US School Shooting from 1970 to 2022 – The Underlying Patterns

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# Abstract

*School shooting has increased in recent years and numerous studies have been conducted in several aspects including shooter’s profiles, the method, the weapons used and the outcome of the attack. This report aims to explore the underlying patterns of US school shooting data from 1970 to 2022 by using force-directed layout algorithm and modularity function. The outcome suggested that there are four underlying patterns to the data and they might be explained reasonably by the existing researches.*

# Introduction

*School shooting phenomenon* has still occurred since the first report in 1764 (K12 Academics, n.d.) and been more common in a 50-year review from 1966 to 2015 (Langman, 2016; cited in Poland & Ferguson, 2021). In addition, an upward trend in school shootings was recorded over the past 5 years (Katsiyannis et al., 2023). The most recent statistics also shows that there have been at least 16 school shooting in US so far this year, as of March 6 (Matthews, 2024). Many researchers studied about the school shooting incidents in the past covering several facets including shooter’s profiles, the method, the weapons used and the outcome of the attack (Poland et al., 2017; cited in Poland & Ferguson, 2021). Rather than exploring the areas mentioned thus far, the goal of this report is to determine whether school shooting statistics from 1970 to 2022 exhibit any underlying patterns. As existing patterns in shooter’s profiles (Burns & Crawford, 1999; Holland et al., 2019; Langman, 2009; Lankford, 2016; Newman et al., 2008; Rocque, 2012 cited in Gammell et al., 2022) or gender identity (Gerard et al., 2016; cited in Gammell et al., 2022), the expectation is that there will be at least a certain pattern among the features of incidents including where and when they happened, the level of school, the shooter’s gender, media attention and the type of weapons used. The report will review the dataset and technical methods used to analyze data, describe the findings, discuss other aspects and related works and then draw the conclusion.

# Dataset and methodology

## Dataset

Dataset is about K12 US Shootings from 1970 to 2022 which was downloaded from Kaggle (Zhuang, 2022). The original source came from the Center for Homeland Defense and Security's research project, the K12-School Shooting Database (K-12SSDB). The dataset is structured as a relational database (compilation of multiple sheets) referenced with a unique incident ID number that links to the corresponding INCIDENT, SHOOTER, VICTIM, and WEAPON files.

* INCIDENT: Incident ID number and the information related to what, where, and when the shooting happened.
* SHOOTER: Incident ID number and details about the shooter. Multiple rows that have similar incident ID numbers indicate multiple shooters involved.
* VICTIM: Incident ID number and details about the victim. Multiple rows have the same incident ID number if there were multiple victims.
* WEAPON: Incident ID number and details about the weapon used (including weapons that were possessed by the shooter during the incident but were not fired). Multiple rows have the same incident ID number if there were multiple weapons used.

## Methodology

The two primary techniques employed in the report are ForceAtlas2 layout – a force-directed algorithm for creating network graph as well as optimizing graph space when applying for large datasets and modularity for pattern discovery beneath data. Both were integrated in Gephi tool.

*Force-directed algorithm* is the one of the most widely used graph layout techniques, which assigns spring-like forces to edges of a graph to keep stable lengths. Furthermore, the layout can dynamically maintain the space between nodes by adjusting the weights of edges (Itoh et al., 2009). The advantages of this method includes good-quality results (“Force-directed”, 2024), laying out small graphs rapidly and versatility for application with large graphs (Klapaukh, 2014). Moreover, it is also easy to implement, modify, extend and apply human physical intuition to (Klapaukh, 2014). A drawback of this method is the computation time (Klapaukh, 2014; “Force-directed”, 2024; Itoh, 2009) and scalability on very large graphs. Classical force-directed algorithms are effective in drawing general graphs with few hundreds of vertices but less for thousands or hundred thousands of vertices (Hachul & Jünger, 2005 cited in Itoh, 2009). Despite the development of more efficient force-directed techniques (Tunkelang, 1998; Quigley & Eades, 2000; Gajer & Kobourov, 2000; Gajer et al., 2000; Harel & Koren, 2000; Walshaw, 2001; Hachul & Jünger, 2004; Hachul, 2005 cited in Hachul & Jünger, 2005), practical limitations persist. For instance, in experiments on GRIP and FMS algorithms, no drawing was generated in case of more than 30,000 nodes due to execution times or memory restrictions (Hachul & Jünger, 2005).

