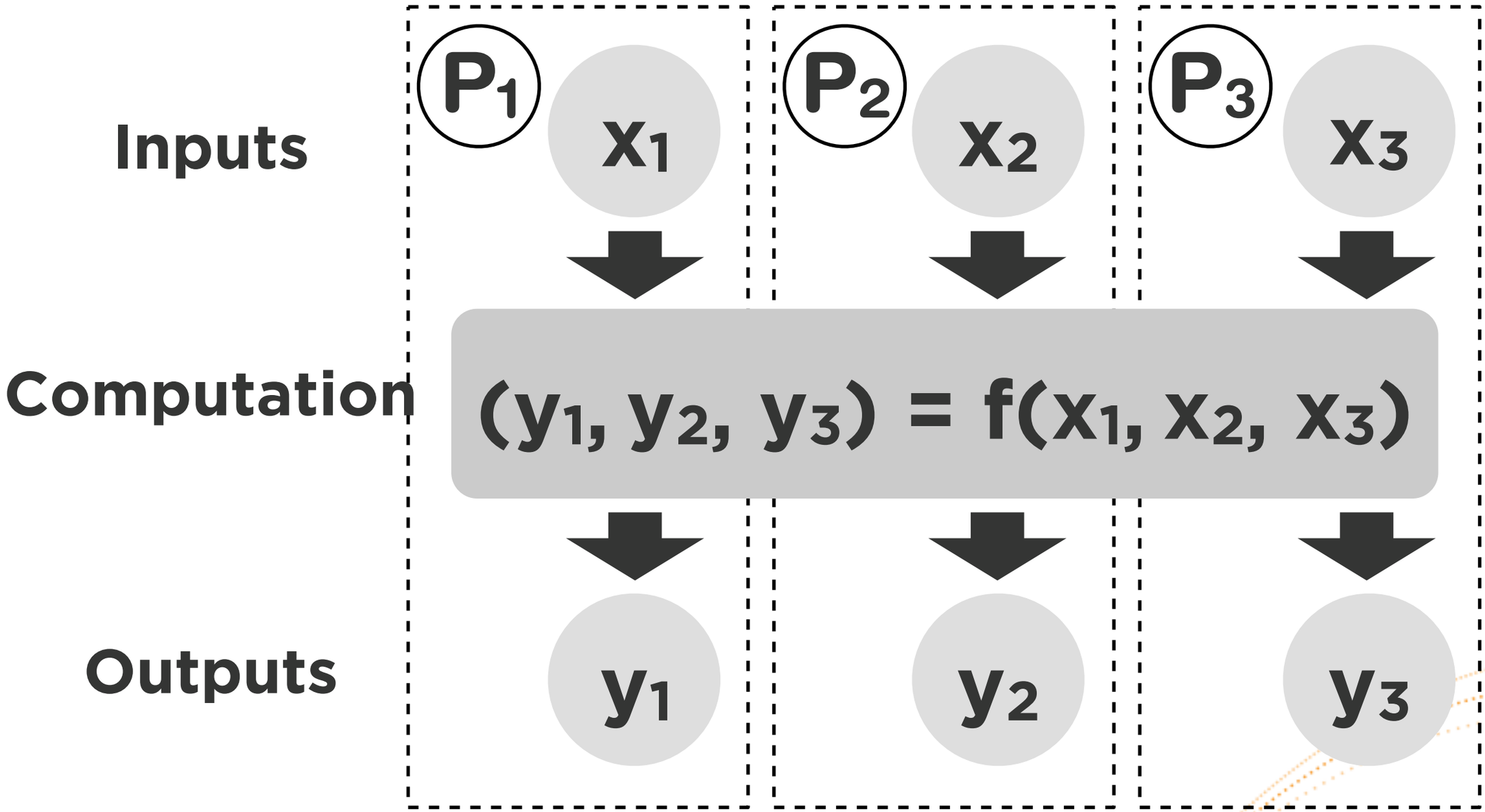
MPC from secret sharing



All operations are composable.

