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IYSE 6501
Course Project
11/28/2022

Summary

Correctional officers at The Indiana Department of Corrections (IDOC) were facing a crisis – violent attacks on prison guards were on the rise. (SAS, n.d.) During an 18-month period, 320 violent assaults were recorded monthly on average across the IDOC's adult facilities. IDOC Researchers Sarah Schelle and Bret Ellis determined that predictive analytics could be used to reduce the number of attacks.

The IDOC had a risk assessment tool, Indiana Risk Assessment System (IRAS), that has some inherent flaws that Schelle and Bret Ellis sought to correct. Notably, the tool was specifically designed to predict likelihood of recidivism, not likelihood of violent attacks. Additionally, IRAS only used static information collected at time of intake and fails to consider ongoing changes to a prisoner's risk status during incarceration.

The below is an analysis of some potential analytical models I believe the IDOC may have used in developing their analytics driven solution to reduce violent crimes perpetrated by incarcerated individuals.

Case Facts

In order to create identifiable and measurable outcomes of analytic modeling, one should break down the components of the case into a mutually exclusive, collectively exhaustive set of problems to answer. Each component can then be analyzed and solved. I have identified the following components:

1. How can we determine if an inmate will commit a violent crime?
2. When should intervention steps be taken?
3. What steps should be taken to intervene before a violent crime is committed?

Note: The objective of this assignment is to identify "at least three different analytics models might have been combined to create the solution." While only two outcomes of the analytic solution have been identified above, please note that at least three analytical models have been identified and discussed below.

Solution

I have summarized the below analysis here for each of the above components.

1. **Given** an inmates intake data and measurements about their day-to-day life,

use a clustering model to identify clusters of inmates and a logistic regression model for each cluster
to predict how likely an inmate is to commit a violent crime.

2. **Given** an inmate's likelihood to commit a violent crime,
   use a CUSUM model
   to identify when to take remediation steps to reduce an inmate's aggression.
3. **Given** an inmate's cluster, respective logistic regression model for calculating their likelihood to commit a violent crime, and various datapoints about them,
   use an optimization model to learn what changes could be made in their routine
   to minimize their likelihood to commit a violent crime.

Analysis

Below I have broken each case component down, and will discuss the considerations, analytical approach, and data needs to solving each component of the case.

1. How can we determine if an inmate will commit a violent crime?

Whether someone will commit a violent crime is ultimately a classification problem. We could look at this as a binary classification, i.e., will the person commit a violent crime or not? Or we could classify the inmates into groups such as not likely to commit a violent crime, likely to commit a violent crime, and highly likely to commit a violent crime.

Model Selection

There are several models we could choose from for a classification problem like this. A couple that come to mind are Support Vector Machines, Logistic Regression, Decision Trees, K-Nearest Neighbor, or even a combination of these.

Before selecting a model, we should analyze a few things about the data we have to analyze and who the audience is.

Data Profile

According to the case study, there are 5,500 staff members and 27,000 inmates across 18 facilities. (SAS, n.d.) Data is recorded about the inmates at intake, and there is a possibility of gathering new data as time progresses. One way we should look at these data points is from the feature side, i.e., what data are we using as our predictors? The data recorded at intake is likely manually recorded by another human, and the new data we could potentially gather about each inmate is also likely to be manually recorded by a human or is an observation of an inmate's behavior. Wholistically, it is starting to look like we are not likely to have more observations per inmate than number of inmates. When comparing SVM's against Logistic regression, this is important to consider. SVM's can be very efficient when there are more features than there are observations, and logistic regression is unable to handle scenarios like that.

Another data point to look at is what is the response we are trying to predict. Consider the training data we would likely have—we probably have database of inmates reaching back 10, maybe 15 years. It would be easy to have the response we are predicting be whether an inmate committed a crime during their incarceration, however, this leaves out two important pieces of information.

1. inmates who have not yet committed a crime but will before the end of their incarceration, and
2. What level of risk is the inmate at for committing a violent crime?

Point two above allows us to strike KNN from our potential models we would use. KNN would only be useful in classifying inmates as low/medium/high risk if the training data we had at hand included a response variable for if past inmates were a low/medium/high risk. Because the only likely data we would have in our dataset is whether a past inmate committed a crime or not, we would not have sufficient information to use KNN.

Instead consideration we may make is, do we want to know just whether an inmate will commit a crime, or is it important to know *how likely* they are to commit a crime? It is probably important to know how likely to commit a crime they are, so a binary classifier like SVM makes lesss sense than logistic regression, which will output a percent of how likely they are to commit a crime.

Target Audience

Another important factor to consider in model selection is who is the target audience. The IDOC is a government entity, and thus likely to be subject to strict laws regarding transparency. Oftentimes, in scenarios like this, we would potentially favor a simpler, more transparent model like logistic regression or a decision tree.

Intended Use

On the flip side, the intent of this model is to stop bodily harm to a human, thus we may tend to favor the more accurate model than the more simplistic model. There's no guarantee one model would be more accurate than another, but it is something we would want to consider by training and validating different models against one another.