*ForceAtlas2 (FA2)* is based on the ForceAtlas (FA) layout algorithm (Bastian et al., 2009) but is faster and perform well for networks fewer than 100,000 nodes. Moreover, experimental results showed that FA2 produced above-average performance layouts with fewer edge crossing and angular resolution but less uniform edge length compared to FA, LinLog, Fruchterman and Reingold algorithm (Hua et al., 2018).

*Modularity* is a metric for community structure evaluation defined by Newman (Newman & Girvan, 2004; Newman, 2006 cited in Nicosia, 2009) for undirected network and extended to capture community structure in directed network (Arenas et al., 2007; Guimerà et al., 2007; Leicht & Newman, 2008 cited in Nicosia et al., 2009). The algorithm of modularity function used in this report, built into Gephi tool, was proposed by Blondel et al. with the outperformance of computation time and the good quality of the detected communities (Blondel et al., 2008).

# Results and findings

A graph with red dots

Description automatically generatedA colorful network of dots

Description automatically generated with medium confidenceThe modularity result indicated that there were 7 groups of nodes in this dataset (see Figure 1, 2). Let’s divide up and explore each one individually.

Figure 1: The graph of US School shooting data

Figure 2: The result of modularity function (resolution = 1)

*Group 1: account for 28.45% of total size of incidents (see Figure 3)*

Figure 3 suggests a context that in the summer incidents can occur on a non-school day, in the evening, at night or dismissal time, typically outside but still on school property. These incidents primarily involve elementary schools, with some occurring in K-8 or K-12 institutions. Local and regional media tend to pay more attention to these incidents, and the shooters in these incidents almost escape (unknown shooter’s gender).

*Group 2: account for 12.89% (see Figure 4)*

A close-up of a network

Description automatically generatedA network of dots and lines

Description automatically generated with medium confidenceFor this group, it suggests that incidents occurring at other types of schools are more likely to be ignored compared to those at elementary, middle, K-8, K-12, and high schools.

Figure 3: Class 2 (12.89%)

Figure 4: Class 1 (28.45%)

*Group 3: account for 11.89% (see Figure 5)*

A context suggested in this group is that incidents in the fall often involve high school level, happen off school property in school event or sport event period.

*Group 4: account for 21.41% (see Figure 6)*

The combination of this group pertains to the incidents inside school building. It suggests that these incidents are more likely to occur in the spring within morning class hour and are associated with middle school level. The international and national also pay attention to these incidents. Even more, there are shortguns and rifles used in these incidents as well as the participant of gender identity other than male.

A green and yellow fireworks

Description automatically generated with medium confidenceA diagram of a network

Description automatically generated with medium confidence

Figure 5: Class 3 (11.89%)

Figure 6: Class 4 (21.45%)

*Group 5: account for 6.33% (see Figure 7)*

A diagram of a bus

Description automatically generated with medium confidenceThe information in this group is actually limited. It seems like the incidents in school bus often occur before school time. However, statistical data on this situation indicates that the difference between incidents occurring before school and after school is not significant (see Table 1).

Table 1: The percentage of incidents occurred at school bus by time period

Figure 7: Class 5 (6.33%)

*Group 6: account for 8.9% (see Figure 9)*

The same as group 5, this group also lacks substantial information. Most of incidents happened at the start of the school day were acted by males (see Table 2).

*Group 7: account for 10.13% (see Figure 8)*

A diagram of a network

Description automatically generatedA diagram of several different types of connections

Description automatically generated with medium confidenceGroup 7 suggests that most incidents in winter occur at lunch or in the afternoon class period and the weapon used commonly is handgun.

Figure 9: Class 6 (8.9%)

Table 2: The percentage of shooters by gender in incidents occurred at start of school day

Figure 8: Class 7 (10.13%)

# Discussion

Discovering whether there exists any underlying pattern in the data about US school shooting from 1970 to 2022 is the main purpose of this report. The analysis divided data into 7 groups and fortunately, these group revealed some considerable patterns about US school shooting.

