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Swiss Federal Institute of Technology Zurich

Lecture with Computer Exercises:
Modelling and Simulating Social Systems with MATLAB

Project Report

Civil Violence
An agent-based computational model

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Agreement for free-download

We hereby agree to make our source code for this project freely available for download from the web pages of the SOMS chair. Furthermore, we assure that all source code is written by ourselves and is not violating any copyright restrictions.

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1 Abstract

This project presents an agent-based computational model of civil violence. Therein goes the central authority for it to suppress decentralized rebellion. In general we build on an existing model of J.M.Epstein and try to make it more realistic by changing and adding certain properties of the "agent" and "cop". The focus of our work lies on the dynamics of the system and not on the political or social order. We are going to compare the results of our model, with those of J.M.Epstein.

2 Individual contributions

Abstract: Fabian and David

Introduction and Motivations: Florian

Description of the Model: David

Implementation: Florian

Simulation Results and Discussion: Fabian

Summary: Fabian and David

Original Code: Florian

Simulation run: David, with additional tweaks from Fabian

3 Introduction and Motivations

During the course of human history, regime changes have often occurred by civilians taking up arms. This civil violence also happens right now in Syria, and a similar movement has just been successful in Libya and Egypt. These uprisings or rebellions have a big impact on our world, and an ever bigger impact on the people actually executing them. So it is imperative to be able to predict such changes, and that's exactly what we strive for: A clear model for civil violence, so that in the future we can better predict outcomes and aftermaths of these events.

Real world examples: Syria, Libya, Egypt, Russia, United States of America, even Switzerland etc.

(The canton Wallis had various unsuccessful uprisings until it was granted autonomy from Bern.)

Today, as taught in our schools, revolutions are formed by normal civilians, who are unhappy with their current situation. Somehow, this unhappy (but non-active) mob produces/elects a leader, who will then lead them into action. This now active mob will then have to fulfill certain tasks, such as taking up weapons against an oppressive military force, or a demonstration of force in form of a peaceful protest. On completion of these tasks, they can then form their own government according to their liking.

While the very first step (unhappy civilians) is often a requirement, the idea of a revolution forming and a revolution marching against the current system is not sophisticated enough. There are many factors which can catalyze or hinder the formation of a rebellion, as we are going to show.

The tactics which can be employed by a system that is under attack are also somewhat left out in our education, take the revolution in Egypt as an example: What would have happened if the government went all out on the protesters? Would the military rule have held another decade?

4 Description of the Model (Cop/Agent)

This is an agent-based model about civil violence. We look at a model where the central authority goes for it to suppress decentralized rebellion. We don't take respect to political or social order, it is just a general case. It is based on the model of J.M.Epstein. This model differs between two main actors. "Agents" are members of the general population and may be actively rebellious or not. "Cops" are the token of the central authority, which arrest actively rebellious agents. Later we will make some more sophisticated characterizations, trying to do a more precise and realistic simulation. J.M.Epstein tried to get recognizable macroscopic revolutionary dynamics of fundamental interest with a model, that is as idealized as possible. We try to improve this model. It is now interesting, if we can make remarkable refinements, such that this model is more realistic. First I will describe the agents. The original part is always from the idea of J.M.Epstein and then the additional specifications are our own ideas and extensions.

4.1 The original agent specification

To simulate a rebellion each agent needs some properties, on which we can measure the feelings of them. Therefore there must be some representation of political grievance. The treatment of this model will be really simple and is denoted by two idealized components, which are called hardship (**H**) and legitimacy (**L**). Their definitions are as follows:

H is the agent's perceived hardship (i.e., physical or economic privation). It is defined exogenous and it is assumed to be heterogeneous across agents. It is simply presumed to be uniformly distributed on the interval (0,1). An other important factor is **L**, the perceived legitimacy of the regime. This is exogenous and is equal across agents. In the different runs, it will be varied over the interval (0,1).

