Network Graph Solutions for Data Pipeline Diagnostics

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Introduction

- A **challenge** for studies using electronic health records (EHR) is the **development** of a data pipeline that **maps the raw EHR data to an analytic dataset**.
- This **data pipeline** is often a **complex network of programs**, owing to a large number of **phenotypes and data domains** that may be integrated in a single analytic dataset.
- Team members must develop and **share, on an ongoing basis, a clear understanding** of a given pipeline in order to make study progress, which can be challenging due to **varying familiarities** with existing database and process **modeling schemes**, such as Universal Modeling Language (UML) and Entity Relationship (ER) diagrams [1,2].
- ER diagrams would allow for **tracking of table dependencies**, but **not process dependencies**, which also affect **data integrity.**
- Within the **computing enclaves** of highly sensitive information, **restrictive security systems** may not allow for installation of **proprietary software** [3], limiting the availability of generalizable tools like those based on UML.
- Here we propose the use of **directed bipartite graph** models, **visualized interactively**, to address these issues and ultimately facilitate the application of advanced analytic methods that rely on data extracted from EHR databases.

Methods

- Our **novel application** of **directed bipartite graph models** allows investigators to
  - **Visualize** the **entire** data curation process
  - **Track dependency** based relevant program and data updates required when making changes to various pipeline components
  - Identify opportunities for optimization or automation of pipeline architecture
- Application:
  - A data pipeline that **links** Veterans Healthcare Administration (VA) EHR data with Medicare and Medicaid claims (CMS) data and **assembles** an analytic dataset comprised of **longitudinal patient trajectories**, including time-varying treatments, confounders, and outcomes.
  - The EHR and claims data reside on **different servers** and in different data formats, within the secure VA computing enclaves, thus both **SAS** and **SQL programming** languages are employed.
- We **implement** the graph model of the codebase using R and packages visNetwork, igraph, and shiny [4, 5, 6]. This provides an interactive visualization that:
  - Organizes a wide range of pipeline metadata
  - Facilitates exploration of the pipeline codebase
  - Surfaces diagnostics and dependency-base triggers

