Longitudinal Analysis of Collaboration Graphs of Forked Open Source Software Development Projects

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What is this about?

Big Picture

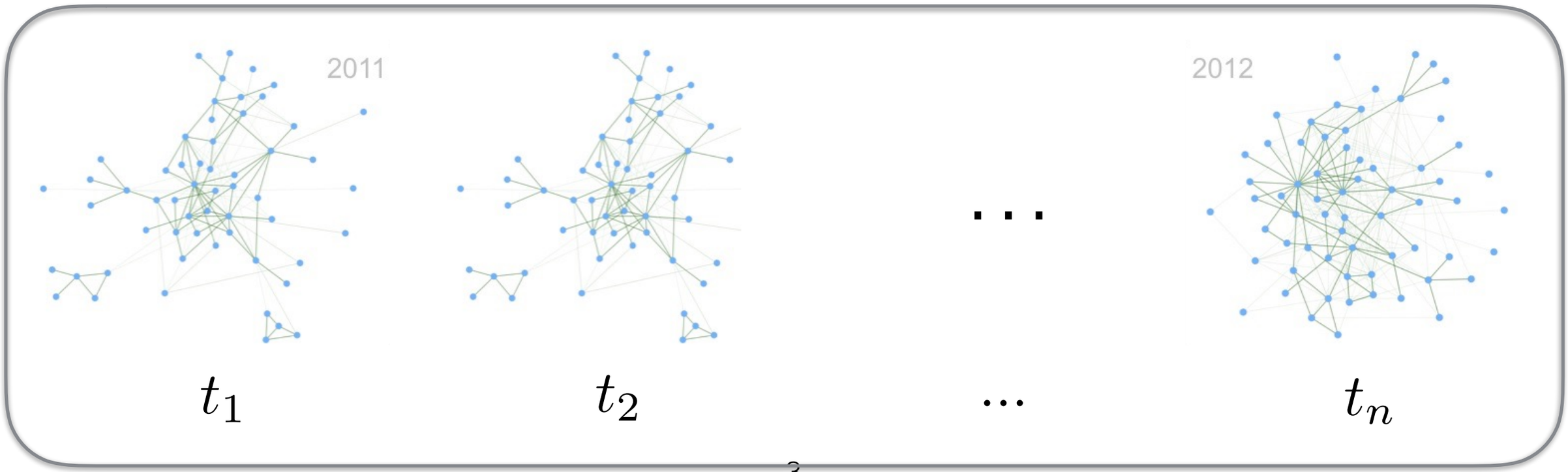
- Developing complex software systems is complex
- Software Developers (SD) interact
  - They can have same/different goals, communication styles, values
- Interactions can be healthy or troubled
- Troubled interactions cause troubled communities -> failure
  - Some of these failures manifest as forks
  - Failure affects many people; developers and users

Can we save troubled projects?

What is this about?

First attempt: problem context

- Interactions can be modeled as graphs
- Graphs change through time
- Can these changing graphs reflect the climate happening during the run-up to fork



What is forking?

- “when a part of a development community (or a third party not related to the project) starts a completely independent line of development based on the source code basis of the project.”