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Strengths / weaknesses

- **Easy to write code for.** Developers apply privacy patterns on classical algorithms.
- **Hybrid execution model** for balancing public and private computations.
- **Very high performance** for arithmetic circuits.
- **Small storage overhead** (3 times for 3 servers).
- **Requires three servers for best possible efficiency** (works with 2 to n servers as well).
- **Performance profile not immediately intuitive.**
- **Custom protocols** may perform better in some cases.

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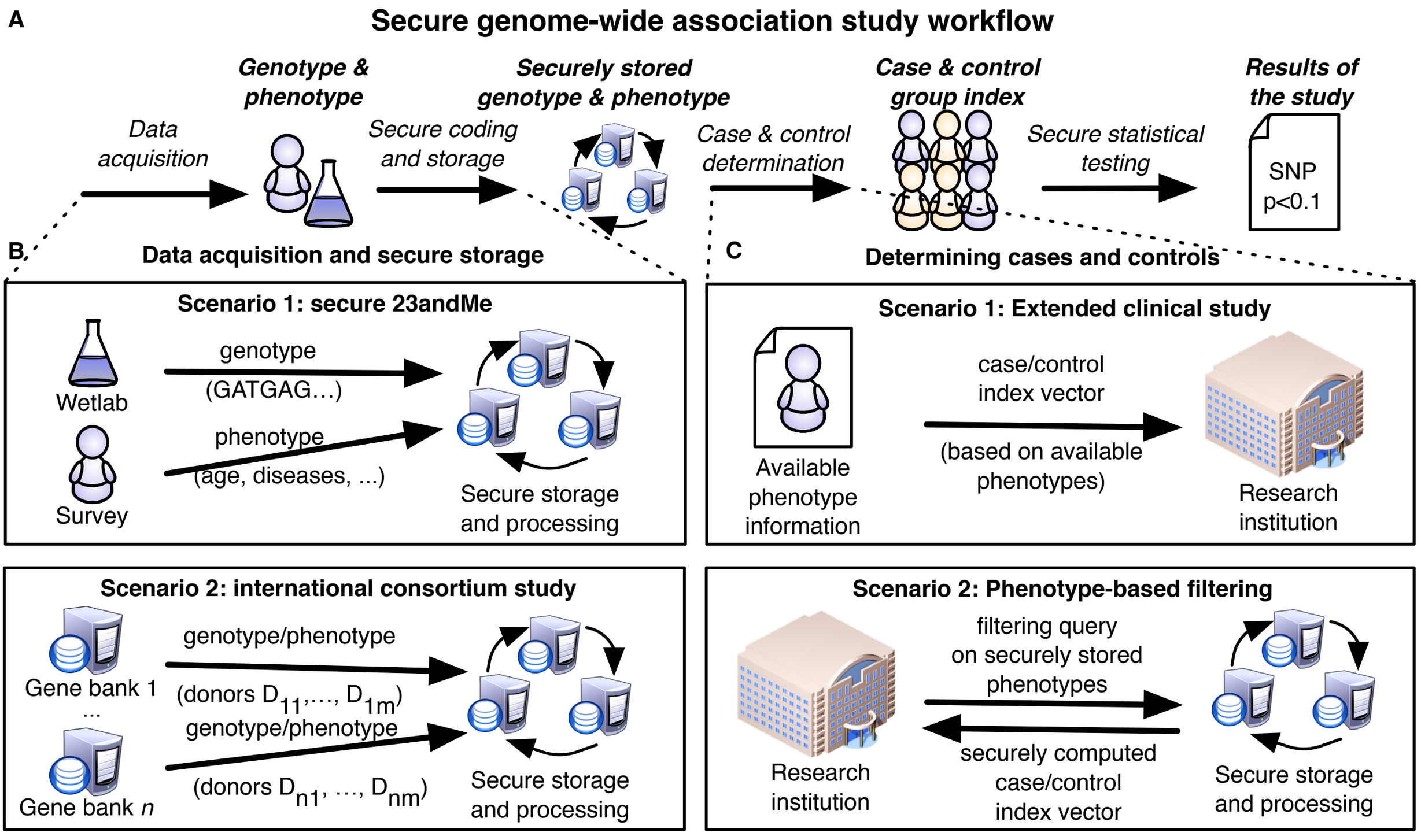
Genome data and MPC