*The first pattern* is that in the summer, at elementary school, outside class but still on school property, at some special period (in the evening, at night, at dismissal time or non-school day), incidents are more likely to occur. This result is aligned partly with previous studies which have found that there was a significant association between higher temperatures and shootings, particularly on weekdays and even more so on weekends and holidays (Reeping & Hemenway, 2020; Michel et al., 2016) and that most of school shootings were committed outside of the school building (Freilich et al., 2022). However, the incidents following this pattern are often like *happen-escape* because most of time the shooters escaped afterward.

*The second pattern* is that in the spring, at middle school, inside school building within morning class, higher chance for incidents to happen and sometimes appear shotgun and rifle; *the third* is in the fall, in sport event or school event period at high school; and *the last pattern* is in the winter, at lunch time or afternoon class period with handgun. Studies indicated that gender role conflict which is ‘a developmental process that begins to emerge in adolescence’ (Watts & Borders, 2005 cited in Steinfeldt & Steinfeldt, 2010) has the relationship with depression (Blazina & Watkins, 1996 cited in Steinfeldt & Steinfeldt, 2010), anxiety (Wong, Pituch, & Rochlen, 2006 cited in Steinfeldt & Steinfeldt, 2010), substance abuse (Monk & Ricciardelli, 2003 cited in Steinfeldt & Steinfeldt, 2010), negative help-seeking attitudes (Lane & Addis, 2005 cited in Steinfeldt & Steinfeldt, 2010), and other negative intrapersonal and interpersonal outcomes (O’Neil, 2008 cited in Steinfeldt & Steinfeldt, 2010). Besides that, experiencing conflicts as well as bad situations can become a motive to cause the incident (McGee & DeBernardo, 1999; Meloy et al., 2001 cited in Gerard et al., 2016). The similarity in the last three patterns is that they imply the ability of occurrence inside school building or an event where the conflict may arise. The so far studies’ results might be an explanation for these patterns.

The other findings didn’t lead to any considerable pattern, but they provided some cases should be paid more attention to such as the incidents occurred at other school level accounted for a high proportion and were likely to be ignored or the idea in line with studies in the past such as most of incidents at school start period were acted by males (in general, most of incidents were acted by males (Gerard et al., 2016; cited in Gammell et al., 2022).

*Limitation*

While some patterns have been identified, it's important to recognize that these are only assumptions for identifying incidents with a high potential for occurrence. The scope of this report is limited to discovery, and further research is needed to evaluate these findings thoroughly. Another limitation is the presence of missing data and the reliability of primary source which was ignored in the approach of this report. Still, this report has just considered some features related to the incidents, there are more facets that could be added for more analysis such as the details of the victims and shooters as well as the attacks themselves. Acknowledging these limitations is crucial for understanding the scope and implications of the findings and for guiding future research efforts in this area.

# Conclusion

In conclusion, this report has identified four contexts for a potential incident identification, which are partially similar to and supported by the findings from previous studies. For instance, the relationship between temperature and shootings (Reeping & Hemenway, 2020; Michel et al., 2016), most of school shootings were committed outside of the school building (Freilich et al., 2022), conflict experiencing can be a potential motive for an incident (McGee & DeBernardo, 1999; Meloy et al., 2001 cited in Gerard et al., 2016) might provide some support for these patterns. The outcomes also suggest the existence of underlying patterns in US school shooting data. However, further detailed studies are necessary to confirm and refine these findings.

Reference

Arenas, A., Duch, J., Fernández, A., & Gómez, S. (2007). Size reduction of complex networks preserving modularity. New Journal of Physics, 9, 176 - 176.

Bastian, M., Heymann, S., & Jacomy, M. (2009). Gephi: An Open Source Software for Exploring and Manipulating Networks. Proceedings of the International AAAI Conference on Web and Social Media.

Blazina, C., & Watkins Jr, C. E. (1996). Masculine gender role conflict: Effects on college men's psychological well-being, chemical substance usage, and attitudes towards help-seeking. *Journal of Counseling Psychology*, *43*(4), 461.

Blondel, V. D., Guillaume, J. L., Lambiotte, R., & Lefebvre, E. (2008). Fast unfolding of communities in large networks. Journal of statistical mechanics: theory and experiment, 2008(10), P10008.

Burns, R., & Crawford, C. (1999). School shootings, the media, and public fear: Ingredientsfor a moral panic. *Crime, law and social change*, *32*, 147-168.

