TWO-DIMENSIONAL CELLULAR AUTOMATON MODELING OF CRIME ZONES IN CHICAGO – A CASE STUDY

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Abstract

This paper demonstrates the significance of cellular automata modeling of crime zones and a suggestive measure for security personnel as to how engage criminals with a priori knowledge on their movement. This idea is being suggested only with the noble social cause of preventing crimes before they occur. The whole exercise has been carried out with the case study related to crimes happened in the year 2016 in the state of Chicago, based on crime data published by the Federal Bureau of Investigation (FBI).

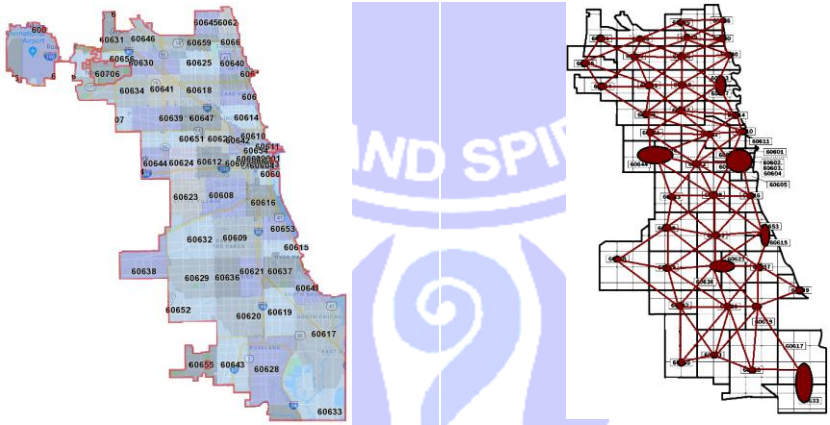
Keywords: Crimes, Crime Metrics, Cellular Automata Modelling

1. Introduction

One can partition the map of entire United States of America in zones, each zone consisting of one or more zip codes and establish directional connectivity, that is, a connected graph of zones. Every zone is assumed to be a 'Crime Zone', just for the sake of theorizing certain concepts. The directional connections were approximated to East (E), South East (SE), South (S), South West (SW), West (W), North West (NW) and North East (NE). This approximation showed a way to map a city on a uniform rectangular lattice so that each crime zone could be addressed by its row and column numbers of the lattice. Each crime zone in the lattice is treated as a cell of a two-dimensional cellular automaton.

Two-Dimensional Cellular Automaton Modeling of Crime Zones in Chicago

Figure 1(a) shows the zip code map of the city of **Chicago**. A total of 58 zip codes are shown in the map of Chicago. For operational convenience, one can partition the map in terms of 'zones', each zone consisting of one or more zip codes. Each central zone (CZ) is surrounded by zones based on eight directions.



(a) Zip code boundaries of the city of Chicago (b) Connected graph of Chicago crime zones

Fig. 1: Zip code boundaries of the city of Chicago and a connected graph

North West **(NW)**	North **(N)**	North East **(NE)**
West **(W)**	Central Zone **(CZ)**	East **(E)**
South West **(SW)**	South **(S)**	South East **(SE)**

One can come across some empty zones also in the lattice, which are called don't care zones. These empty zones should not be considered as central zones, of course, they could be considered as boundary zones having a value '0'. Figure 27.1.1(b) shows a graph consisting of 41 vertices (nodes) and edges (links). Each node represents a crime zone and each zone one or more zip codes. The zip codes 60613 and 60657 are combined and treated as a zone. The zip codes 60642 and 60610 form one zone. A total of 12 zip codes 60601 to 60607, 60611, 60654, 60661, 60290 and 60699 form one zone. The zip codes 60624 and 60644 are combined to form one zone.

The zip codes 60653 and 60615 form another zone. The purpose of combining zip codes is due to two reasons. The first reason is that some zip codes like 60601 to 60607 put together represent very small regions when compared to adjacent regions. So, it is better to combine all such zip codes to form one region. The second reason is that some zip codes have common boundaries with a large adjacent zip code. For example, zip codes 60636 and 60621 share a common boundary with zip code 60609. Hence 60636 and 60621 are combined to form one zone to share common boundary with 60609. The links that connect a zip code to other adjacent zip codes may show arbitrary directions, which vary from node to node.

