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An Integrated Framework for Modeling and Simulation of the U.S. Southern Border: A Border Patrol Perspective

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Abstract

Border Security is a complex system consisting of many interrelated components that must function as a whole in order to be effective. The efficacy of border security is dependent on several independent agencies; these include U.S. Customs and Border Patrol (CBP), Immigration and Customs Enforcement (ICE), the Department of Justice (DOJ), state and local law enforcement, and many others. Border security is not only a function of how well each of the agencies perform individually but also how well they interact to accomplish a goal. This paper attempts to model border security from a Border Patrol (BP) perspective using discrete event simulation in conjunction with Markovian analysis. The model will provide a baseline of the system's current effectiveness as well as any interventions made to the system.

Keywords

Border Patrol, Discrete Event Simulation, Desirability Function

1. Introduction

For modeling and simulation (M/S) to positively impact any environment it needs to have been appropriately modeled at the beginning stages. M/S is part of a much larger series of steps that takes place during any improvement process. It allows researchers to "play out" hypothetical scenarios of an environment and any interventions before they are applied in the "real world." This, in turn reduces the amount of capital and time required to develop an understanding of the system.

One of the real benefits of modeling and simulation is its ability to accomplish a time and space compression between the interrelationships within a system. This brings into view the results of interactions that would normally escape us because they are not closely related in time and space. Modeling and simulation can provide a way of understanding dynamic complexity.

The way modeling and simulation impacts a process depends on the process itself. First the correct M/S approach must used, some approaches include: systems dynamics models, discrete event models and agent-based models just to name a few. Once a modeling technique is selected then begins the process or actually building the model. Essentially researchers are trying to recreate a portion of the "real world" in a simulated environment; this environment is most often created in the computer. After the environment has been created, the model is run and "fine tuned" in order to create a representation of the current system state, this is called model validation.

After the model has been validated, then begins the task to experimentation. By adjusting various parameters in the model, researchers can observe behavior that takes place. This behavior can then be compared to previous events for further validation or it can be used to make predictions about the system.

2. Modeling and Simulation in the context of Border Security

Border security can essentially be defined as five fundamental capabilities, these include: deterrence, detection, apprehension, processing, and return. The capabilities encompass the entire process of ensuring no unauthorized aliens enter the United States. These capabilities are further explained below:

Deterrence – The process by which aliens are deterred from entering the United States. There are essentially two components that comprise deterrence, macro-deterrence and micro-deterrence. Macro-deterrence refers to deterring individuals from afar, for example through some intervention an alien living in southern Mexico is deterred from traveling to the U.S. Border to attempt entry. Micro-deterrence refers to deterring individual at the border, for example by the use of surveillance cameras or unmanned aerial vehicles (UAV's) an alien is deterred from crossing the border from Mexico into the United States.

Detection – The process by which individuals are detected once they have entered into the United States. Detection can be accomplished using many means, some may include: surveillance cameras, border agents, UAV's, concerned citizens, etc.

Apprehension – The process by which illegal aliens are apprehended and detained.

Processing – The process by which illegal aliens are identified, determined to be a threat to U.S. security, identified as committing a felony, and processed using fingerprint identification.

Return – The process by which illegal aliens are returned to their country of origin. There are several methods by which aliens are retuned to their homeland. Each case is unique and depending on what country the alien is from dictates how and when the alien will be returned.

2.1 The INS's Automated Biometric Fingerprint Identification System (IDENT)

In 1989, Congress provided the initial funding for the INS to develop an automated fingerprint identification system. One of the main purposes of the system was to identify and track aliens who were repeatedly apprehended trying to enter the United States illegally. The system was also intended to identify apprehended aliens who were suspected of criminal activity, had outstanding arrest warrants, or who had been previously deported. The conferees were concerned over the so-called "revolving door" phenomenon of illegal entry by aliens. This phenomenon involves repeated attempts by aliens to cross U.S. borders, requiring continual apprehension, removal and repeat apprehension of the same individual by INS officials.