These two properties can be combined to the level of grievance any agent feels towards the regime. It is suggested, because of the many functional relationships as:

$$G = H(1 - L) \quad (1)$$

Grievance is the product of perceived hardship (**H**) and perceived "illegitimacy" (**1-L**). The intuition behind this formula is simple. If you think it is legitimate how the government acts (high **L**) then you will not revolt, do not matter how bad things are going on. And if the perceived hardship is pretend to be low, then the grievance towards the regime will be low, too. It does not matter what the perceived illegitimacy is. Because the decision to rebel depends on more than one's grievance, there is defined **R** as the agent's level of risk aversion. Heterogeneous across agents, this is assumed to be uniformly distributed on (0,1) and it is fixed for the agent's lifetime.

Everyone thinks before getting active, what the current risk is to get arrested and this is assumed to be proportional with the cop-to-active ratio $(\mathbf{C}/\mathbf{A})_{\mathbf{v}}$ within vision **v**. Where the vision **v** is defined as the agent's vision, this is the number of lattice positions (north, south, east and west of the agent's current position) that the agent is able to inspect. Now is the agent's estimated arrest probability **P** defined by

$$P = 1 - \exp[-k(\mathbf{C}/\mathbf{A})_{\mathbf{v}}] \quad (2)$$

The constant k is set to ensure a plausible estimate (of **P** = 0.9) when **C**=1 and **A** = 1. Notice that $(\mathbf{C}/\mathbf{A})_{\mathbf{v}}$ is always defined, because the agent counts always with himself

as active, so \mathbf{A} is at least 1. Finally we define the agent's net risk $\mathbf{N} = \mathbf{RP}$, what is the product of his risk aversion and estimated arrest probability. This is the special case of $\mathbf{N} = \mathbf{RPJ}^\alpha$, where \mathbf{J} is the jail term, as discussed in Epstein. A quiescent agent is called an agent in state Q and an active agent is called an agent in state A. Now we can write down the agent's rule:

$$\text{Agent rule } A : \text{If } G - N > T \text{ be active; otherwise, be quiet.} \quad (3)$$

Typically, T is set at some small positive value. So we consider, that the agents weigh expected costs and benefits rationally.

4.2 Additional agent specification

Our aim was now, to get a better simulation for revolutions. In the real world, there is a point on which the people try to kill the cops and vice versa. Therefore we implemented a murder threshold $\mathbf{T_murder}$ and if $(\mathbf{G} - \mathbf{N}) > \mathbf{T_murder}$, then he tries to kill cops. Therefore exists a **murder success rate** and a **murder assassin death rate**, which define his success by murdering cops and the probability, that he dies during this action, himself. This means, that if a certain level is reached, the agents can now murder cops, too. During an arrest, there can occur some trouble. Therefore, there exists the **agent death chance**, the probability, that the agent dies during this conflict. And the **cop death chance** is the probability, that the cop dies. If we have the first case, that an agent dies, then the legitimacy drops by the **agent death legitimacy penalty**. And if a cop dies, then the legitimacy increases by the **cop death legitimacy boost**.

With this new attribute, we hope to get a new dynamic. Because if cops are murdered, then the $(\mathbf{C}/\mathbf{A})_v$ will drop and so there can go more agents active. Otherwise if a agent dies, there is the **agent death legitimacy penalty** for balancing the raised $(\mathbf{C}/\mathbf{A})_v$.

Again a unreal setting of the original version is that everyone has the same legitimacy. For that we define the **legitimacy_mod**, so that the personal legitimacy equals $L + L_personal$, where $L_personal$ is a value out of $U(-legitimacy_mod, legitimacy_mod)$. This means, that we have a certain variance of personal legitimacy. Now we may have agents with an higher personal legitimacy and go earlier active than the others. This means, that they are a trigger for other agents to go active and so we have a starting point of a revolution.

4.3 The original cop specification

The cops are much simpler than the agents. The properties of them are:

\mathbf{v}^* is the cops vision and it is like \mathbf{v} the number of lattice positions that the cop is able to inspect. It is exogenous and equal across cops. But it does not have to be equal to \mathbf{v} . The rule, with which the cops operate is:

$$\text{Cop rule } C : \text{Inspect all sites within } v^* \text{ and arrest arandom active agent.} \quad (4)$$

In the basic model of J.M.Epstein cops never defect to the revolution.