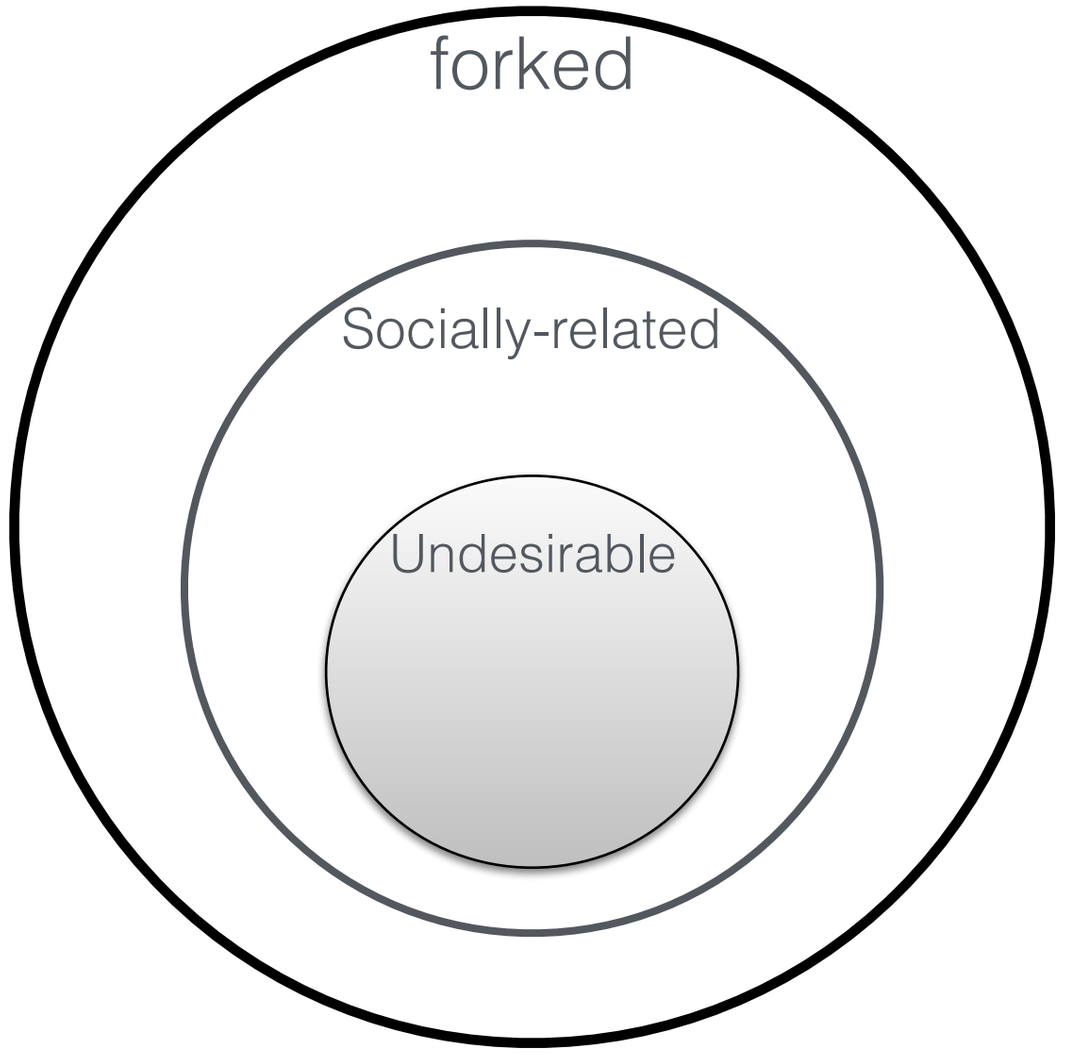
- It can be Undesirable:
  - Dilution of workforce
  - Flaming & unhealthy dynamics
  - Redundant work

} people suffer

Undesirable forks = ?

- **Undesirable forks:** Perceived as bad forks, that affects the developer community and users negatively, and would've been avoided if possible.

- **Socially-related forks**: Could have left traces in the developers' interactions data.



Why Projects Fork?

Socially-related { H.F. / U.F. }

Reason for forking	Example forks
Technical (Addition of functionality)	Amarok & Clementine Player
More community-driven development	Asterisk & Callweaver
Differences among developer team	Kamailio & OpenSIPS
Discontinuation of the original project	Apache web server
Commercial strategy forks	LibreOffice & OpenOffice.org
Experimental	GCC & EGCS
Legal issues	X.Org & XFree

Related Work

What we can know about FOSS	What we do *not know*
Identifying knowledge brokers [47]	Static point of view; People are important, but how do these roles change, how they move around around
Visual exploration of collaboration [52]	Interesting, but not quantitatively conclusive. Many hidden processes that remain unexplored
Post-forking porting of new features [7]	
Social structures and dynamics [10]	How these structures change through time
Identifying “key” events [1]	Compared only two snapshots; not longitudinal
Tension between diversity & homogeneity [28]	
Age of developers and survival rate [21]	How can this be used to understand forking
Communication patterns [24]	Change through time?
Sustainability [31]	How to maintain a sustainable project without forking

Gap: **Run-up to forks** seldom studied

Research Goals

Quantitative

- Any traces left?
- Do different forks leave different traces?
- Key indicators = ?