Model Selection – Conclusion

Given the above, I would select a combination of logistic regression and a clustering model, k-means. More specifically, you could identify clusters within the inmate population, and run a separate logistic regression model for each cluster. This approach has several benefits:

- Using a logistic regression model allows us to rank inmates rather than just classify them as "will commit a violent crime" or "will not commit a violent crime". IDOC likely is operating with limited resources, so they would likely benefit from being able to identify certain populations as "highly likely" or "extremely highly likely" to commit a violent crime and intervene with those inmates first.

- Prescriptive use – the coefficients of the resulting logistic regression functions could be analyzed to determine next best steps for intervention (something I will explore further into the analysis). For example, one cluster could have a very low log-odds coefficient for time spent exercising. This would indicate that giving the inmate more time to exercise likely would not be an effective remediation step.
- Running a different logistic regression model for each cluster would allow us to better understand different stressors for different populations. For example, a 26-year-old male that was committed for a violent crime is likely more stressed by lack of time to exercise than an older male who values time reading and other indoor activities.

Data Needs

Now that we have determined what type of model, we need to consider what data we would want to use as inputs into this model. Additionally, we would want to consider how we could collect this information and what data is ethical to use.

Model Inputs

For inputs to the k-means and logistic regression model, we can categorize them into stationary data, in that it does not change, and continuous data, that we can continue to collect over time and shape's the inmate's aggression "score".

Stationary Data

- Age
- Sex
- Ethnicity
- Committed for violent/non-violent crime
- Weight
- Height
- Marital Status
- Dependents at home
- Medical History

Continuous Data

- Behavior reports from correctional officers
- Time spent in different activities (library time, TV time, exercise time, etc.)
- Time in Cell per day
- Past reports of aggression
- Remaining sentence length
- Gang Affiliations
- What community the inmate is in[1]

[1] To keep this project on track and in scope of the three original questions I posed at the beginning, I will not do a full analysis of this analytic model, but I think a cool use here would be the Louvain community detection algorithm. Using the, we could identify what physical space community an inmate closely belongs to, and use it as an input in our logistic regression model. The Louvain network model takes in three inputs: source, target, and weight. We could model our prisoner data to fit this where each network node would be one (cont. on next page)

I would use lasso regression, as I would expect there to be many variables, and we are unsure which are relevant. Since lasso regression allows for 0 coefficients, we could eliminate unimportant metrics from our model.

Model Output – Conclusion

In summary, given an inmates intake data measurements of their day-to-day life, we could use clustering model to identify clusters of inmates and a logistic regression model in order to predict how likely an inmate of that cluster is to commit a violent crime (will be referred to as likelihood to commit a violent crime here forward, or LCVC).

2. When Should Intervention Steps be Taken?

Once we have identified how likely an inmate is to commit a violent crime, how do we determine when the appropriate time is to take remediation steps?

Typically, for a logistic regression model, we could use some sort of cost analysis to draw a line and determine something like "anyone over 80% likely to commit a violent crime should have intervention steps started." However, when modeling human behavior, how do we assign a cost to a misclassifying a violent inmate as non-violent? Also, since the goal of this is to track an inmate over time, would that really be an effective way to intervene when someone is getting violent? What if someone is initially assess (SAS, n.d.) (SAS, n.d.)ed to have a 10% likelihood of getting violent, and over three months, that is 7x multiplied and they are now 70% likely to commit a violent crime? Lastly, what if the has a large coefficient for something that can vary da-to-day, like time outdoors? We wouldn't want to send an inmate to a stress de-escalation program because it was rainy one day.

For that reason, I would suggest a change detection model, CUSUM, to detect when an inmate has reached a sustained critical level of likeliness to commit a violent crime.

Model Inputs

A CUSUM model takes in several parameters, and outputs an indicator when the observed value at time *t* exceeds a critical threshold.

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prisoner, and the weight between the nodes would be reflective of whether two inmates share a lunch time, if they share the same work job, etc. Therefore, the source node is one prisoner, their target nodes are all the other prisoners, and the weight between the source and each target node is how much time they spend in physical proximity to the other prisoners.

This would give us an input to our logistic regression model that would be rather impactful. For example, if we saw an inmate was getting increasingly more likely to commit a violent crime, and we saw that that inmate's particular cluster had a high coefficient for the community variable, we could use an optimization model to determine which lunch/work/etc. schedule that inmate should be placed in to minimize aggression likelihood.

The formula for a CUSUM model is:

$$S_t = max\{0, S_{t-1} + (x_t - \mu - C)\}$$
$$\text{Is } S_t \geq T \text{ ?}$$

X_t – This is our observed value at time t. In the case of our model, the value we are observing, and monitoring is an inmate's likelihood to commit a crime. Thus, X_t would be the output of the logistic regression model discussed above.