Application development

Description of the data analysis task

Business logic

SecreC language

Data model

UX requirements

Controller library

Application Server package

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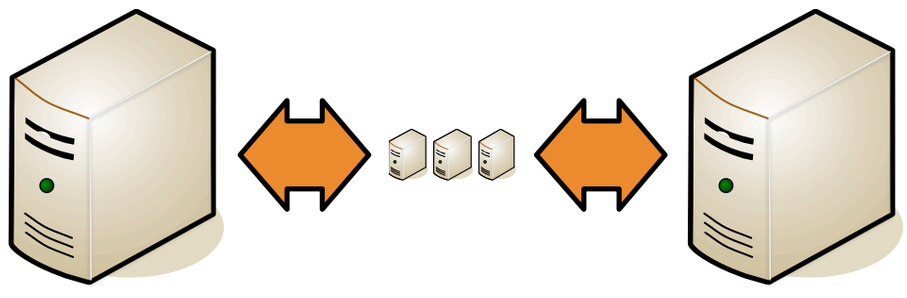
secure application servers



End user applications

end users (data owners, analysts etc)

Our competition entry

- **Task 2.1**
  - Importer (C++/SecreC), ~200 lines of code
  - Analyzer (C++/SecreC), ~200 lines of code
  - Secure operations used: secure integer arithmetic, floating point arithmetic, including division.
- **Task 2.2**
  - Importer (C++/SecreC), ~200 lines of code
  - Analyzer (C++/SecreC), ~300 lines of code
  - Secure operations used: secure integer arithmetic, shuffling, AES.

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The Rmind tool

LXTerminal

File Edit Tabs Help

LXTerminal | LXTerminal

```
'citation()' on how to cite R or R packag

Type 'demo()' for some demos, 'help()' fo
'help.start()' for an HTML browser interf
Type 'q()' to quit R.

> subject <- read.csv ("subject1000.csv",
> salary <- read.csv ("avg-salaries.csv",
> edu <- merge (subject, salary)
> age <- edu$age
> sal <- edu$avgSalary100
> plot(age, sal)
>
```