Force-directed graph drawing*.* (2024, April 15). In *Wikipedia*.https://en.wikipedia.org/wiki/Force-directed\_graph\_drawing

Freilich, J. D., Chermak, S. M., Connell, N. M., Klein, B. R., & Greene-Colozzi, E. A. (2022). Using open-source data to better understand and respond to American school shootings: Introducing and exploring the American School Shooting Study (TASSS). *Journal of school violence*, *21*(2), 93-118.

Gajer, P., Goodrich, M. T., & Kobourov, S. G. (2000, September). A multi-dimensional approach to force-directed layouts of large graphs. In *International Symposium on Graph Drawing* (pp. 211-221). Berlin, Heidelberg: Springer Berlin Heidelberg.

Gajer, P., & Kobourov, S. G. (2000, September). Grip: Graph drawing with intelligent placement. In *International Symposium on Graph Drawing* (pp. 222-228). Berlin, Heidelberg: Springer Berlin Heidelberg.

Gammell, S. P., Connell, N. M., & Huskey, M. G. (2022). A descriptive analysis of the characteristics of school shootings across five decades. *American journal of criminal justice*, *47*(5), 818-835.

Gerard, F. J., Whitfield, K. C., Porter, L. E., & Browne, K. D. (2016). Offender and offence characteristics of school shooting incidents. *Journal of Investigative Psychology and Offender Profiling*, *13*(1), 22-38.

Guimerà, R., Sales-Pardo, M., & Amaral, L.A. (2007). Module identification in bipartite networks with applications to directed networks.

Hachul, S. (2005). *A Potential-Field-Based Multilevel Algorithm for Drawing Large Graphs* (Doctoral dissertation, Universität zu Köln).

Hachul, S., & Jünger, M. (2004, September). Drawing large graphs with a potential-field-based multilevel algorithm. In *International Symposium on Graph Drawing* (pp. 285-295). Berlin, Heidelberg: Springer Berlin Heidelberg.

Hachul, S., & Jünger, M. (2005, September). An experimental comparison of fast algorithms for drawing general large graphs. In International Symposium on Graph Drawing (pp. 235-250). Berlin, Heidelberg: Springer Berlin Heidelberg.

Harel, D., & Koren, Y. (2000, May). A fast multi-scale method for drawing large graphs. In *Proceedings of the working conference on Advanced visual interfaces* (pp. 282-285).

Holland, K. M. (2019). Characteristics of school-associated youth homicides—United States, 1994–2018. *MMWR. Morbidity and Mortality Weekly Report*, *68*.

Hua, J., Huang, M. L., & Wang, G. (2018). Graph layout performance comparisons of force-directed algorithms. International Journal of Performability Engineering.

Itoh, T., Muelder, C., Ma, K. L., & Sese, J. (2009, April). A hybrid space-filling and force-directed layout method for visualizing multiple-category graphs. In 2009 IEEE Pacific Visualization Symposium (pp. 121-128). IEEE.

Katsiyannis, A., Rapa, L. J., Whitford, D. K., & Scott, S. N. (2023). An examination of US school mass shootings, 2017–2022: Findings and implications. Advances in neurodevelopmental disorders, 7(1), 66-76.

Klapaukh, R. (2014). An empirical evaluation of force-directed graph layout (Doctoral dissertation, Open Access Te Herenga Waka-Victoria University of Wellington).

K12 Academics. (n.d.). *History of School Shootings in the United States*. Retrieved April 21, 2024, fromhttps://www.k12academics.com/school-shootings/history-school-shootings-united-states

Lane, J. M., & Addis, M. E. (2005). Male gender role conflict and patterns of help seeking in Costa Rica and the United States. *Psychology of Men & Masculinity*, *6*(3), 155.

Langman, P. (2009). Rampage school shooters: A typology. *Aggression and violent behavior*, *14*(1), 79-86.

Langman, P. (2016). Multi-victim school shootings in the United States: A fifty-year review. The Journal of Campus Behavioral Intervention, 4, 5-17.

Lankford, A. (2016). Public mass shooters and firearms: A cross-national study of 171 countries. *Violence and victims*, *31*(2), 187-199.

Leicht, E. A., & Newman, M. E. (2008). Community structure in directed networks. Physical review letters, 100(11), 118703. <https://doi.org/10.1103/PhysRevLett.100.118703>

Matthews A. L. (2024, March 7). *School shootings in the US: Fast facts.* CNN. https://en.wikipedia.org/wiki/Force-directed\_graph\_drawing

McGee, J. P., & DeBernardo, C. R. (1999). The classroom avenger: A behavioral profile of school based shootings. *The Forensic Examiner*.