4.4 Additional cop specification

Because cops are human, too, the government can not do whatever they want to do with them. After a certain point (see rule S), they realize, that they do not want to work for the government anymore and stop their work. If it gets even worse, then they can defect (go to the agents).

Then we thought about this, how to model. And we have got the result, that we have to introduce a legitimacy for the cops, too. Therefore they get the same basic legitimacy like the agents, but with an other interval for the personal legitimacy change. And then the personal legitimacy equals $L + L_personal$, where $L_personal$ is now a value out of $U(-legitimacy_mod_cop, legitimacy_mod_cop)$.

Therefor we define two new rules:

*Stop rule S : If $L + L_personal \leq legitimacy_threshold_stop$,
then he will not arrest agents anymore.*

*Defect rule D : If $L + L_personal \leq legitimacy_threshold_defect$,
then the cop transforms to an agent.*

It is clear, that $legitimacy_threshold_defect \leq legitimacy_threshold_stop$.

4.5 Movement and Jail Terms

One fundamental property of people, is the movement. This gives the whole model a certain dynamic, because the agent information (the number of cops and actives they see) is heterogeneous. And this dynamic will change, by changing \mathbf{v} and \mathbf{v}^* . The movement rule is the same for both agents and cops:

Movement rule M : Move to a random site within your vision. (5)

For the jail term, the user set a a value for the maximum jail term, **J_max**. Then, any arrested active is assigned a jail term drawn randomly from $U(0, \mathbf{J_max})$. This is an important term in the model, which handles the duration of removing actives from circulation. If you set alpha to zero, there will be no deterrent effect of increasing the jail term.

4.6 General changes of the model

To analyse some scenarios we implemented the **each_round_legitimacy_change**. If you set it not equal to zero, the legitimacy (**L**) will change every round by this factor. And so you can see what happens if the legitimacy of the government drops constantly. To get even more heterogeneous agents and cops, we let the vision \mathbf{v} and \mathbf{v}^* , of the agents and

cops, be various and uniformly distributed in $(\text{vision_Min_agent}, \text{vision_Max_agent})$ and in $(\text{vision_Min_cops}, \text{vision_Max_cops})$.

One last diversification is, that in the beginning all the cops start in the middle of the space and than move from there on. This should be the scenario, that the agent can communicate, where they will meet and the cops get the information not until they met!

5 Implementation

The implementation of our model brings many features, as well as some added complexity. A short overview about the core functionality:

5.1 Problem Generation

According to user-set constants, the playfield is filled with Agents and Cops. These players are generated with all the required functionality to later perform their actions. Agents, for example, are already equipped with Hardship.

5.2 Step

Since the problem is now specified, we can loop one step at a time, until we reach some final state. In each step, there are a few things that must be done:

5.2.1 Reset Moves

Every Cop and Agent can move exactly once per step, so we must ensure that they can now move properly.

5.2.2 Release imprisoned

All the imprisoned Agents have their sentence reduced by one. All Agents with a sentence of zero or less are set free. They are randomly put onto empty fields on the playfield.

5.2.3 Move Cops and Agents

Agents scout out the empty fields in their vision, and choose one at random. In case there are no empty fields, they stay put.

Cops scout for active Agents, as well as empty fields. If they spot an Agent, they move to the Agent's field and arrest him. Should no Agent be inside the Cop's vision, they randomly move to an empty field. In case they can't find an Agent or an empty field, they stay put.

5.2.4 Set Status of Agents

With all the Agents and Cops moved, the Agents need to re-evaluate whether they want to be active. Their activeness is set for the next round, as well as for display purposes. Cops as well as empty squares are also saved for display.

5.2.5 Display current Model

With the saved values from the step above, a graph can be plotted, showing all Agents and Cops, as well as some info about them.

5.3 Display summarizing plots

At the very end, plot some graphs of the most important values during the computation. Current graphs include active Agents, inactive Agents, imprisoned Agents, active Cops, Legitimacy.