LXTerminal

File Edit Tabs Help

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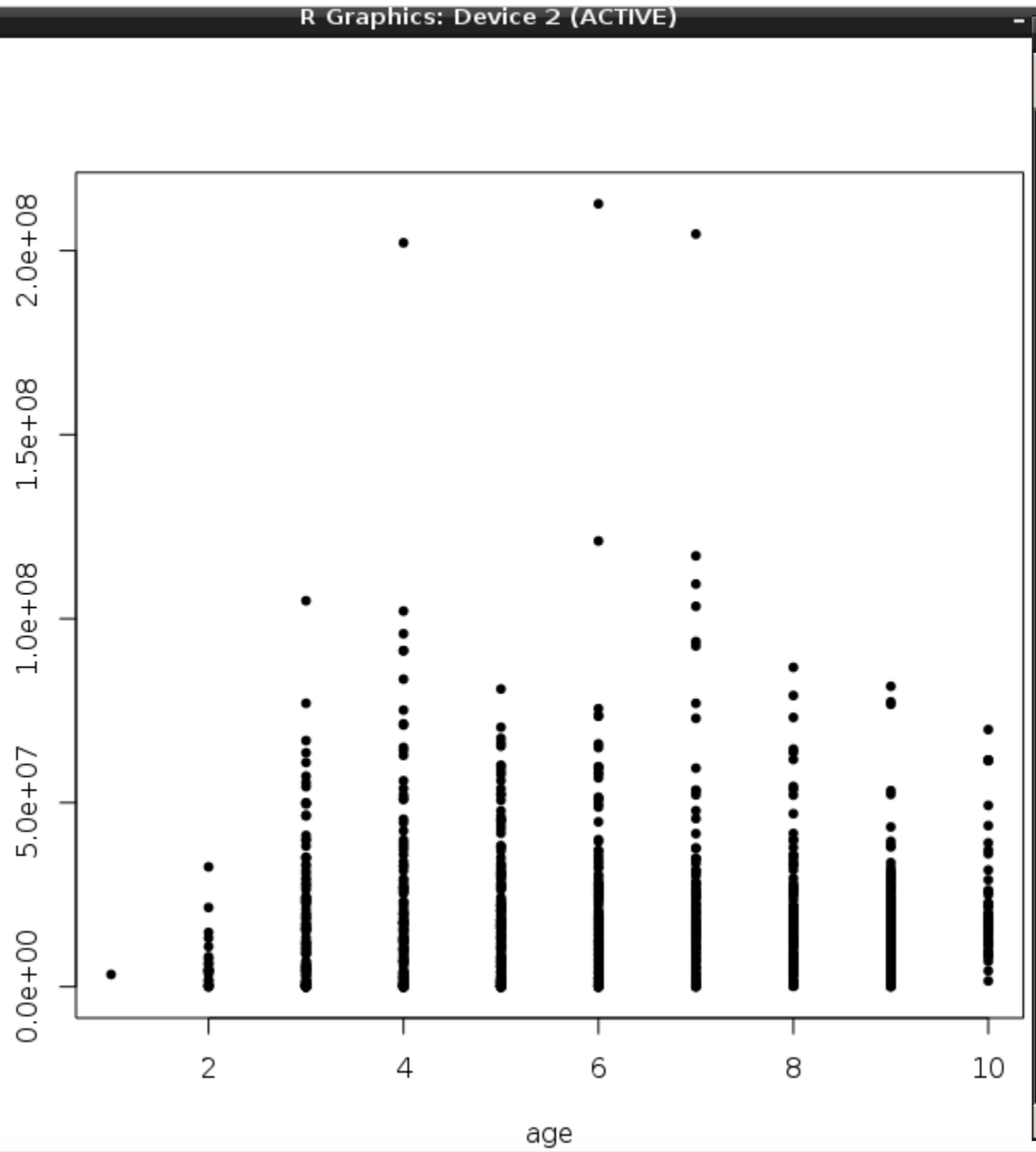
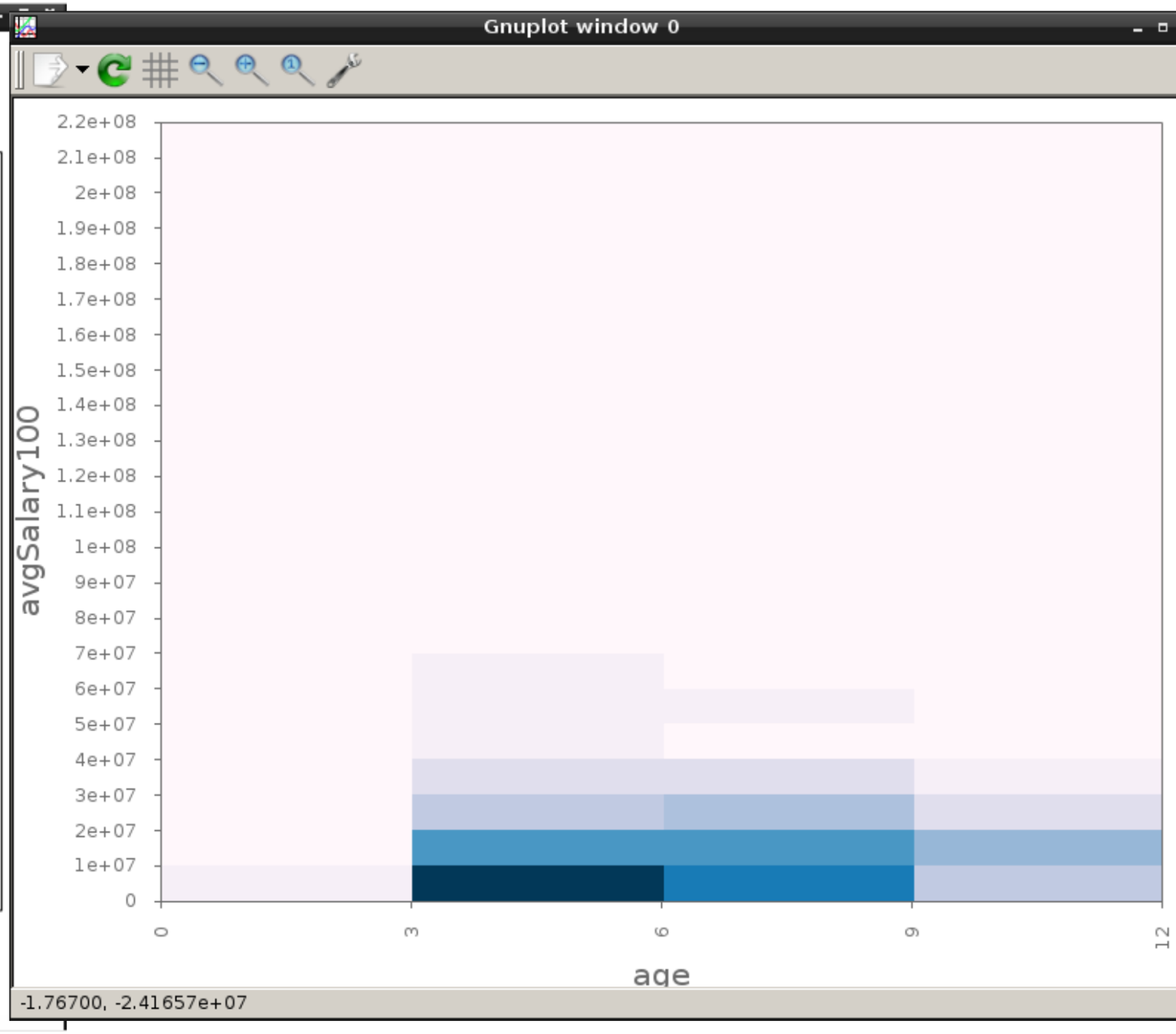
```
[sharemind@sm-build-vm rmind]$ ./rmind
Rmind
Copyright (C) Cybernetica AS
Type ‘q()’ to quit
Connecting to Sharemind...
Connected
> salary <- load("DS1", "salaries")
> subject <- load("DS1", "subjects")
> edu <- merge(subject, salary)
> age <- edu$age
> sal <- edu$avgSalary100
> heatmap (age, sal)
>
```