In order to standardize the link directions, they are approximated to East (E), South East (SE), South (S), South West (SW), West (W), North West (NW) and North East (NE). This approximation shows a way to map a city on a uniform rectangular lattice so that each zone could be addressed by its row and column numbers of the lattice. Table 1 shows 41 zones made out of 58 zip codes modeled as a '2D Cellular Automaton Lattice of size 12x5'. The zone that has a valid zip code(s) is called 'active crime zone. The zone which does not have a valid zip code(s) is called an 'empty zone' or 'don't care zone'. Valid zones act as Central Zones (CZ), that is, 'Crime Zones'. Empty zones are 'Abstract Zones', and so they are not considered as valid Central Zones. Each zone is treated as a site of a 2D cellular automaton with a variable $\xi_{i,j}$ attached to it. The address of the zone is <i, j> where i is the row number and j is the column number. Having thus created a technique for cellular automaton modeling of crime zones of a city, one would look into the possibilities of predicting crimes in all zones simultaneously, unlike linear prediction which works on just one time series. We call this technique of cellular automata-based prediction as 'Multilinear Prediction'. Usually, people make use of Multiple Linear Regression technique to predict a value based on certain previous multivariate values.

The technique proposed in this section is to use parallel processing cell value updating using a global rule that involves a cell value and the values of a specific neighborhood cells. This rule is called two-dimensional cellular automaton updating rule. This technique is robust and reliable in the sense that all cell values are updated simultaneously at a single instant of time. In order to implement this technique, it is mandatory to introduce don't care boundary cells all around the lattice. The empty zones that form the boundary of the lattice shown in table 2 are $\xi_{1,1}, \xi_{1,2}, \xi_{1,3}, \xi_{1,4}, \xi_{1,5}, \xi_{1,6}\xi_{1,7}, \xi_{2,7}, \xi_{3,7}, \xi_{4,7}, \xi_{5,7}, \xi_{6,7}, \xi_{7,7}, \xi_{8,7}, \xi_{9,7}, \xi_{10,7}, \xi_{11,7}, \xi_{12,7}, \xi_{13,7}, \xi_{14,7}, \xi_{14,6}, \xi_{14,5}, \xi_{14,4}, \xi_{14,3}, \xi_{14,2}, \xi_{14,1}, \xi_{13,1}, \xi_{12,1}, \xi_{11,1}, \xi_{10,1}, \xi_{9,1}, \xi_{8,1}, \xi_{7,1}, \xi_{6,1}, \xi_{5,1}, \xi_{4,1}, \xi_{3,1}, \xi_{2,1}$. This amounts to saying that the lattice size increases from 12x5 to 14x7. Now this lattice is amenable to 2D cellular automata generation of 2D configurations from an initial configuration with the help of an updating rule. Table 2 shows such an arrangement of don't care boundary cells all around the lattice of Chicago crime zones.

Table 1: 2D Cellular Automaton Lattice model of Chicago consisting of 41 zones

Columns → Rows ↓	1	2	3	4	5
1	$\xi_{1,1}$	$\xi_{1,2}$	60645	60626	$\xi_{1,5}$
2	60631	60646	60659	60660	$\xi_{2,5}$
3	60656	60630	60625	60640	$\xi_{3,5}$
4	60634	60641	60618	60613 60657	$\xi_{4,5}$
5	$\xi_{5,1}$	60639	60647	60614	$\xi_{5,5}$
6	$\xi_{6,1}$	60651	60622	60642 60610	$\xi_{6,5}$
7	$\xi_{7,1}$	60624 60644	60612	60601 to 60607 60611 60654 60661 60290 60699	$\xi_{7,5}$
8	$\xi_{8,1}$	60623	60608	60616	$\xi_{8,5}$
9	$\xi_{9,1}$	60632	60609	60653 60615	$\xi_{9,5}$
10	60638	60629	60636 60621	60637	60649
11	$\xi_{11,1}$	60652	60620	60619	$\xi_{11,5}$
12	$\xi_{12,1}$	60655	60643	60628	60617 60633

Table 2: 2D Cellular Automaton Lattice model consisting of 41 zones with 38 boundary cells