Qualitative

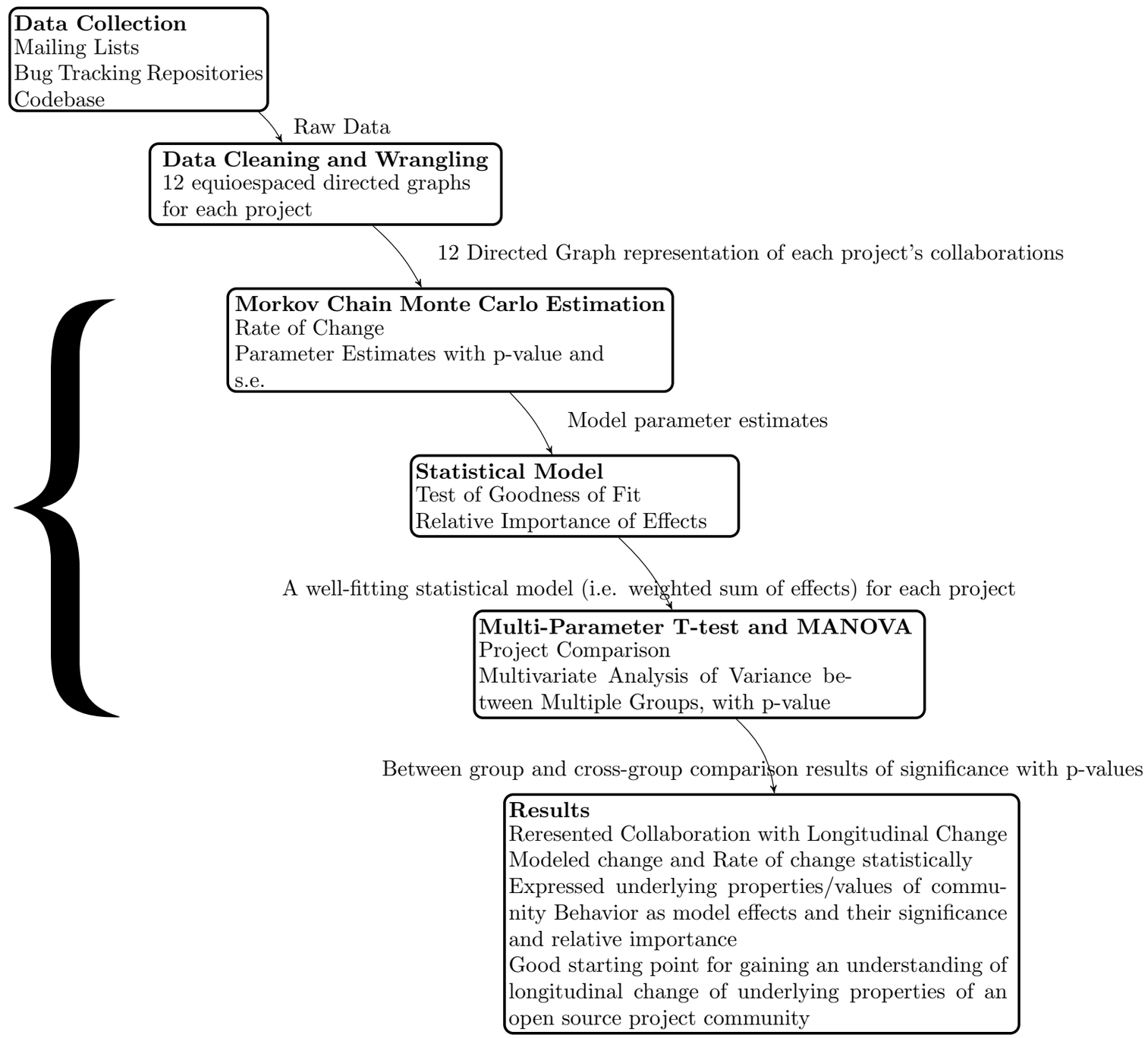
- Validate
  - Interviews
  - Surveys

- Why these are important:
  Because if we know these, we could identify unhealthy dynamics and fix them before it's irreversible.