Meloy, J. R., Hempel, A. G., Mohandie, K., Shiva, A. A., & Gray, B. T. (2001). Offender and offense characteristics of a nonrandom sample of adolescent mass murderers. *Journal of the American Academy of Child & Adolescent Psychiatry*, *40*(6), 719-728.

Michel, S. J., Wang, H., Selvarajah, S., Canner, J. K., Murrill, M., Chi, A., ... & Schneider, E. B. (2016). Investigating the relationship between weather and violence in Baltimore, Maryland, USA. *Injury*, *47*(1), 272-276.

Monk, D., & Ricciardelli, L. A. (2003). Three dimensions of the male gender role as correlates of alcohol and cannabis involvement in young Australian men. *Psychology of Men & Masculinity*, *4*(1), 57.

Newman M. E. (2006). Modularity and community structure in networks. Proceedings of the National Academy of Sciences of the United States of America, 103(23), 8577–8582. https://doi.org/10.1073/pnas.0601602103

Newman, K. S., Fox, C., Harding, D., Mehta, J., & Roth, W. (2008). *Rampage: The social roots of school shootings*. Hachette UK.

Newman, M. E., & Girvan, M. (2004). Finding and evaluating community structure in networks. Physical review. E, Statistical, nonlinear, and soft matter physics, 69(2 Pt 2), 026113. https://doi.org/10.1103/PhysRevE.69.026113

Nicosia, V, Mangioni, G, Carchiolo, V, and Malgeri, M. Extending the definition of modularity to directed graphs with overlapping communities. United Kingdom. <https://doi.org/10.1088/1742-5468/2009/03/P03024>

O'Neil, J. M. (2008). Summarizing 25 years of research on men's gender role conflict using the Gender Role Conflict Scale: New research paradigms and clinical implications. *The counseling psychologist*, *36*(3), 358-445.

Poland, S., Conte, B., VanHasselt, V., & Bourke, M. (2017). School violence (chapter). *Handbook of behavioral criminology: Contemporary strategies and issues*.

Poland, S., & Ferguson, S. (2021). School Shootings: An Overview. Lessons Learned From School Shootings: Perspectives from the United States of America, 1-12.

Quigley, A., & Eades, P. (2000, September). Fade: Graph drawing, clustering, and visual abstraction. In *International Symposium on Graph Drawing* (pp. 197-210). Berlin, Heidelberg: Springer Berlin Heidelberg.

Reeping, P. M., & Hemenway, D. (2020). The association between weather and the number of daily shootings in Chicago (2012–2016). *Injury epidemiology*, *7*, 1-8.

Rocque, M. (2012). Exploring school rampage shootings: Research, theory, and policy. *The Social Science Journal*, *49*(3), 304-313.

Steinfeldt, J. A., & Steinfeldt, M. C. (2010). Gender role conflict, athletic identity, and help-seeking among high school football players. *Journal of Applied Sport Psychology*, *22*(3), 262-273.

Tunkelang, D. (1998, August). JIGGLE: Java interactive graph layout environment. In *International Symposium on Graph Drawing* (pp. 413-422). Berlin, Heidelberg: Springer Berlin Heidelberg.

Walshaw, C. (2001). A multilevel algorithm for force-directed graph drawing. In *Graph Drawing: 8th International Symposium, GD 2000 Colonial Williamsburg, VA, USA, September 20–23, 2000 Proceedings 8* (pp. 171-182). Springer Berlin Heidelberg.

Watts Jr, R. H., & Borders, L. D. (2005). Boys' perceptions of the male role: Understanding gender role conflict in adolescent males. *The Journal of Men’s Studies*, *13*(2), 267-280.

Wong, Y. J., Pituch, K. A., & Rochlen, A. B. (2006). Men's restrictive emotionality: An investigation of associations with other emotion-related constructs, anxiety, and underlying dimensions. *Psychology of men & masculinity*, *7*(2), 113.

Zhuang, S. L. (2022, June). US School Shootings (1970-2022), Version 2. Retrieved April 11, 2024 from <https://www.kaggle.com/datasets/shilongzhuang/us-school-shootings-19702022>