Columns → Rows ↓	1	2	3	4	5	6	7
1	$\xi_{1,1}$	$\xi_{1,2}$	$\xi_{1,3}$	$\xi_{1,4}$	$\xi_{1,5}$	$\xi_{1,6}$	$\xi_{1,7}$
2	$\xi_{2,1}$	$\xi_{2,2}$	$\xi_{2,3}$	60645	60626	$\xi_{2,6}$	$\xi_{2,7}$
3	$\xi_{3,1}$	60631	60646	60659	60660	$\xi_{3,6}$	$\xi_{3,7}$
4	$\xi_{4,1}$	60656	60630	60625	60640	$\xi_{4,6}$	$\xi_{4,7}$
5	$\xi_{5,1}$	60634	60641	60618	60613, 60657	$\xi_{5,6}$	$\xi_{5,7}$
6	$\xi_{6,1}$	$\xi_{6,2}$	60639	60647	60614	$\xi_{6,6}$	$\xi_{6,7}$
7	$\xi_{7,1}$	$\xi_{7,2}$	60651	60622	60642, 60610	$\xi_{7,6}$	$\xi_{7,7}$
8	$\xi_{8,1}$	$\xi_{8,2}$	60624 60644	60612	60601 to 60607, 60611 60654, 60661 60290, 60699	$\xi_{8,6}$	$\xi_{8,7}$
9	$\xi_{9,1}$	$\xi_{9,2}$	60623	60608	60616	$\xi_{9,6}$	$\xi_{9,7}$
10	$\xi_{10,1}$	$\xi_{10,2}$	60632	60609	60653 60615	$\xi_{10,6}$	$\xi_{10,7}$
11	$\xi_{11,1}$	60638	60629	60636 60621	60637	60649	$\xi_{11,7}$
12	$\xi_{12,1}$	$\xi_{12,2}$	60652	60620	60619	$\xi_{12,6}$	$\xi_{12,7}$
13	$\xi_{13,1}$	$\xi_{13,2}$	60655	60643	60628	60617 60633	$\xi_{13,7}$
14	$\xi_{14,1}$	$\xi_{14,2}$	$\xi_{14,3}$	$\xi_{14,4}$	$\xi_{14,5}$	$\xi_{14,6}$	$\xi_{14,7}$

Every configuration is a prediction of the previous configuration. The rule that predicts a configuration from just the previous configuration is called first order rule. The rule that predicts a configuration from previous n configurations is called the n^{th} order rule. Configurations are predicted at discrete instants of time.

For example, the two-dimensional crime velocity configurations of a lattice of zones could be predicted at every day or every week or every month.

2. Weekly Configurations for Shooting Crime Data of Chicago from FBI database

Table 3: Shooting crime data of 1st, 2nd and 3rd week of the year 2016

Chicago shooting velocity (1st Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	0	0	0	0	0	0

Chicago shooting velocity (2nd Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**01**	**0**	**0**	**0**	0
0	**0**	**01**	**0**	**0**	**0**	0
0	**0**	**02**	**01**	**0**	**0**	0
0	**0**	**11**	**01**	**0**	**0**	0
0	**0**	**03**	**01**	**02**	**0**	0
0	**0**	**0**	**03**	**03**	**0**	0
0	**0**	**02**	**01**	**0**	**0**	0
0	**0**	**0**	**01**	**02**	**0**	0
0	**0**	**0**	**04**	**0**	**0**	0
0	0	0	0	0	0	0

Chicago shooting velocity (3rd Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**01**	**0**	**0**	**0**	0
0	**0**	**01**	**03**	**01**	**0**	0
0	**0**	**21**	**04**	**01**	**0**	0
0	**0**	**12**	**01**	**0**	**0**	0
0	**0**	**0**	**03**	**02**	**0**	0
0	**0**	**03**	**04**	**01**	**01**	0
0	**0**	**0**	**03**	**01**	**0**	0
0	**0**	**0**	**02**	**06**	**0**	0
0	0	0	0	0	0	0

Table 4: Shooting crime data of 4th, 5th and 6th week of the year 2016

Chicago shooting velocity (4th Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	01	0	0
0	03	0	0	0	0	0
0	0	04	02	03	0	0
0	0	13	0	03	0	0
0	0	21	04	01	0	0
0	0	06	01	01	0	0
0	0	05	04	0	0	0
0	0	03	08	01	02	0
0	0	01	01	08	0	0
0	0	01	04	02	03	0
0	0	0	0	0	0	0

Chicago shooting velocity (5th Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	02	02	0	0
0	0	05	0	0	0	0
0	0	05	03	02	0	0
0	0	11	0	0	0	0
0	0	03	02	0	0	0
0	0	02	0	08	0	0
0	01	05	09	02	05	0
0	0	0	08	0	0	0
0	0	0	04	0	04	0
0	0	0	0	0	0	0

Chicago shooting velocity (6th Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	01	0	0	0	0	0
0	0	0	02	0	0	0
0	0	02	0	0	0	0
0	0	01	06	0	0	0
0	0	08	03	04	0	0
0	0	08	11	03	0	0
0	0	09	05	01	0	0
0	0	01	0	01	0	0
0	0	02	04	0	0	0
0	0	0	02	04	0	0
0	0	0	03	04	05	0
0	0	0	0	0	0	0

