Graph-Based Modelling of Students’ Interaction Data from Exploratory Learning Environments

Alex Poulavassilis, Sergio Gutierrez-Santos, Manolis Mavrikis
The Problem

- Much research focuses on interactive educational applications that encourage students’ open-ended experimentation within a knowledge domain.
- For students to benefit from interaction with such *Exploratory Learning Environments* (ELEs) there is a need for explicit pedagogical support to be provided.
- Has led to research in intelligent techniques for providing *personalised, adaptive support* to students, to foster their productive interaction with ELEs.
- Data gathered from students' interactions in ELEs has the potential to help pedagogical experts understand how students are interacting with the system, and technical experts to develop enhanced intelligent support features.
The Problem

- However, log files from ELEs can contain large quantities of data, making their interpretation difficult and costly.
- Also, it is not possible to always know in advance what data are relevant for analytical purposes, therefore an exploratory analysis of the data gathered may be needed.
- In this paper we consider how modelling student-system interaction data as a graph makes possible graph-based queries and analyses that can provide insights into the ways that students are using the affordances of the ELE, and the effects of system interventions on students’ behaviour.
- Our ultimate aim is to feed back this understanding into improving the design of the ELE and its intelligent support.
- Two case studies: eXpresser and FractionsLab.
eXpresser microworld
student feedback: a nudge…
This is correct. But use a general rule to show the link between these numbers.
feedback after a student’s explicit request for help…

Check the number of tiles in your **building block**. How many building blocks do you have? What’s the rule needed here?

OK  More help...

How many tiles?

3 x = 2

Add these tiles (+)  Remove these tiles (−)

Model Rule

I am trying to  colour  the patterns in My Model. Help

See previous
FractionsLab microworld

Make a fraction and right click it. Select 'Find equivalent' and partition the fraction into 2, 3, 4 and 5.
Low-interruption feedback

Make a fraction and right click it. Select 'Find equivalent' and partition the fraction into 2, 3, 4 and 5.

Excellent. Now, how are you going to partition the fraction?
Make a fraction and right click it. Select 'Find equivalent' and partition the fraction into 2, 3, 4 and 5.
High-interruption feedback

Make a fraction and right click it. Select 'Find equivalent' and partition the fraction into 2, 3, 4 and 5.

Excellent. Now, how are you going to partition the fraction into 3?
The data gathered

- Event-based data:
  - Students’ interactions with the ELE
  - Occurrence of key *indicators* as students interact with the ELE
  - Provision of feedback by the ELE to students
- Students' constructions:
  - including history of development of these
- Task information: learning goals, solution approaches
- Students' learner models
Core Graph Data Model
Fragment of Graph Data (FractionsLab)

- **344712**
  - dateTime: 20150215091741
  - taskID: 56
  - constrID: 4
  - userID: 5
  - sessionID: 1
  - occurrenceOf
    - startTask
      - eventID: 0
      - eventStatus: 0
      - eventCat: taskEv

- **344758**
  - dateTime: 20150215091828
  - taskID: 56
  - constrID: 4
  - userID: 5
  - sessionID: 1
  - occurrenceOf
    - fractionChanged
      - eventID: 1002
      - eventStatus: 1
      - eventCat: sfractionEv
  - occurrenceOf
    - fractionReleased
      - eventID: 1003
      - eventStatus: 1
      - eventCat: fractionEv

- **344759**
  - dateTime: 20150215091832
  - taskID: 56
  - constrID: 4
  - userID: 5
  - sessionID: 1
  - occurrenceOf
    - interventionShown
      - eventID: 6002
      - eventStatus: 2
      - eventCat: systemEv