μ – This is the average of X, if there is no change. Thus, this would be the average likelihood to commit a crime. Now, we could do a CUSUM model for every cluster from the above model, with each CUSUM model having a different value μ. However, I don't believe this would be appropriate. For example, if there was one cluster for middle aged men incarcerated for a violent crime, and their average LCVC is 80%, we would not want that to be the baseline for their CUSUM model. That would mean that individual could sustain long periods of time at 80% or even 90% LCVC before intervention steps are taken. As such, I would propose we use one CUSUM model, and the value of μ would be the average LCVC across all inmates.

T – This is the threshold for which we should consider an inmate an acute risk for committing a violent crime. One way to look at this value is in combination with *C*. If our data is pseudo-normally distributed, we can pick values of T and C based off one standard deviation (σ) of LCVC is amongst the inmates. For sake of this case, we will assume a pseudo-normal distribution. As such, the value of T could represent how many days an inmate sustains a LCVC greater than σ. So, if we wanted to raise a flag when an inmates LCVC is greater than one standard deviation than average for more than three days, we would set T equal to 3σ. I believe this is an appropriate measure. An inmate is likely to have swings their LCVC based on their environment (all of which are inputs to our first model), but after three sustained days of an inmate having a high LCVC it is probably time to check in with them.

C – Lastly, we have our *C* value, which acts as a damper. Essentially, we tell the model to not start accumulating any observed values of x each day until it is greater than C. As mentioned earlier, we can relate this value to the standard deviation of LCVC's across the population. I would be inclined to set this value to 0. Small swings in an inmates LCVC are expected, but even setting this value to 1σ would mean we don't even pay mind to an inmate's rising aggression until their likelihood to commit a violent crime is greater than ~85% of the population on a given day. I believe removing this buffer would lead to faster identification of aggressive inmates.

Conclusion

In summary, **given** an inmate's likelihood to commit a violent crime, **use** a CUSUM model **to** identify when to take remediation steps to reduce an inmate's aggression.

3. What steps should be taken to intervene before a violent crime is committed?

Now that we have identified models that tell us how aggressive an inmate is, and when they have had a sustained aggression for a period of time, we need to have an action plan on how to remediate the situation.

If we look back into our first model, I proposed using a clustering model to first identify distinct groups of inmates, and then each cluster would have their own logistic regression model fitted to predict their LCVC. The output of this model would be a linear function, where the coefficients of the logistic regression could tell us how important each feature of an inmate is to their LCVC, and the values multiplied by the coefficients would be the datapoints for that inmate.

For example, let's say one of the clusters had a logistic function that resulted in something like this:

$$logit(LCVC) = .2 + X_1\beta_1 + X_2\beta_2$$

Where X_1 is the time spent reading per day, and β_1 is the coefficient for time spent reading, and X_2 is time spent outdoors, and β_2 is the respective coefficient. If we wanted to decrease the inmate's likelihood to commit a violent crime, we could do things like increase their time spent outdoors.

Of course, the logistic regression model would have many more coefficients than just these two, it would have one for every input to the model, and some inputs would have multiple coefficients where we would have had to hot-encode categorical variables. And, not all of those X values could change – for example, we could not change the fact that an inmate was committed as a violent offender to decrease their LCVC.

So how do we keep this all straight, change only the things we are able to, and adjust for other constraints like only allowed to have one job, cannot spend more than 2 hours a day outside, etc.? We can use optimization models.

Model Inputs

An optimization model requires three parts; an objective function over which we would want to minimize/maximize, variable we are able to change, and constraints around how we can change those variables.

Objective function

I have already lightly touched on this, the value we want to minimize is an inmate's likelihood to commit a violent crime. Therefore, the objective function we would want to minimize would be the formula that gives that value, i.e., the logistic regression function for each cluster.

$$logit(LCVC) = .2 + \sum_{i=1}^{c} X_i \beta_i$$

Variables

Not all of our coefficient multiplies should be allowed to change, i.e., we can't change a person's race. Therefore, the variables would only be the features we can directly change to impact an inmate's aggression. This would be things such as work assignment, time spent in different activities, etc.

Constraints

Now, we would need to consider what constraints we would want to use. We would need to consider things such as:

- Can an inmate have multiple jobs?
- What are the prison's policies around maximum time outdoors?
- What is a reasonable amount of time to increase time spent on an activity? (Wouldn't want to suggest an inmate spend .3 extra minutes outdoors)
- If we need to move the inmate to a different physical community, where are they allowed to go? We can't move a Solitary Housing Unit inmate back to gen-pop if they are a risk to others.

These are just a few of the constraints, there would need to be interviews conducted with prison staff to learn what we are missing.

Once we have all of this information, we could take a given inmate, and run the model to learn what changes we could make in the inmates' environment that would minimize their likelihood to commit a violent crime.

Summary

In summary, given an inmate's cluster, respective logistic regression model for calculating LCVC, and various datapoints about them, use an optimization model to learn what changes could be made to minimize their likelihood to commit a violent crime.

Works Cited

SAS. (n.d.). *Prison violence dramatically drops with analytics-based risk assessment*. Retrieved from SAS: https://www.sas.com/en_us/customers/idoc.html