Table 5: Shooting crime data of 7th, 8th and 9th week of the year 2016

Chicago shooting velocity (7th Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	01	0	03	0	0
0	0	0	0	0	0	0
0	0	02	0	01	0	0
0	0	06	0	03	0	0
0	0	22	0	01	0	0
0	0	12	03	01	0	0
0	0	05	01	07	0	0
0	01	05	02	06	14	0
0	0	01	07	01	0	0
0	0	0	0	04	0	0
0	0	0	0	0	0	0

Chicago shooting velocity (8th Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	01	0	01	0	0
0	0	01	0	0	0	0
0	0	02	04	0	0	0
0	0	09	01	0	0	0
0	0	11	03	02	0	0
0	0	04	03	0	0	0
0	0	0	03	02	0	0
0	0	03	08	04	0	0
0	0	02	11	07	0	0
0	0	0	01	09	09	0
0	0	0	0	0	0	0

Chicago shooting velocity (9th Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	01	0	0	0
0	03	01	0	0	0	0
0	0	01	02	0	0	0
0	0	04	01	01	0	0
0	0	06	08	0	0	0
0	0	14	05	0	0	0
0	0	01	0	0	0	0
0	01	01	01	09	02	0
0	0	0	0	0	0	0
0	0	0	02	0	02	0
0	0	0	0	0	0	0

Table 6: Shooting crime data of 10th, 11th and 12th week of the year 2016

Chicago shooting velocity (10th Week)						
0	0	0	0	0	0	0
0	0	0	01	0	0	0
0	0	0	0	0	0	0
0	0	01	02	0	0	0
0	0	0	0	0	0	0
0	0	01	04	0	0	0
0	0	05	0	0	0	0
0	0	10	04	02	0	0
0	0	16	03	01	0	0
0	0	02	02	02	0	0
0	01	02	06	03	05	0
0	0	02	08	07	0	0
0	0	0	0	04	02	0
0	0	0	0	0	0	0

Chicago shooting velocity (11th Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	02	0	0	0
0	0	0	01	01	0	0
0	0	0	0	0	0	0
0	0	0	06	01	0	0
0	0	11	0	0	0	0
0	0	05	03	07	0	0
0	0	06	03	0	0	0
0	0	0	0	0	0	0
0	01	0	03	04	01	0
0	0	01	03	04	0	0
0	0	0	0	03	02	0
0	0	0	0	0	0	0

Chicago shooting velocity (12th Week)						
0	0	0	0	0	0	0
0	0	0	0	01	0	0
0	0	0	0	0	0	0
0	0	0	02	0	0	0
0	0	01	0	0	0	0
0	0	01	0	0	0	0
0	0	09	02	0	0	0
0	0	29	01	0	0	0
0	0	02	01	0	0	0
0	0	02	02	01	0	0
0	01	07	07	02	01	0
0	0	0	03	01	0	0
0	0	0	02	04	04	0
0	0	0	0	0	0	0

Table 7: Shooting crime data of 10th, 11th and 12th week of the year 2016

Chicago shooting velocity (13th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**01**	**02**	**01**	**0**	0
0	**0**	**0**	**0**	**01**	**0**	0
0	**0**	**06**	**04**	**01**	**0**	0
0	**0**	**07**	**01**	**02**	**0**	0
0	**0**	**22**	**08**	**01**	**0**	0
0	**0**	**10**	**04**	**01**	**0**	0
0	**0**	**01**	**04**	**10**	**0**	0
0	**01**	**10**	**17**	**02**	**01**	0
0	**0**	**0**	**09**	**02**	**0**	0
0	**0**	**01**	**07**	**04**	**03**	0
0	0	0	0	0	0	0

Chicago shooting velocity (14th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**04**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**02**	**02**	**0**	**0**	**0**	0
0	**0**	**03**	**04**	**0**	**0**	0
0	**0**	**04**	**05**	**0**	**0**	0
0	**0**	**18**	**09**	**02**	**0**	0
0	**0**	**09**	**05**	**08**	**0**	0
0	**0**	**06**	**0**	**02**	**0**	0
0	**02**	**04**	**09**	**03**	**21**	0
0	**0**	**02**	**13**	**08**	**0**	0
0	**0**	**0**	**01**	**09**	**09**	0
0	0	0	0	0	0	0

Chicago shooting velocity (15th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**0**	**01**	**01**	**0**	**0**	0
0	**0**	**0**	**01**	**01**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**0**	**02**	**05**	**02**	**0**	0
0	**0**	**17**	**04**	**06**	**0**	0
0	**0**	**06**	**02**	**01**	**0**	0
0	**0**	**05**	**08**	**07**	**0**	0
0	**04**	**01**	**18**	**03**	**07**	0
0	**0**	**01**	**05**	**12**	**0**	0
0	**0**	**0**	**04**	**13**	**15**	0
0	0	0	0	0	0	0