Emerging technology in the area of automated fingerprint identification systems has the potential for providing empirical data to clearly define the problem of recidivism as well as immediately identify those criminal aliens who should remain in the custody of INS. Between 1991 and 1994, the INS conducted several studies of automated fingerprint systems, primarily in the San Diego, California, Border Patrol Sector. These studies demonstrated to the INS the feasibility of using a biometric fingerprint identification system to identify apprehended aliens on a large scale. In September 1994, Congress provided almost $30 million for the INS to deploy its fingerprint identification system. In October 1994, the INS began using the system, called IDENT, first in the San Diego Border Patrol Sector and then throughout the rest of the Southwest Border (DOJ, 2001).

2.2 The FBI's Integrated Automated Fingerprint Identification System (IAFIS)

Since the 1920s, the FBI's Identification Division has maintained a central repository of ten-fingerprint cards of criminal offenders. In 1967, the National Crime Information Center (NCIC) was created to provide a national name-based database of information on wanted individuals and stolen articles, vehicles, guns, and license plates submitted by participating federal, state, and local law enforcement agencies. The Interstate Identification Index, which contains information on arrests and dispositions, was added to NCIC in 1983.

An Advisory Policy Board (APB) composed of approximately 30 representatives from the federal, state, and local criminal justice community was organized in 1967 to establish policy and procedures for the management and use of the NCIC system and make recommendations to the FBI Director. In June 1989, the FBI Director asked the APB to expand its role and provide advice and guidance on fingerprint identification issues. In February 1990, the APB recommended that the FBI overhaul its paper-based fingerprint identification system and create a new system, IAFIS, that would allow electronic searches for fingerprint matches (DOJ, 2001).

The INS and the FBI periodically discussed integrating their automated fingerprint identification systems since both agencies began developing them around 1990. However, the INS had differing needs for its system and developed it faster than the FBI developed its own system. As a result, the INS deployed IDENT in 1994, well before the FBI's fingerprint scanning systems - IAFIS or the fingerprint biometric element of NCIC 2000 - were deployed in July 1999.

IAFIS is an automated ten-fingerprint matching system that relies on rolled fingerprints rather than flat pressed prints. IAFIS contains more than 40 million ten-print fingerprint records in its criminal master file and is connected electronically with all 50 states and some federal agencies. IAFIS was built to handle a large volume of fingerprint checks against a large database of fingerprints. But to support searches for latent fingerprints found at crime scenes, IAFIS requires ten-rolled fingerprints, rather than IDENT's two pressed prints. Rolled fingerprints obtain more points of comparison for each finger. NCIC 2000 was built to handle a much more limited volume of fingerprint checks against a much smaller database of fingerprints for individuals who have wants and warrants outstanding.

3. Model Development

Associated with each of the capabilities (deterrence, detection, apprehension, procession, return) is a performance metric ranging from zero to one. These performance metrics indicate how effective a capability is, for example suppose detection is operating at .53, this means that 53% of all aliens entering the U.S. are being detected.

Figure 1: Capabilities that comprise Border Patrol.

What is needed is a model that incorporates the five capabilities as function of various resources being applied to the system. The resources may be in the form of dollars, equipment, personnel, policy changes or other various forms. Though an accurate model of the system may be created, several fundamental questions are still left unanswered, these include:

1. How many illegal aliens are entering the United States over any given period of time?
2. Of those entering, how many have been deterred by the use of some intervention (i.e. propaganda, policy, etc.)?
3. How many illegal aliens entering the United States are being detected?
4. Of those that are detected, how many are apprehended?
5. Of those that are returned to their homeland, how many attempted to return to the United States?

Of all of these questions, only one can be answered with complete certainty, how many aliens are recaptured (recidivism rate). Through the use of the IDENT-IAFIS system it is known with near certainty how many times an individual has attempted entry into the United States and thereby provides a reliable data point.

The unknown parameters in the model are:

1. The initial population (the number of aliens attempting to enter the U.S)
2. The performance metrics of each of the capabilities (deterrence, detection, apprehension, procession, return)
3. The rate at which illegal aliens enter the United States.

If the model is constructed correctly, it should predict how many aliens are attempting to enter the country. In addition the model should predict the recidivism rate of illegal aliens. Figure 2 shows a graph of the recidivism rate of illegal aliens, once a discrete event simulation is constructed, various parameters in the model will be adjusted to create a model that is similar to “real world” data. The parameters in the model, which include effectiveness of the five capabilities (deterrence, detection, apprehension, procession and return) will give a baseline of the current system.