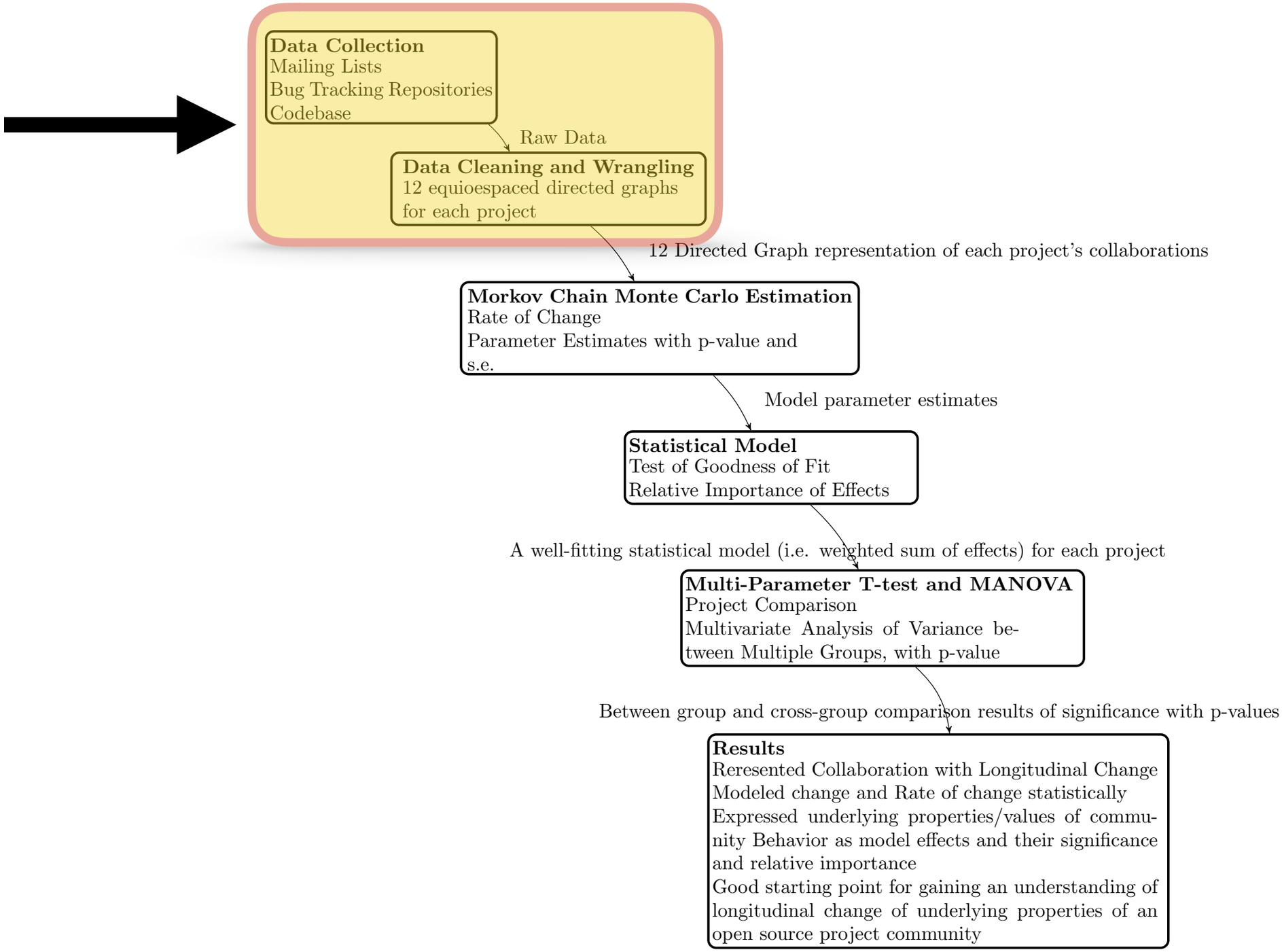
Methodology

Data Collection

Statistical Modeling



Methodology: Data Collection



Data Collection Categories

Table 6: The three types of projects for which data is collected in this study

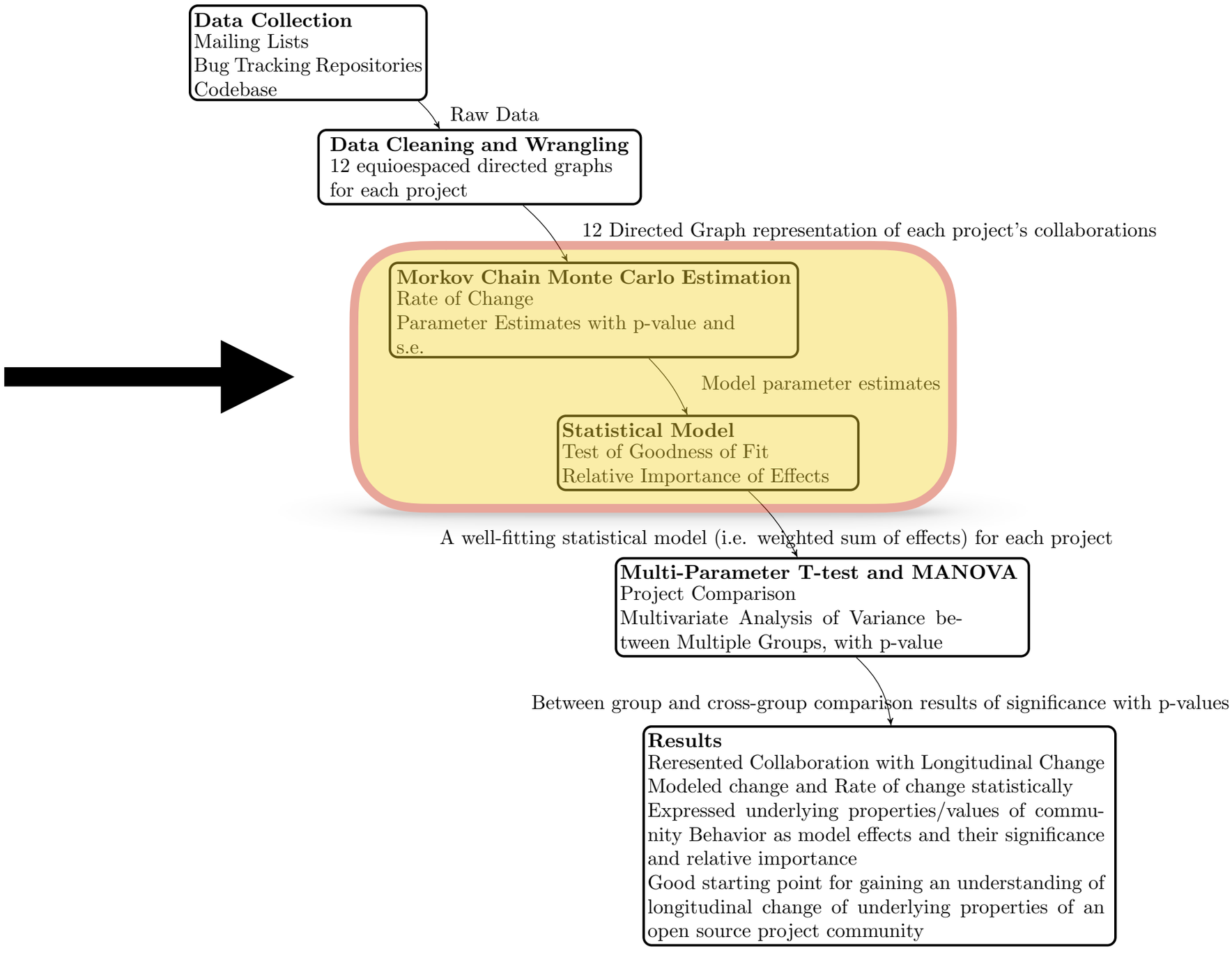
Type of forking	**Abbreviation**
Undesirable & socially-related forking	U.F.
Other socially-related forking	H.F.
No forking at all (as the control group)	No.F.

Data Collection Projects

Table 7: List of projects in U.F. H.F., and No.F. categories selected based on the criteria described in section 5.1 for our study

	Projects	Reason for forking	Year forked	Type
U.F. (personal)	Kamailio & OpenSIPS	Differences among developer team	2008	U.F.
	ffmpeg & libav	Differences among developer team	2011	U.F.
U.F. (community-driven)	Asterisk & Callweaver	More community-driven development	2007	U.F.
	rdesktop & FreeRDP	More community-driven development	2010	U.F.
	freeglut & OpenGLUT	More community-driven development	2004	U.F.
H.F.	Amarok & Clementine Player	Technical (Addition of functionality)	2010	H.F.
	Apache CouchDB & BigCouch	Technical (Addition of functionality)	2010	H.F.
	Pidgin & Carrier	Technical (Addition of functionality)	2008	H.F.
	MPlayer & MPlayerXP	Technical (Addition of functionality)	2005	H.F.
No.F.	Ceph	Not forked	-	No.F.
	Python	Not forked	-	No.F.
	OpenStack Neutron	Not forked	-	No.F.
	GlusterFS	Not forked	-	No.F.

Methodology: Statistical Modeling



Statistical Model **Covariates**

What can make an impact to result in forking?