Evaluation of Results

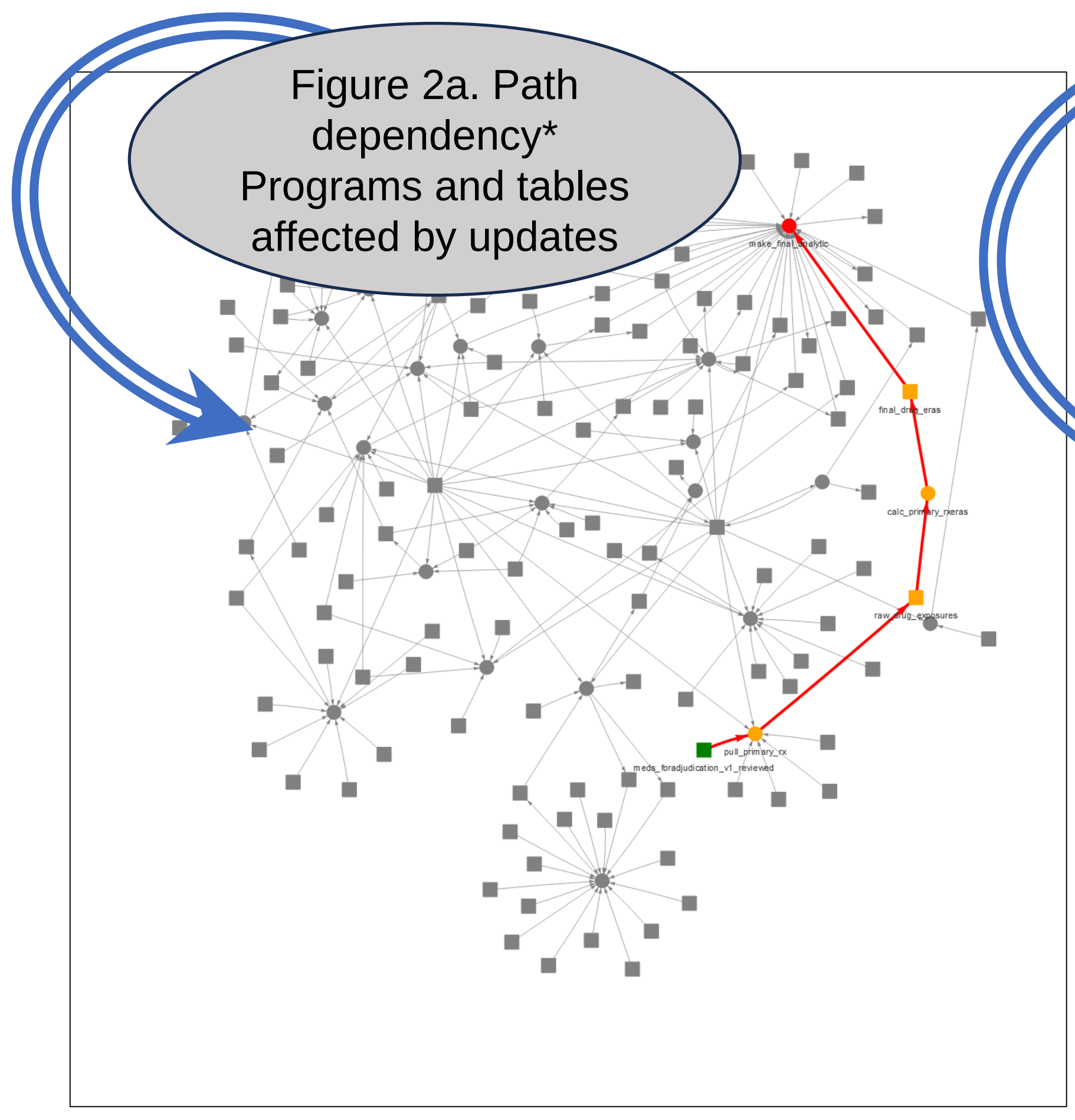


Figure 2a. Path dependency* Programs and tables affected by updates