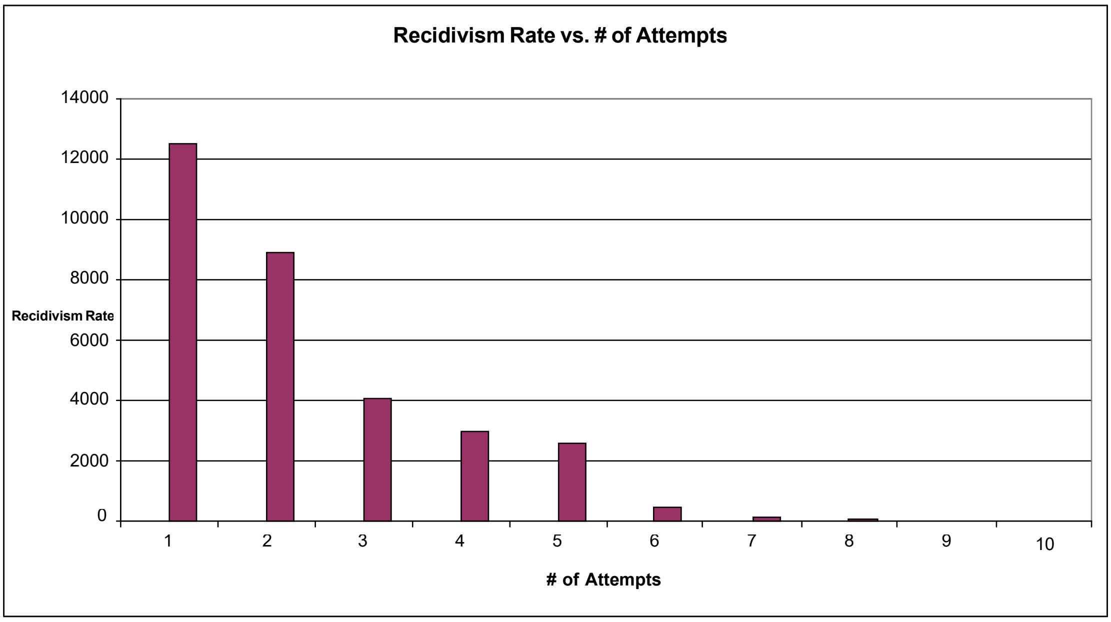

Figure 2: Graph of Alien Recidivism

3.1 Performance Metrics

To evaluate any system, first appropriate evaluation criteria must be developed. Traditionally, performance measures have included measures such as production rates, profits, etc. However, many times it is often difficult to create performance measures of a sub-system in absolute terms. What is needed is an approach that evaluates the system as a relative measure compared to its maximum operating potential. The proposed approach creates as measure of how "desirable" the sub-systems are compared to what they can be. The approach uses a desirability function developed by Derringer and Suich (1980) to determine the current operating characteristic of each sub-system as well as the super-system.

For each response $Y_i(x)$, a desirability function $d_i(Y_i)$ assigns numbers between 0 and 1 to the possible values of Y_i, with $d_i(Y_i) = 0$ representing a completely undesirable value and $d_i(Y_i) = 1$ representing a completely desirable or ideal response value. The individual desirability's are then combined using the geometric mean, which gives the overall desirability D_T :

$$D_T = (d_1(Y_i) * d_2(Y_2) * ... * d_k(Y_k))^{1/k} \qquad (1)$$

where k denotes the number of responses. Notice that if any response Y_i is completely undesirable $d_i(Y_i) = 0$ then the overall desirability is zero.

Desirabilities are often assigned using the following stepwise function:

$$d_1(X_1) = \begin{cases} 1.0 & , X_1 < T_1 \\ \left(\dfrac{X_1 - U_i}{T_i - U_i} \right)^{r_1} & , T_1 \le X_1 \le U_1 \\ 0 & , X_1 > U_1 \end{cases} \qquad (2)$$

$$d_2(X_2) = \begin{cases} 0 & ,X_2 < L_2 \\ \left(\dfrac{X_2 - L_2}{T_2 - L_2}\right)^{r_2} & ,L_2 \le X_2 \le T_2 \\ 1.0 & ,Z > T_2 \end{cases} \quad (3)$$

$$D_T = (d_1(X_i) * d_2(X_2)...d_n(X_n))^{1/n} \quad (4)$$

A target value Ti must first be determined. This value represents an idea system state, meaning if the system is operating at this value, the system is in an "ideal" state and given a desirability of one. Also depending on the operating characteristics of the system, upper Ui and lower Li values are specified that define completely undesirable system states. Once the system is operating above or below these values, the system is given a desirability of zero.