Table 8: Shooting crime data of 16th, 17th and 18th week of the year 2016

Chicago shooting velocity (16th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**01**	**01**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**06**	**0**	0
0	**0**	**03**	**0**	**01**	**0**	0
0	**0**	**05**	**04**	**0**	**0**	0
0	**0**	**03**	**01**	**02**	**0**	0
0	**0**	**16**	**0**	**04**	**0**	0
0	**0**	**07**	**08**	**01**	**0**	0
0	**0**	**04**	**16**	**03**	**0**	0
0	**02**	**16**	**15**	**07**	**04**	0
0	**0**	**01**	**01**	**06**	**0**	0
0	**0**	**0**	**04**	**04**	**03**	0
0	0	0	0	0	0	0

Chicago shooting velocity (17th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**01**	**02**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**02**	**0**	**01**	**0**	**0**	0
0	**02**	**02**	**01**	**0**	**0**	0
0	**0**	**18**	**10**	**01**	**0**	0
0	**0**	**26**	**03**	**04**	**0**	0
0	**0**	**36**	**05**	**08**	**0**	0
0	**0**	**26**	**12**	**02**	**0**	0
0	**0**	**06**	**16**	**10**	**0**	0
0	**01**	**04**	**18**	**15**	**09**	0
0	**0**	**03**	**10**	**05**	**0**	0
0	**0**	**0**	**04**	**10**	**03**	0
0	0	0	0	0	0	0

Chicago shooting velocity (18th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**01**	**0**	**02**	**0**	0
0	**0**	**0**	**0**	**01**	**0**	0
0	**0**	**01**	**01**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**03**	**0**	**0**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**0**	**01**	**03**	**02**	**0**	0
0	**0**	**02**	**10**	**07**	**03**	0
0	**0**	**0**	**06**	**10**	**0**	0
0	**0**	**0**	**03**	**07**	**05**	0
0	0	0	0	0	0	0

Table 9: Shooting crime data of 19th, 20th and 21st week of the year 2016

Chicago shooting velocity (19th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**01**	**0**	**01**	**0**	0
0	**01**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**02**	**0**	0
0	**0**	**06**	**0**	**0**	**0**	0
0	**0**	**04**	**0**	**0**	**0**	0
0	**0**	**13**	**04**	**09**	**0**	0
0	**04**	**0**	**0**	**06**	**0**	0
0	**0**	**0**	**03**	**01**	**0**	0
0	**0**	**0**	**0**	**09**	**01**	0
0	0	0	0	0	0	0

Chicago shooting velocity (20th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**03**	**01**	**0**	**0**	**0**	0
0	**0**	**0**	**05**	**0**	**0**	0
0	**0**	**26**	**03**	**01**	**0**	0
0	**0**	**43**	**02**	**04**	**0**	0
0	**0**	**27**	**05**	**03**	**0**	0
0	**0**	**01**	**11**	**03**	**0**	0
0	**0**	**04**	**15**	**05**	**04**	0
0	**0**	**0**	**07**	**18**	**0**	0
0	**0**	**0**	**04**	**16**	**01**	0
0	0	0	0	0	0	0

Chicago shooting velocity (21st Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**04**	**01**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**02**	**02**	**0**	**0**	0
0	**0**	**0**	**04**	**0**	**0**	0
0	**0**	**03**	**01**	**03**	**0**	0
0	**0**	**03**	**0**	**0**	**0**	0
0	**0**	**18**	**02**	**01**	**0**	0
0	**0**	**01**	**03**	**01**	**0**	0
0	**0**	**07**	**06**	**0**	**0**	0
0	**02**	**06**	**11**	**18**	**06**	0
0	**0**	**0**	**04**	**03**	**0**	0
0	**0**	**0**	**02**	**02**	**03**	0
0	0	0	0	0	0	0

Table 10: Shooting crime data of 22nd, 23rd and 24th week of the year 2016

Chicago shooting velocity (22nd Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	01	0	0	0
0	0	0	01	0	0	0
0	07	03	01	0	0	0
0	0	03	02	0	0	0
0	0	03	0	0	0	0
0	0	12	01	0	0	0
0	0	05	0	02	0	0
0	0	0	10	10	0	0
0	02	05	14	23	08	0
0	0	01	05	15	0	0
0	0	0	03	09	02	0
0	0	0	0	0	0	0