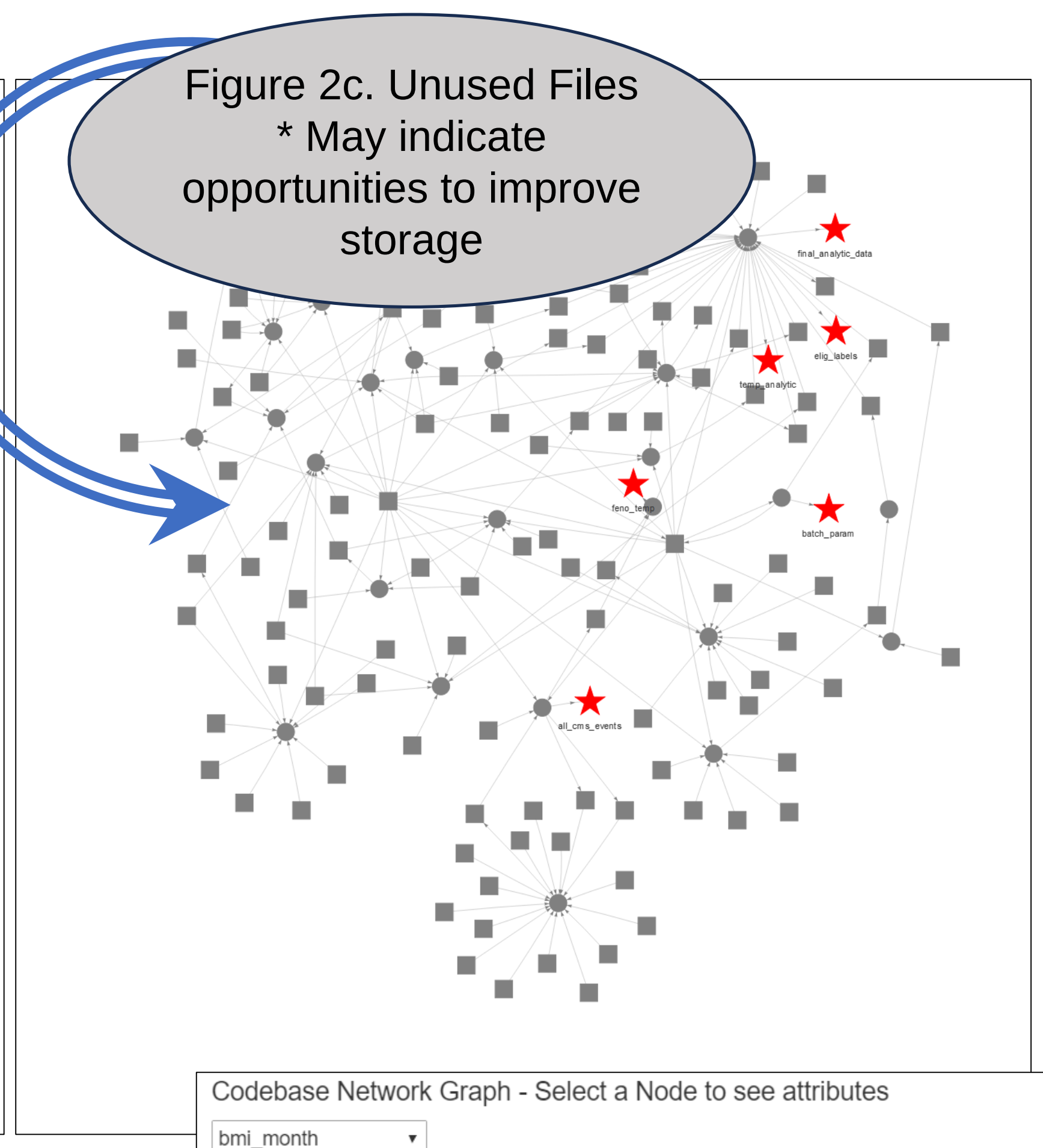


Figure 2c. Unused Files
* May indicate opportunities to improve storage

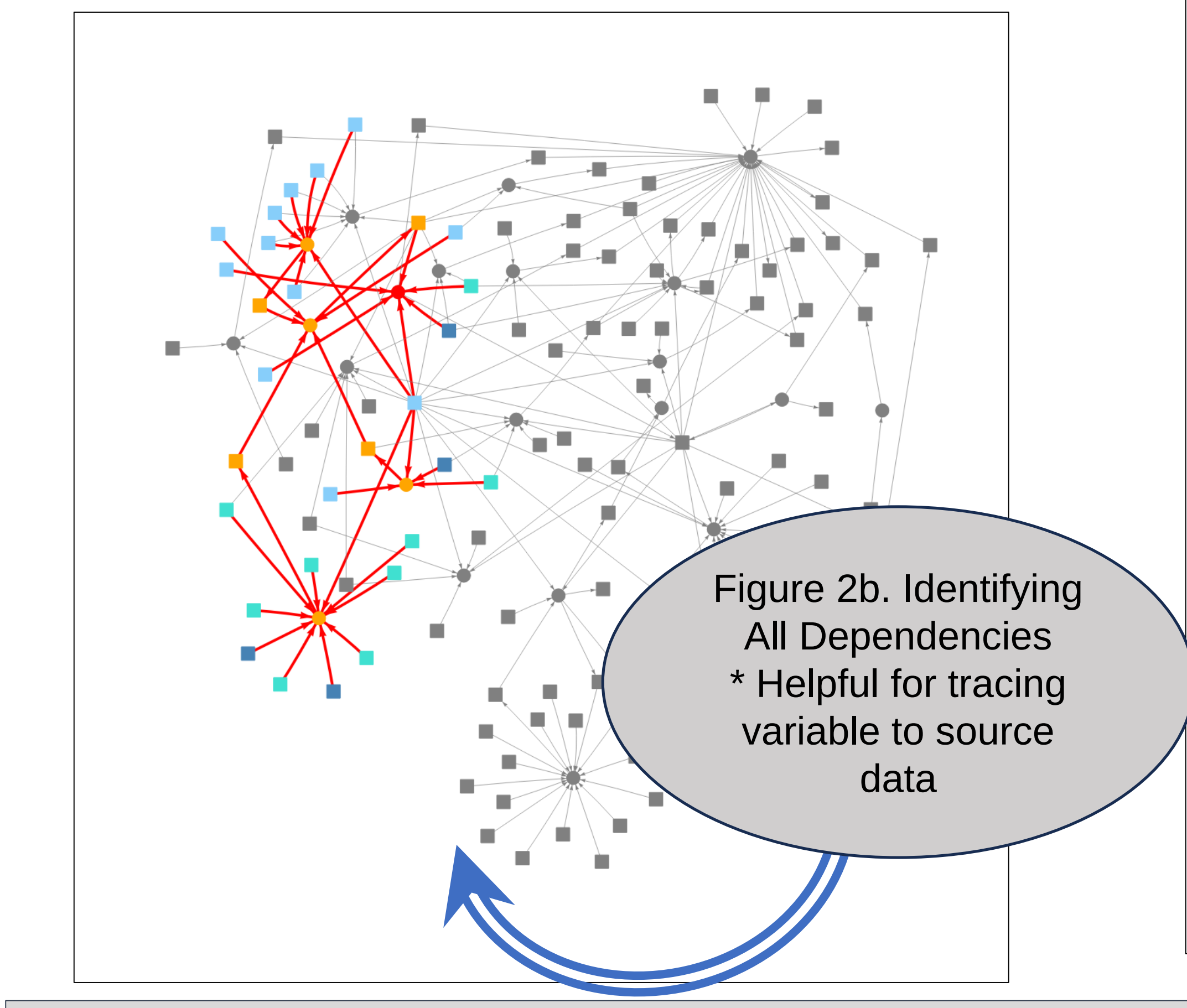