- **Reciprocity**
- Closure (**balance**)
    - Transitive triplets
- Three-cycles
- in-in degree **assortativity**
- in-out degree assortativity
- Developer's l**evel of contribution**/activity (e.g. code commits per month, or mailing list posts per month)
- Developer's **level of privilege/prestige** (e.g. admin privilege-holder vs. core contributor vs. marginal developer/user)
- Developer's **level of negative experience** (e.g. number of rejected pull requests: especially in forks for more community- driven development)
- Developer's **age/seniority** (either birth age, (young 20-year-old developer vs. older 50-year-old developer) or their seniority as a development community member (i.e. how long they have been in the community)
- Developer's **propensity for short-responses** vs. long-responses. (under-communicator vs. over-communicator)
- Developer's **communication sentiment** (generally bitter in communication known as "a jerk", or has a positive communication prose)
- Developer's **engagement style** (i.e. dive-bomber- style contributor who jumps in, overcommits and leave, vs. a steady and increasingly engaged contributor who starts off slow and grows his/her commitment gradually)

What do we expect to have pre-fork impact in each category?

Table 8: Expectations for significance of the statistical model covariates based on intuition. Note that * indicates significantly-related; +/- indicates positively/negatively related.

Model parameter	**U.F. Pers. Dif.**	**U.F. More Comm.**	**H.F. Tech. Dif.**
Reciprocity	*		*
Transitive triplets	*		*
Number of developers at distance two		*-	
Three-cycles	*		*
out-out degree assortativity		*+	
Covariate-V1 [Developer's contribution level]-related popularity	*		*
Covariate-V2 [Developer's privilege level]-related dissimilarity		*-	*
Covariate-V3 [Developer's negative experience level]-related popularity		*	
Covariate-V3 [Developer's negative experience level]-related dissimilarity	*		
Covariate-V4 [Developer's age-seniority level]-related popularity	*		
Covariate-V4 [Developer's age-seniority level]-related dissimilarity	*	*	
Covariate-V5 and V6[Developer's under/over communicator & sentiment history]-related activity and dissimilarity	*		
Covariate-V7 [Developer's graduality level]-related activity	*	*-	
Covariate-V7 [Developer's graduality level]-related dissimilarity	*	*-	

Statistical Model

- Longitudinal
- Developer-oriented:
  - Developers choose whom to talk to
    - Likelihood of forming ties, maintaining ties, …
- Stochastic
  - Developers behave to optimize an objective function; included our covariates
  - Assume observed graphs as outcomes of a continuous-time Markov process
- Estimated

Statistical Model
Mathematical notation

- Data: M repeated observations on a graph with g developers

- Representation: Directed graphs with adjacency matrices $X(t_m) = (X_{ij}(t_m))$ for $m = 1, \ldots, M$
  - where i and j range from $1, ..., g$

- X_{ij} shows whether at time t, there exists a tie from i to j (value 1) or not (value 0).

Statistical Model

Longitudinal change = a series of mini-steps

To model graph evolution from $X(t_1)$ to $X(t_2)$,
and so on, we treat the dynamics as the results of
a series of small atomic changes (mini-steps)

Statistical Model
Mini-steps

- Developer whose tie is changing, has control over the change

- The graph changes one tie at a time (**1 mini-step**)

- The moment of change & the kind of change **depends on observed covariates** and the **graph structure**

- The **moment of change** is stochastically determined by the *rate function*

- The particular **kind of change** is determined by the objective function

Statistical Model
Rate Function

The **rate function** $\lambda_i(x)$ for developer *i* is the rate at which developer *i*'s outgoing connection changes occur.

$$\lambda_i(x) = \lim_{dt \to 0} \frac{1}{dt} \mathrm{P}\big(X_{ij}(t+dt) \neq X_{ij}(t) \quad for \quad some \quad j \in \{i, ..., g\} | X(t) = x)\big)$$

It models *how frequently* the developers make mini-steps.

Statistical Model

Objective function

The **objective function** $f_i(s)$ for developer i is the value attached to the network configuration x.

$$f_i(\beta, x) = \sum_{k=1}^{L} \beta_k s_{ik}(x)$$

- Functions $s_{ik}(x)$ are the effects we define. Parameters $\beta = (\beta_1, ..., \beta_L)$ is to be estimated.

