A graph data model facilitates analysis of collaboration in an emergency department

Matthew B Carson, PhD\textsuperscript{1}, Stephanie J Gravenor\textsuperscript{2}, Young Ji Lee, PhD, RN\textsuperscript{1}, Denise M Scholtens, PhD\textsuperscript{1}, Conor N Frailey, PhD\textsuperscript{3}, Nicholas D Soulakis, PhD\textsuperscript{1}

\textsuperscript{1}Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, Chicago IL
\textsuperscript{2}Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University, Chicago IL

\textbf{Introduction}

Healthcare is a complex system of interactions between patients and providers on many levels. During an encounter, a variety of personnel perform a different but overlapping set of activities in a cooperative effort to facilitate patient care. Recently, graph databases have been used to explore and gain knowledge from complex data sets in many industries. The inherent connectivity of the graph data model makes it ideal for exploring collaborative relationships between providers.

\textbf{Methods}

We identified workflow in the ED and translated this to a labeled property graph model.

From Northwestern Medicine’s Enterprise Data Warehouse (NM EDW) we extracted 259,289 ED encounters from 2012 - 2014 involving 155,976 patients and approximately 11,676 providers performing 75,220,941 activities.

• Our data management pipeline is shown below.

\textbf{Provider-Activity Network}

\begin{itemize}
  \item **Before:** Activities in the ED workflow (grey nodes, clockwise from the bottom left in order of occurrence) and a subset of the providers who performed them. Providers are colored by position type: \textit{Physician}, Res/Fellow, Med Student, \textit{Nurse}, ED assistant, Pharmacist, RAD, HLM, LSP.
  \item **After:** A Labeled Property Graph Model that allows for relationships between providers in the same and different encounter sets.
  \item **Advantages of graph databases:**
    \begin{itemize}
      \item Inherent connectivity of all data yields faster query times and avoids the "join problem".
      \item Lack of a predefined schema allows for easy updating and modification of the model; no table alterations required.
      \item In the labeled property graph model both nodes and relationships can have properties (key-value pairs); this creates a rich data representation and facilitates ad hoc queries.
    \end{itemize}
  \item **Hypotheses:**
    \begin{itemize}
      \item Identify specific instances of an activity and allow relationships between n ≥ 2 entities (i.e., Provider P performed Activity A during encounter E).
      \item Add flexibility by allowing data subsetting, e.g., an analysis of all providers and activities associated with specific workflow steps.
    \end{itemize}
\end{itemize}

\textbf{Results}

• In terms of patient satisfaction, collaborative relationships between pairs of providers are not equal.
• Individual providers are often involved in both high- and low-scoring collaborations.
• An increase in the number of shared encounters between a pair of providers may improve collaboration in some cases.

\textbf{Related Research / Future Directions}

• To continue to apply our collaboration evaluation method to new clinical domains, most recently cardiology[1]
• Using our graph model and database to facilitate improved FMEA practices[2]
• Extending the SPOR metric to teams of ≥ 3 providers
• Our graph model could be expanded to include auxiliary health information such as genomic and proteomic data, regulatory pathways, and precision medicine information for more in-depth analyses.

\textbf{References}


$^\text{§Corresponding author}$
Matthew Carson, matthew.carson@northwestern.edu