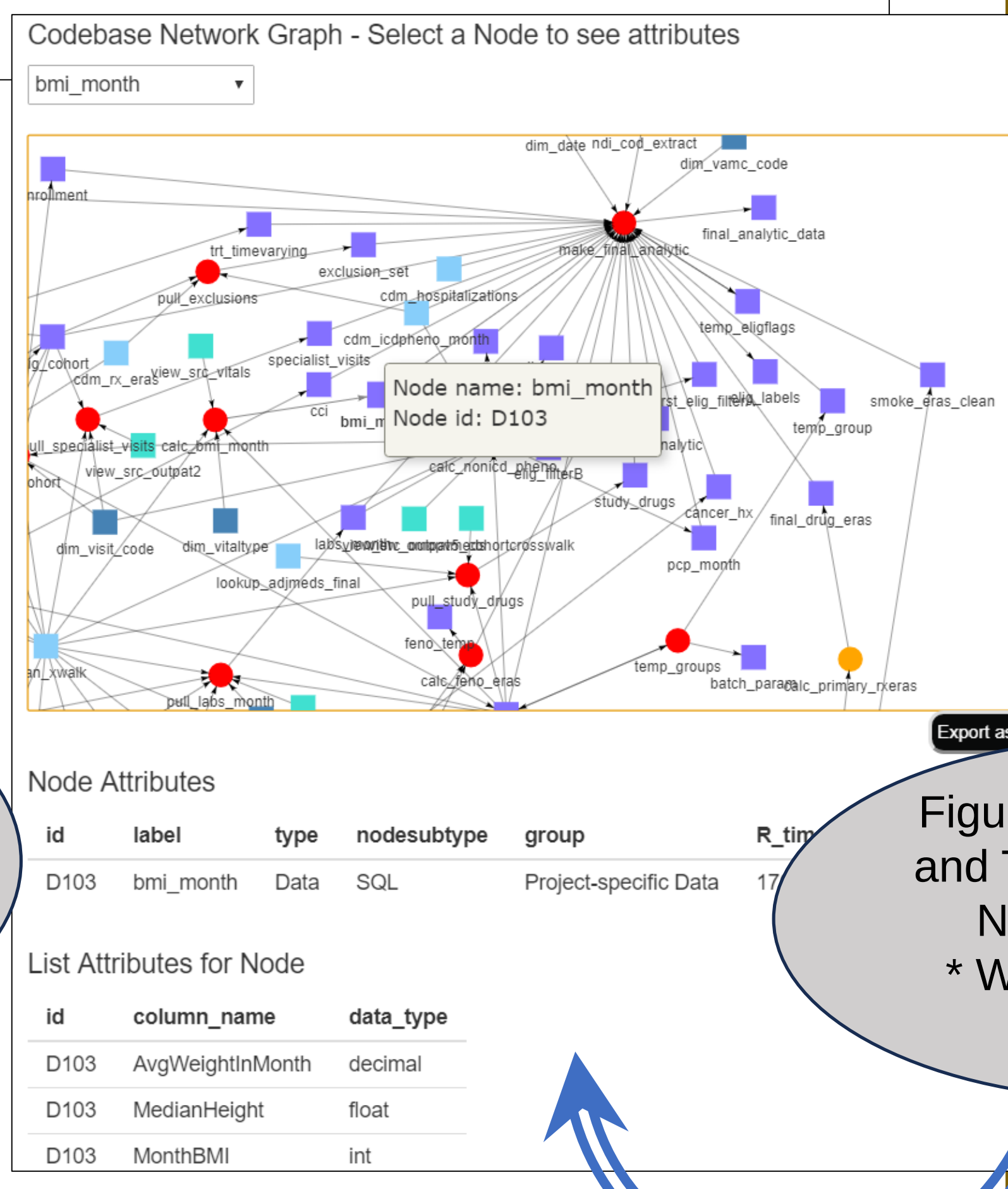


Figure 2b. Identifying All Dependencies
* Helpful for tracing variable to source data