Desirabilities as classified into three categories: larger-the-better, smaller-the-better, and target-the-better.

- Larger-the-better – refers to a system where increasing the value of the dependent variable increases the desirability of the system, exhibit 1.
- Smaller-the-better – refers to a system where decreasing the value of the dependent variable increases the desirability of the system, exhibit 2.
- Target-the-better – refers to a system where approaching a specific value of the dependent variable increases the desirability of the system, exhibit 3.

Desirabilities may also be assigned using other various functions such as logistic functions with the characteristic "S-shape", one of which is the Harrington Function (Figure 3). These functions represent the law of diminishing return that is often observed when applying resources to a system. It is thought that using the desirability function as a predictor of effectiveness based on resources allocated will provide an accurate representation for each capability as a function of resources.

3.2 Interpreting Desirabilities

The current system desirability can be ascertained based on the desirabilities (effectiveness) of each of the subsystems. This allows for a baseline or "ground state" measure of the system without any interventions. Once an initiative has been inserted into the system, its impact on the desirabilities can be evaluated for each subsystem as well as the super-system. This impact, known as the Impact Factor (IF) can be can be quantified into a measure that allows for comparisons of single or multiple initiatives. The Impact Factor (IF) provides the decision maker with a value that gives an idea of how effective an initiative will be for each subsystem and for the super-system. The IF is also amenable for the selection of multiple initiatives and can give an idea of synergistic or antagonistic interaction effects between multiple initiatives.

Once the desirabilities have been determined for each of the sub-systems, an interpretation of these values must be developed. Using a ranking system that employs the Harrington Function (Table 1, Smirnov, 2005), qualitative measures can be provided for the possible ranges of the desirability values. The measures allow researchers to provide descriptions of the system state in lay terms. The ranking systems also allows for qualitative responses to be translated into quantitative values when establishing a baseline system state

Desirability	Value on scale
Very good	1.00-0.80
Good	0.80-0.63
Fair	0.63-0.37
Poor	0.37-0.20
Very poor	0.20-0.00

Table 1. Qualitative – Quantitative Desirability Relationships

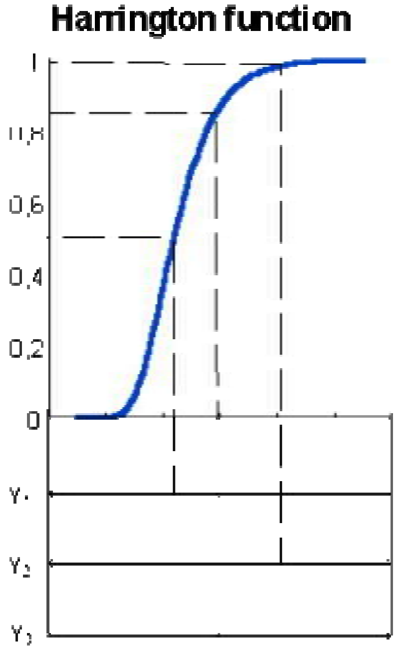

Figure 3. Harrington Function

4. Conclusions

Various components (resources) comprise each of the subsystems. In order to understand how various initiatives (insertions) affect the system (positively or negatively) first we must determine the current state of the system. In other words, "how well is the system performing in its current state?" Various measures can be incorporated for not only the super-system but also each of the sub-systems. By incorporating "absolute" measures, often times it becomes difficult to make comparisons of how well each system is performing relative to other sub-systems and the super-system as a whole. What is needed is a measure that gives the systems engineering the ability to make one-to-one comparisons between the super-system, the systems and the subsystems. As a solution, we propose using a desirability function approach suggested by Derringer and Suich (1980) which creates a measure of desirability for each subsystem as well as the super-system.

By constructing a discrete event simulation model we can predict how many illegal aliens are attempting to enter the United States along with the number of entries and reentries. The predictions can then be compared to the known values from the IDENT-IAFIS system used by the border patrol for model validation. Once the model has been validated, parameters in the model can be adjusted to examine the efficacy of various proposed initiatives that may be enacted by lawmakers.

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