



Evaluating Two Approaches to Assessing Student Progress in Cybersecurity Exercises

**Valdemar Švábenský, Richard Weiss, Jack Cook, Jan Vykopal,
Pavel Čeleda, Jens Mache, Radoslav Chudovský, Ankur Chattopadhyay**

Masaryk University (Czech Republic), Evergreen State College (USA), New York University (USA),
Lewis & Clark College (USA), Northern Kentucky University (USA)

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Goal

Assess student practical skills in cybersecurity exercises

- Provide instructors with classroom situational awareness
- Identify students' strengths and shortcomings
- Help students learn

Summary

- Cybersecurity students need to develop **practical skills** such as using command-line tools. Hands-on exercises are recommended.
- Assessing students' mastery by modeling and visualizing student progress automatically throughout the exercise is a viable method.
- To summarize progress, we implemented **two types of graph models** and compared them using data from 46 students at two universities.
- To evaluate our models, we **surveyed computing instructors** and qualitatively analyzed their responses.
- The majority of instructors interpreted the graph models effectively and identified strengths, weaknesses, and assessment use cases.

Contributions

- We demonstrate how **multiple institutions can collaborate** to share approaches to modeling student progress in hands-on exercises.
- Our **modeling techniques generalize** to data from different environments to support student assessment, even outside the cybersecurity domain.
- We **share the acquired data and open-source software** so that others can use the models in their classes or research.
 - <https://zenodo.org/record/5752288>

KYPO CRP and EDURange – Two Testbeds for Cybersecurity

- Platforms that allow instructors to create hands-on cybersecurity exercises
- A collection of exercises
- Tools for visualizing student command history
 - Primary goal: simplify many lines of commands into visual form that enables the instructor to judge easily if the student needs help.
- See more at:
 - <https://crp.kypo.muni.cz/>
 - <http://www.edurange.org/>

Modeling Student Progress in Command-Line exercises

We examined **two approaches** to modeling student progress on our platforms:

1. Trainee Graphs

- Authors manually and iteratively create a reference graph that represents an example solution.
- Student activity is then automatically mapped against this example, and visualized.

2. Milestone Graphs

- Exercises are broken into discrete tasks, called milestones, with each having a uniquely identifiable regular expression.
- Each line of students' bash history is then checked against these milestones to find matches.

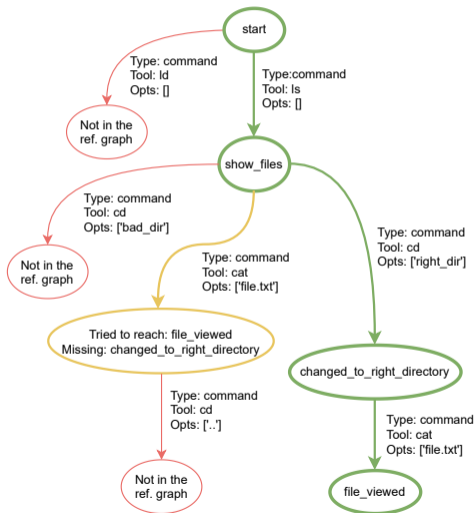
Benefits of the Modeling Approaches

- Quickly and accurately identify high or low-performing students in the class
- Identify successes and struggles of a specific student – and across the class
- Give each student their own graph to reflect on their approach and self-evaluate their learning process

Both KYPO CRP and EDURange produce these models fully **automatically**.

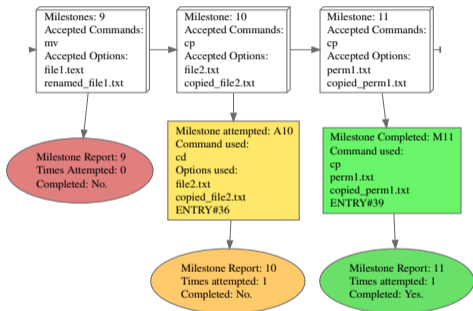
Since both platforms analyze bash history, modeling techniques are **interchangeable**.

Example Trainee Graph



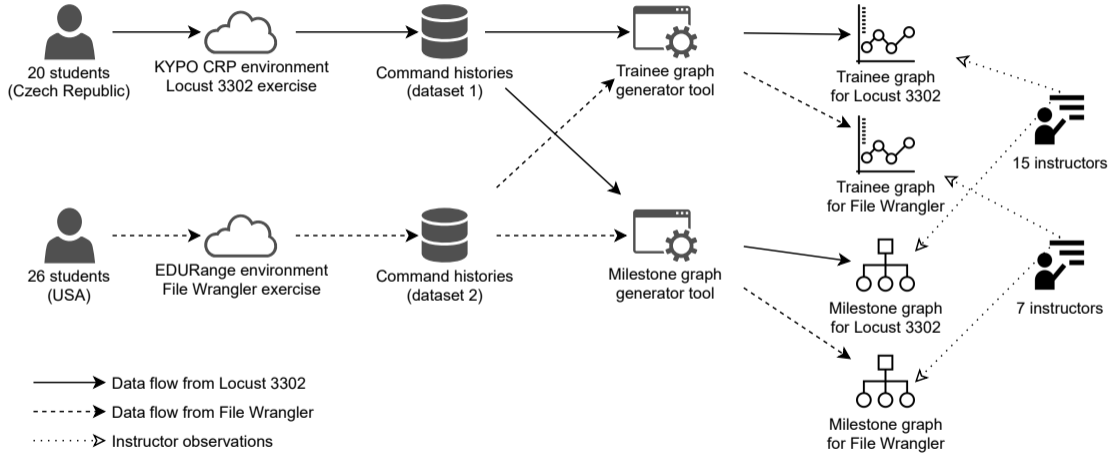
- Green: successful steps mapped to the reference graph.
- Red: actions that were likely erroneous or unnecessary.
- Yellow: actions with missing prerequisites, possible new solutions.

Example Milestone Graph



- Milestone boxes (white) are created from left-to-right at the top of the graph
- Descending rectangular nodes correspond to student activity, ellipses contain summary data
- Descending nodes are colored:
 - Red: Unattempted
 - Yellow: Partial Attempt
 - Green: Success

Research Methods



Survey Results

- Most instructors interpreted each graph effectively, and were able to identify strengths, weaknesses, and use cases for each graph.
- **Trainee graphs** were better for in-depth information about the student.
- **Milestone graphs** were better for a quick overview of how the student did and how far they got.
- We received specific comments that we can use to improve the graphs' readability.

Limitations and Future Work

- Creating new exercises requires designers to define new reference graphs or milestones
- Real-time evaluation as opposed to retrospective
- Machine learning methods to cluster students and provide automated assistance

Publicly Available Contributions

Full paper and slides:

<https://muni.cz/en/research/publications/1797699>

Supplementary materials:

<https://zenodo.org/record/5752288>



Collected
dataset



Analytical
tools



Full
results

Stay in Touch

Richard Weiss

✉ weissr@evergreen.edu

EDURange

🖥 <http://www.edurange.org/>

Valdemar Švábenský

✉ svabensky@ics.muni.cz

Cybersecurity Laboratory

🐦 <https://twitter.com/cybersecmuni>

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