Rmind

The Rmind tool





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Features of Rmind

- **Data import**: CSV, anything with custom importers
- **Descriptive statistics:** stdev, var, cov, quantiles, histogram, frequency plots, heatmap
- **Quality assurance:** filtering, outlier removal with median absolute deviation
- **Transformations**: Sorting, merging, aggregation
- **Testing**: t-test, chi-square, Cochrane-Armitage, transmission disequilibrium, Wilcoxon, Mann-Whitney
- **Multiple testing:** Bonferroni correction, Benjamini-Hochberg procedure
- **Regressions**: linear, logistic
- We are continuously implementing new functions.

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Legal situation

- In January 2014, the Estonian Data Protection Agency cleared the use of Sharemind/Rmind for education records of Estonian students.
- In January 2015, the Estonian Tax and Customs Board cleared the use of Sharemind/Rmind for analyzing tax records of working students.
- We also have experience in forming contracts with all associated parties under European law.
- The EU PRACTICE project published a legal analysis of the technology from a European perspective. http://practice-project.eu/downloads/publications/D31.1-Risk-assessment-legal-status-PU-M12.pdf

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Literature

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3. [KBLV13] Liina Kamm, Dan Bogdanov, Sven Laur, Jaak Vilo. **A new way to protect privacy in large-scale genome-wide association studies**. Bioinformatics 29 (7): 886-893, 2013. http://bioinformatics.oxfordjournals.org/content/29/7/886
4. [B13] Dan Bogdanov. **Sharemind: programmable secure computations with practical applications**. PhD thesis. University of Tartu. 2013. http://hdl.handle.net/10062/29041

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Acknowledgments

Our entry to the iDASH Privacy & Security Workshop Secure Genome Analysis Competition was prepared with support from

PRACTICE

http://practice-project.eu/

"The **PRACTICE** project has received funding from the European Union's Seventh Framework Programme ([FP7/2007-2013]) under grant agreement number ICT-609611."

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