Chicago shooting velocity (23rd Week)						
0	0	0	0	0	0	0
0	0	0	0	06	0	0
0	0	0	0	0	0	0
0	0	0	02	02	0	0
0	01	01	02	0	0	0
0	0	02	03	0	0	0
0	0	06	01	01	0	0
0	0	24	04	04	0	0
0	0	14	02	0	0	0
0	0	08	12	10	0	0
0	03	07	14	13	07	0
0	0	01	17	17	0	0
0	0	0	04	06	01	0
0	0	0	0	0	0	0

Chicago shooting velocity (24th Week)						
0	0	0	0	0	0	0
0	0	0	0	02	0	0
0	0	0	0	0	0	0
0	0	0	06	02	0	0
0	01	02	06	04	0	0
0	0	10	01	02	0	0
0	0	19	03	0	0	0
0	0	63	07	04	0	0
0	0	26	14	02	0	0
0	0	08	24	09	0	0
0	03	07	31	29	08	0
0	0	04	30	32	0	0
0	0	0	06	24	15	0
0	0	0	0	0	0	0

Table 11: Shooting crime data of 25th, 26th and 27th week of the year 2016

Chicago shooting velocity (25th Week)						
0	0	0	0	0	0	0
0	0	0	0	01	0	0
0	0	0	0	0	0	0
0	0	0	0	02	0	0
0	0	0	01	0	0	0
0	0	03	01	0	0	0
0	0	17	01	03	0	0
0	0	11	14	05	0	0
0	0	06	04	01	0	0
0	0	01	04	04	0	0
0	02	05	14	05	03	0
0	0	01	05	16	0	0
0	0	01	10	18	07	0
0	0	0	0	0	0	0

Chicago shooting velocity (26th Week)						
0	0	0	0	0	0	0
0	0	0	0	03	0	0
0	0	0	0	01	0	0
0	0	0	01	02	0	0
0	0	0	0	0	0	0
0	0	06	0	0	0	0
0	0	16	01	02	0	0
0	0	21	09	04	0	0
0	0	20	08	09	0	0
0	0	05	12	03	0	0
0	02	11	06	09	09	0
0	0	03	20	09	0	0
0	0	0	05	13	11	0
0	0	0	0	0	0	0

Chicago shooting velocity (27th Week)						
0	0	0	0	0	0	0
0	0	0	02	0	0	0
0	0	0	0	01	0	0
0	0	0	01	0	0	0
0	01	0	04	0	0	0
0	0	01	0	0	0	0
0	0	04	04	03	0	0
0	0	39	18	09	0	0
0	0	12	04	0	0	0
0	0	03	07	05	0	0
0	01	09	12	13	08	0
0	0	05	17	14	0	0
0	0	0	06	13	07	0
0	0	0	0	0	0	0

Table 12: Shooting crime data of 28th, 29th and 30th week of the year 2016

Chicago shooting velocity (28th Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	02	02	0	0
0	01	03	0	0	0	0
0	0	01	02	0	0	0
0	0	15	05	02	0	0
0	0	26	08	04	0	0
0	0	09	05	01	0	0
0	0	06	12	08	0	0
0	0	11	11	09	10	0
0	0	03	14	15	0	0
0	0	0	03	03	15	0
0	0	0	0	0	0	0

Chicago shooting velocity (29th Week)						
0	0	0	0	0	0	0
0	0	0	0	01	0	0
0	0	0	0	0	0	0
0	0	0	01	02	0	0
0	01	01	0	02	0	0
0	0	0	03	0	0	0
0	0	17	03	05	0	0
0	0	18	0	05	0	0
0	0	0	11	01	0	0
0	0	04	14	03	0	0
0	01	14	27	16	22	0
0	0	0	13	23	0	0
0	0	01	03	04	21	0
0	0	0	0	0	0	0

Chicago shooting velocity (30th Week)						
0	0	0	0	0	0	0
0	0	0	0	03	0	0
0	0	0	0	0	0	0
0	0	0	02	04	0	0
0	01	01	01	0	0	0
0	0	03	01	0	0	0
0	0	04	03	04	0	0
0	0	06	03	03	0	0
0	0	07	08	01	0	0
0	0	02	02	07	0	0
0	01	02	02	04	04	0
0	0	0	04	06	0	0
0	0	0	0	06	02	0
0	0	0	0	0	0	0