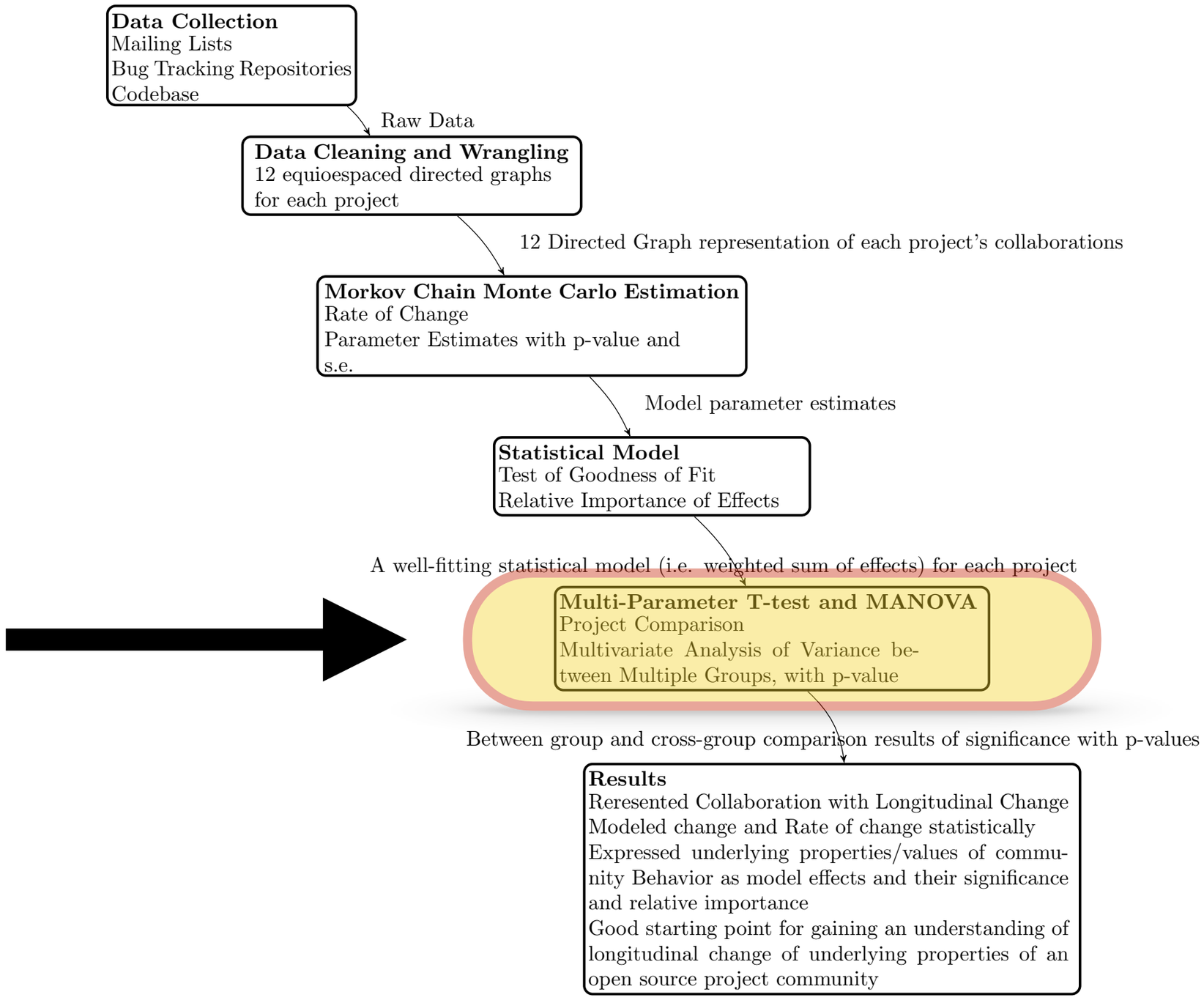
- Idea: Given the opportunity to make a change in his out-going tie variables $(X_{i1},...,X_{ig})$, developer i selects the change that gives the greatest increase in the objective function.

Statistical Model
Simulation and Estimation

- Using Method of Moments (MoM)
  - Equate the observed sample statistics to the theoretical population statistics and solve the equation to find the coefficients
- Markov Chain Monte Carlo (MCMC) estimation
  - Simulate the network evolution, and estimate the model based on the simulations