Codebase Network Graph - Select a Node to see attributes

bmi_month

Node name: bmi_month
Node id: D103

Export as png

Node Attributes

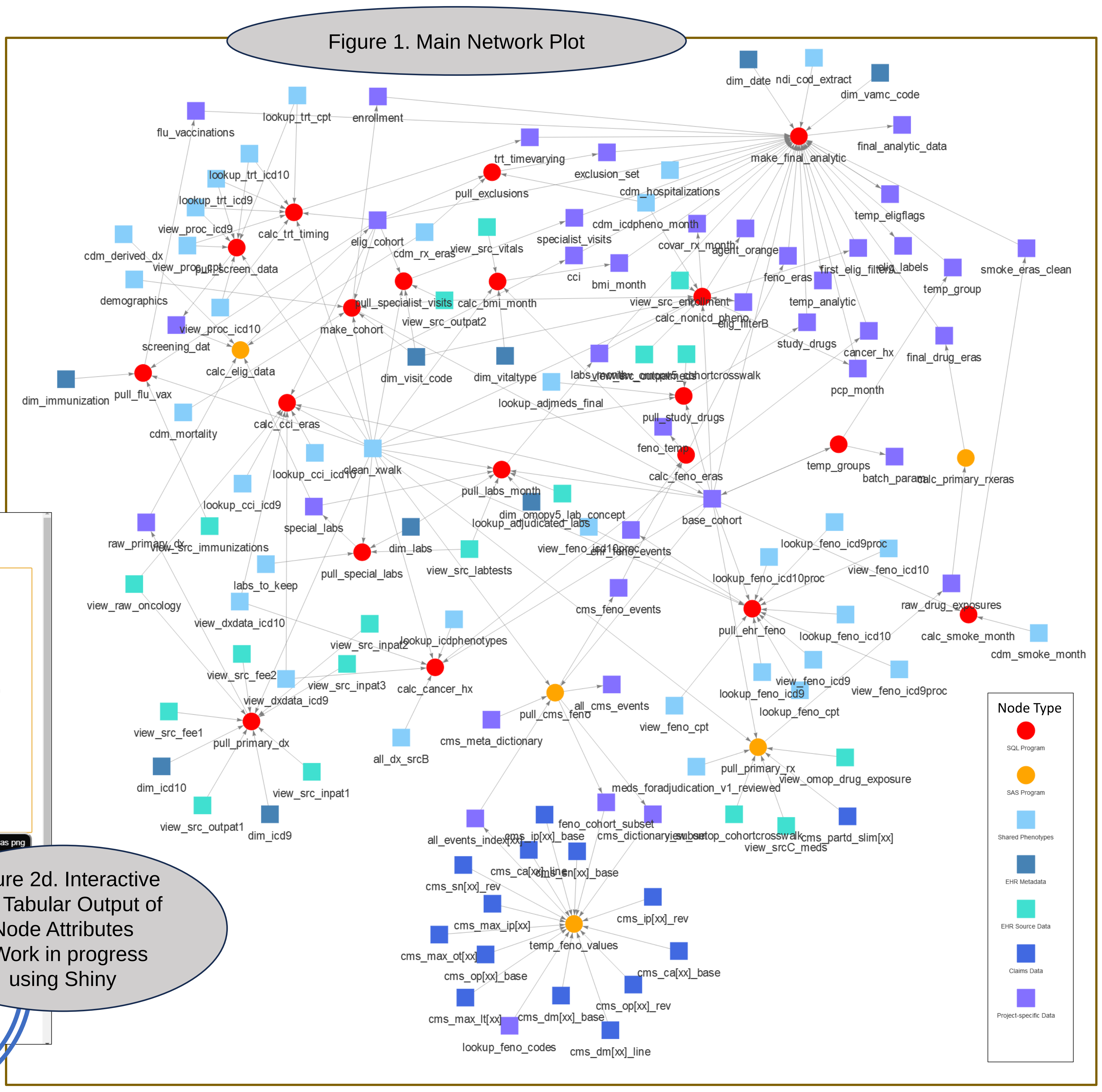
id	label	type	nodesubtype	group	R_tim
D103	bmi_month	Data	SQL	Project-specific Data	17

List Attributes for Node

id	column_name	data_type
D103	AvgWeightInMonth	decimal
D103	MedianHeight	float
D103	MonthBMI	int

Figure 2d. Interactive and Tabular Output of Node Attributes
* Work in progress using Shiny

Figure 1. Main Network Plot



Conclusions

- The representation of a data curation codebase in a bipartite network model provides a **natural way** for users to visualize, interrogate, and refine the data engineering process.
- By promoting both **transparency and data integrity**, this diagnostic approach may help **to improve the reproducibility** and quality of studies that rely on EHR and administratively-collected healthcare data.
- This framework can support tool development, process standardization, and graph-theoretical optimizations. **Future directions** of functionality include:
  - Variable tracing, incorporating semantic analysis of source programs
  - Robust quality control and verification checks, leveraging graph-theory dependency analysis
  - Flexible inspection and selection, through the continued development of an interactive interface

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