Table 13: Shooting crime data of 31st, 32nd and 33rd week of the year 2016

Chicago shooting velocity (31st Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**01**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**01**	**0**	0
0	**01**	**02**	**01**	**01**	**0**	0
0	**0**	**05**	**06**	**0**	**0**	0
0	**0**	**11**	**03**	**10**	**0**	0
0	**0**	**19**	**11**	**0**	**0**	0
0	**0**	**05**	**08**	**06**	**0**	0
0	**0**	**01**	**02**	**04**	**0**	0
0	**0**	**09**	**09**	**05**	**17**	0
0	**0**	**01**	**01**	**08**	**0**	0
0	**0**	**0**	**04**	**07**	**08**	0
0	0	0	0	0	0	0

Chicago shooting velocity (32nd Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**01**	**01**	**0**	0
0	**0**	**0**	**02**	**0**	**0**	0
0	**0**	**0**	**01**	**01**	**0**	0
0	**02**	**0**	**0**	**02**	**0**	0
0	**0**	**06**	**07**	**0**	**0**	0
0	**0**	**12**	**02**	**03**	**0**	0
0	**0**	**18**	**05**	**09**	**0**	0
0	**0**	**03**	**11**	**04**	**0**	0
0	**0**	**04**	**11**	**03**	**0**	0
0	**0**	**07**	**17**	**04**	**07**	0
0	**0**	**05**	**04**	**05**	**0**	0
0	**0**	**01**	**04**	**16**	**12**	0
0	0	0	0	0	0	0

Chicago shooting velocity (33rd Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**03**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**01**	**0**	**0**	**0**	0
0	**02**	**01**	**01**	**01**	**0**	0
0	**0**	**14**	**04**	**0**	**0**	0
0	**0**	**14**	**02**	**0**	**0**	0
0	**0**	**32**	**16**	**06**	**0**	0
0	**0**	**17**	**0**	**01**	**0**	0
0	**0**	**03**	**17**	**05**	**0**	0
0	**0**	**0**	**15**	**14**	**01**	0
0	**0**	**03**	**09**	**06**	**0**	0
0	**0**	**01**	**07**	**09**	**01**	0
0	0	0	0	0	0	0

Table 14: Shooting crime data of 34th, 35th and 36th week of the year 2016

Chicago shooting velocity (34th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**01**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**01**	**01**	**0**	**0**	**0**	0
0	**0**	**05**	**03**	**01**	**0**	0
0	**0**	**15**	**01**	**0**	**0**	0
0	**0**	**21**	**0**	**04**	**0**	0
0	**0**	**14**	**04**	**01**	**0**	0
0	**0**	**02**	**02**	**03**	**0**	0
0	**02**	**05**	**16**	**03**	**01**	0
0	**0**	**0**	**03**	**02**	**0**	0
0	**0**	**0**	**06**	**07**	**05**	0
0	0	0	0	0	0	0

Chicago shooting velocity (35th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**04**	**02**	**0**	**0**	0
0	**0**	**11**	**0**	**01**	**0**	0
0	**0**	**11**	**02**	**01**	**0**	0
0	**0**	**17**	**19**	**04**	**0**	0
0	**0**	**17**	**06**	**07**	**0**	0
0	**0**	**01**	**07**	**0**	**0**	0
0	**02**	**07**	**13**	**05**	**04**	0
0	**0**	**02**	**02**	**06**	**0**	0
0	**0**	**0**	**04**	**04**	**10**	0
0	0	0	0	0	0	0

Chicago shooting velocity (36th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**06**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**0**	**0**	**02**	**02**	**0**	0
0	**01**	**06**	**02**	**01**	**0**	0
0	**0**	**16**	**06**	**01**	**0**	0
0	**0**	**32**	**05**	**02**	**0**	0
0	**0**	**70**	**25**	**03**	**0**	0
0	**0**	**22**	**11**	**02**	**0**	0
0	**0**	**06**	**18**	**15**	**0**	0
0	**03**	**29**	**28**	**29**	**19**	0
0	**0**	**04**	**21**	**22**	**0**	0
0	**0**	**01**	**16**	**34**	**32**	0
0	0	0	0	0	0	0

Table 15: Shooting crime data of 37th, 38th and 39th week of the year 2016

Chicago shooting velocity (37th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**01**	**0**	**0**	**0**	0
0	**0**	**05**	**01**	**0**	**0**	0
0	**0**	**05**	**0**	**0**	**0**	0
0	**0**	**12**	**03**	**0**	**0**	0
0	**0**	**04**	**02**	**01**	**0**	0
0	**0**	**01**	**01**	**01**	**0**	0
0	**0**	**05**	**09**	**03**	**01**	0
0	**0**	**0**	**01**	**03**	**0**	0
0	**0**	**0**	**0**	**03**	**03**	0
0	0	0	0	0	0	0