We fitted/have a model

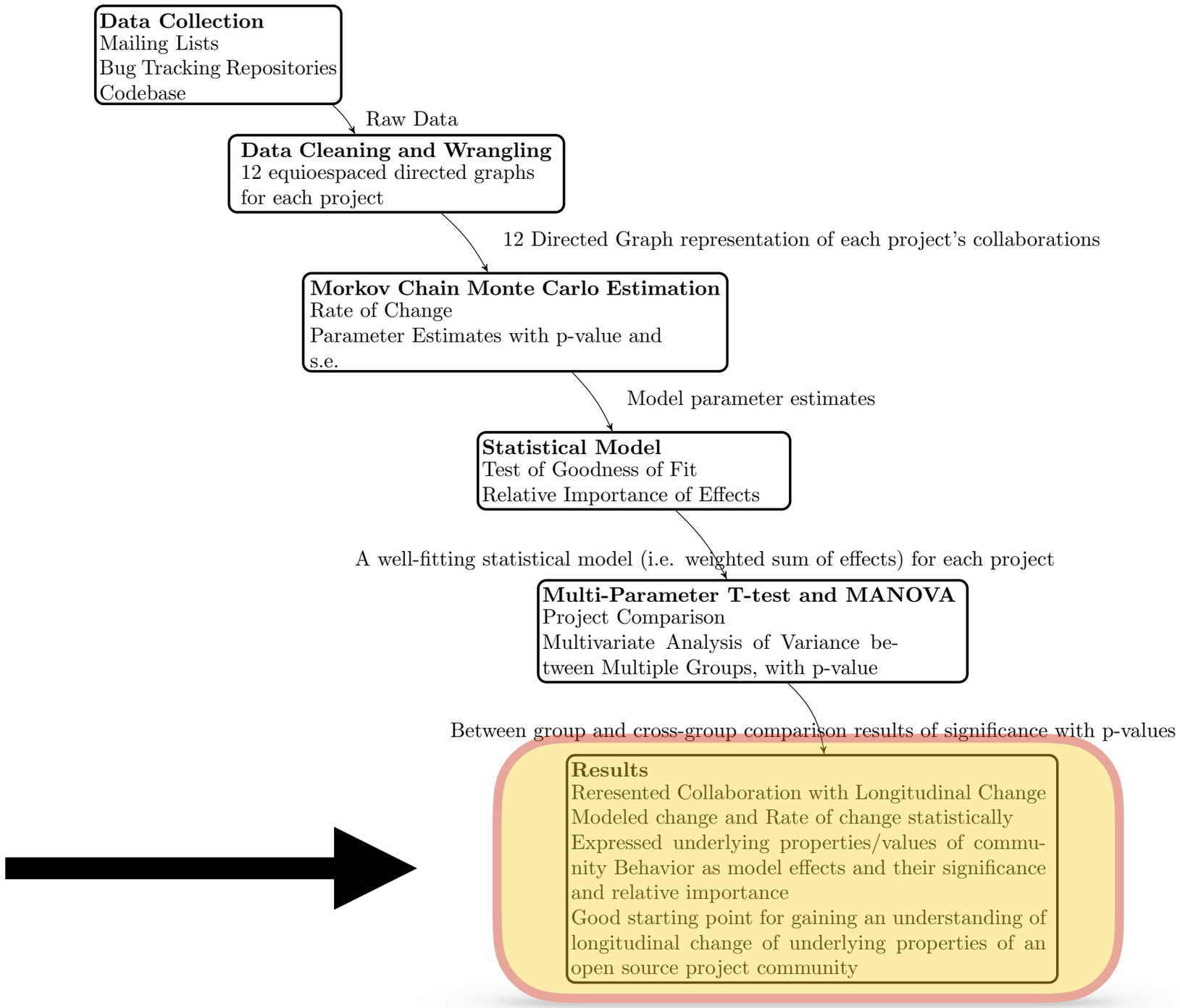
Methodology: Hypothesis Testing



Hypothesis Testing

- Single parameter test
  - To determine the significance of covariates in the model; longitudinal changes can be [partially] explained by that covariate
- Multi-parameter differences between groups
  - To compare two project models
- Multivariate ANOVA
  - To compare a group of projects and a project

Methodology: Results



Qualitative Validation

- Interviews/surveys
  - Semi-structured interviews with contributors
  - Not ~~open-coding~~. Using pre-existing categories in coding that maps to the covariates in the model
  - Multiple coders
- Sentiment analysis
  - Contents of messages sent/received by top contributors
  - A time series of sentiments, to analyze

Summary

- Represented Collaboration with Longitudinal Change
- Modeled change and Rate of change statistically
- Expressed underlying properties/values of community behavior as model effects and their significance and relative importance
- Validated using qualitative methods
- Good starting point for gaining an understanding of longitudinal change of underlying properties of an open source project community. (e.g. Github plug-in indicator)

What has been done, What remains to be done

- Data collection for mailing list archives is completed.
- Issue tracking system & source code interactions data is in the progress.
- Once all data is collected an cleaned, will do the statistical modeling.
- Next, we will do the qualitative validation.

Thank you!

Questions? Suggestions? Help?