- **344760**
  - dateTime: 20150215091833
  - taskID: 56
  - constrID: 4
  - userID: 5
  - sessionID: 1
  - occurrenceOf
    - clickButton
      - eventID: 3002
      - eventStatus: 0
      - eventCat: taskEv
Some Exploratory Queries

\[(\?X, \?Y, \?Z) \leftarrow (\?X, \text{occurrenceOf, interventionShown}), \]
\[ (\?X, \text{next, } \?Y), \]
\[ (\?Y, \text{occurrenceOf, } \?Z) \]

allows researchers to see types of events directly follow the display of an intervention message; allows confirmation/contradiction of their expectations regarding the immediate effect of intervention messages on students’ behaviours

\[(\?X, \?Y, \?Z) \leftarrow (\?X, \text{occurrenceOf, interventionShown}), \]
\[ (\?X, \text{next+}, \?Y), \]
\[ (\?Y, \text{occurrenceOf, } \?Z) \]

allows researchers to see types of events directly or indirectly follow the display of an intervention message; allows confirmation/contradiction of expectations regarding longer-term effects of intervention messages on students’ behaviours
modify the query to retain only pairs X, Y that relate to the same construction:

\[
(?X,?Y,?Z) \leftarrow (?X, \text{occurrenceOf}, \text{interventionShown}),
\]
\[
(?X, \text{constrID}, ?C), (?X, \text{next+}, ?Y),
\]
\[
(?Y, \text{constrID}, ?C), (?Y, \text{occurrenceOf}, ?Z)
\]

use a path variable to return the matched paths through the data as well:

\[
(?X,?P, ?Y,?Z) \leftarrow (?X, \text{occurrenceOf}, \text{interventionShown}),
\]
\[
\]
\[
(?Y, \text{constrID}, ?C), (?Y, \text{occurrenceOf}, ?Z)
\]

use approximate matching to return increasingly longer paths to the user:

\[
(?X,?P, ?Y,?Z) \leftarrow (?X, \text{occurrenceOf}, \text{interventionShown}),
\]
\[
(?X, \text{constrID}, ?C), \text{APPROX} (?X, \text{next : ?P, ?Y}),
\]
\[
(?Y, \text{constrID}, ?C), (?Y, \text{occurrenceOf}, ?Z)
\]
In addition to evaluating queries over the interaction data, by representing the data in the form of a graph it is possible to apply graph structure analyses such as the following:

- **Path finding and clustering**: for determining patterns of interest across a whole dataset, or focusing on particular students, tasks or sessions
- **Average path length**: determining the amount of student activity
- **Graph diameter**: determining the most long-running or most intensive task(s)
- **Degree centrality**: identifying key event types occurring during students’ interactions
- **Betweenness centrality**: identifying event types that play key mediating roles between other event types
Ad hoc analyses: Transitions between indicator types
Implementation in a Graph DB (Neo4j)
Conclusions

- We have presented a general graph model for representing event-based student-system interaction data arising from ELEs.
- We have explored the possibilities that evaluating regular path queries over this graph-based representation provides for exploring the behaviours of students as they are working in the ELE and the effectiveness of the ELE’s intelligent support.
- We have also identified additional graph algorithms that may yield further insights about learners, tasks and significant interaction indicators.
- In recent work, we have transformed and uploaded an interaction data set gathered during a trial of FractionsLab into the Neo4J graph database.
Future Work

- Design, implementation and evaluation of meaningful queries, analyses and visualisations over the graph data, in collaboration with pedagogical experts and teachers
- Aiming to lead to improved understanding of student-system interaction, and to feed back into enhanced design of the ELEs
- Investigation of how existing flexible querying processing techniques for graph data might be applied/adapted/extended to fine-granularity student-system interaction data, and to the pedagogical setting of providing effective intelligent support to learners undertaking exploratory tasks in ELEs
Acknowledgements

- **MiGen** team members, particularly Eirini Geraniou, Ken Kahn, Darren Pearce-Lazzard, Celia Hoyles, George Magoulas, Richard Noss

- **iTalk2Learn** team members, particularly Beate Grawemeyer, José Luis Fernandez-Gomez, Wayne Holmes

- Alex Wollenschlaeger: interactions data transformation and uploading to Neo4J, generation of new visualisations