Chicago shooting velocity (38th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**02**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**01**	**01**	**0**	**0**	**0**	0
0	**0**	**03**	**0**	**0**	**0**	0
0	**0**	**08**	**01**	**01**	**0**	0
0	**0**	**22**	**05**	**04**	**0**	0
0	**0**	**08**	**04**	**0**	**0**	0
0	**0**	**01**	**02**	**01**	**0**	0
0	**0**	**04**	**05**	**05**	**03**	0
0	**0**	**0**	**06**	**09**	**0**	0
0	**0**	**0**	**07**	**08**	**13**	0
0	0	0	0	0	0	0

Chicago shooting velocity (39th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**0**	**0**	**01**	**0**	**0**	0
0	**0**	**01**	**02**	**0**	**0**	0
0	**0**	**11**	**01**	**0**	**0**	0
0	**0**	**18**	**09**	**2**	**0**	0
0	**0**	**06**	**08**	**02**	**0**	0
0	**0**	**02**	**02**	**04**	**0**	0
0	**0**	**0**	**03**	**0**	**01**	0
0	**0**	**01**	**03**	**06**	**0**	0
0	**0**	**0**	**03**	**05**	**02**	0
0	0	0	0	0	0	0

Table 16: Shooting crime data of 40^{th}, 41^{st} and 42^{nd} week of the year 2016

Chicago shooting velocity (40^{th} Week)						
0	0	0	0	0	0	0
0	0	0	0	01	0	0
0	0	0	0	0	0	0
0	02	0	0	01	0	0
0	0	05	01	0	0	0
0	0	14	02	0	0	0
0	0	10	01	0	0	0
0	0	11	11	0	0	0
0	0	16	03	01	0	0
0	0	12	08	04	0	0
0	04	06	31	05	04	0
0	0	06	03	15	0	0
0	0	0	08	16	10	0
0	0	0	0	0	0	0

Chicago shooting velocity (41^{st} Week)						
0	0	0	0	0	0	0
0	0	0	0	01	0	0
0	0	0	03	01	0	0
0	0	01	0	0	0	0
0	01	0	0	01	0	0
0	0	01	0	0	0	0
0	0	11	0	0	0	0
0	0	04	02	0	0	0
0	0	0	0	0	0	0
0	0	03	04	05	0	0
0	01	01	04	0	0	0
0	0	01	15	04	0	0
0	0	0	03	05	0	0
0	0	0	0	0	0	0

Chicago shooting velocity (42^{nd} Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	01	0	0	0	0
0	0	01	0	0	0	0
0	0	0	02	0	0	0
0	0	0	01	0	0	0
0	0	0	0	0	0	0

Table 17: Shooting crime data of 43^{rd}, 44^{th} and 45^{th} week of the year 2016

Chicago shooting velocity (43^{rd} Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	01	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	01	0	0
0	0	0	0	0	0	0

Chicago shooting velocity (44^{th} Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	01	0	0	0
0	0	01	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	05	01	0
0	0	0	0	0	0	0

Chicago shooting velocity (45^{th} Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	01	0	0	0	0
0	0	0	0	0	0	0
0	0	0	02	0	0	0
0	0	0	0	0	0	0

Table 18: Shooting crime data of 46^{th}, 47^{th} and 48^{th} week of the year 2016

Chicago shooting velocity (46^{th} Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	01	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	01	0	0	0
0	0	0	0	0	0	0

Chicago shooting velocity (47^{th} Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Chicago shooting velocity (48^{th} Week)						
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Table 19: Shooting crime data of 49th, 50th, 51st week of the year 2016

Chicago shooting velocity (49th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	0	0	0	0	0	0

Chicago shooting velocity (50th Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	0	0	0	0	0	0

Chicago shooting velocity (51st Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	0	0	0	0	0	0

Table 19: Shooting crime data of 52nd week of the year 2016

Chicago shooting velocity (52nd Week)						
0	0	0	0	0	0	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	**0**	**0**	**0**	**0**	**0**	0
0	0	0	0	0	0	0

Empty Space

Empty Space

Having thus arrived at the point that the entire zip code wise representation of Chicago city could be mapped on a rectangular lattice of cells of a 2D cellular automaton, one would always explore the possibility of formulation of an important notion of Crime Proliferation.

3. Conclusions and Future Perspectives

The entire zip code wise representation of Chicago city is mapped on a rectangular lattice of cells of a 2D cellular automaton. This leads to the possibility of using cellular automata concepts and principles for evaluating crime flow and proliferation in a specific region represented by a zip code.

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