5.4 Tweaks

This core model has been enhanced by many tweaks and options, listed here:

5.4.1 Size

The size of the playfield can now be changed.

5.4.2 Occupied to Unoccupied Ratio

This ratio regulates Occupied Spaces vs. Unoccupied Spaces. In the original paper, the author started with a full playfield, but that might not always be desired.

5.4.3 Cop to Agent Ratio

This ratio sets the global amount of Cops vs. Agents. Especially useful when simulating low/heavy police presence with varying playfield size.

5.4.4 Jailterm Min/Max

Minimum and Maximum amount of steps an Agent will spend in jail if arrested.

5.4.5 Jail sentence

In the original paper, the jail sentence was chosen uniformly from zero to some maximum. In reality, jail sentences are not chosen uniformly, and so this function can be altered in whatever way desired. It uses the Jailterm Min/Max discussed above.

5.4.6 Jail Aggreivance

In the original paper, released Agents left the jail just as aggrieved as when they were captured. Modeling different criminal justice systems is nearly impossible that way. Therefor, we implemented this variable. If Agents are badly treated in jail, they now will be released in an angry state.

5.4.7 Activism Threshold

The attitude of an agent against the regime is computed by subtracting the net risk of arrest for that agent from his personal grievance. But what attitude is needed for an Agent to actually go active? In the original paper, this was assumed to be zero, but we implemented a variable to model different people and their resistance to regimes.

5.4.8 Murder Threshold

In order to model militant uprisings we needed some functionality for Agents to actually kill or at least attack Cops. This murder threshold is the outcome. Normally much higher than the activism threshold, if fulfilled, the Agent will no longer protest but instead go and hunt down Cops.

5.4.9 Murder success rate

Depending on the tools available to murdering Agents, they may or may not succeed in killing a cop. This is used to differentiate between countries with easy/difficult access to weapons for civilians.

5.4.10 Murder assassin death rate

Sometimes Agents might get killed while trying to kill a Cop. If the Cops are taken by surprise the revolution might go much more smoothly than if all Cops are heavily armed and have orders to kill every attacker.

5.4.11 Vision Min/Max

These variables, separate for Agents and Cops, govern the visible field. In every step, players can only gauge what happens in their field of vision, and act upon it. Large fields of vision will allow Cops to become more effective, while Agents can better interpret their chances of getting arrested.

5.4.12 Death

Whenever a Cop tries to arrest an Agent, either one of them might die. As seen in 2008 in Greece, the death of Alexandros Grigoropoulos sparked violence. So whenever an Agent dies while being arrested, the Legitimacy of the regime suffers. To somewhat even out the effect, in case a Cop dies, the Legitimacy receives a boost. These variables are especially useful when gauging if a regime should use many Cops to quickly crack down on Agents, or whether they should use a moderate force to slowly curb the unrest.

5.4.13 Important Places

In the original paper, Cops as well as Agents wander pretty much randomly. When modeling Egypt's revolution in and around Tahir square, the idea of randomly moving doesn't cut it. Both Agents and Cops marched to one important place, and then clashed there. To model such an important point, this feature was added.

5.4.14 Important people

Nearly every revolution had its heroes. While they were not so powerful by themselves, they would often tip the balance in their favor. We modeled important people with an extended Vision, as well as enhanced effectiveness: When an Agent tries to find out his chances of arrest, he will measure a low chance when standing next to an important Agent, but a very high chance when seeing an important Cop.

5.4.15 Defective Cops

Normally, Cops won't defect to the Agents side. In special cases, such as Egypt and Tunesia, the Cops decided to join the Agents since the Legitimacy of the regime had fallen too low. We modeled this using two variables. Should the Legitimacy fall below some threshold, Cops will stop arresting Agents. If the Legitimacy falls further, they will abandon their post and join the Agents.

5.4.16 Better Legitimacy

Legitimacy is normally not globally perceived. Some people will always agree with a certain regime, while others will always disagree. To model such cases, we assigned every Agent and Cop his own impression of the regime. This allows for some more believable outcomes, such as Agents with low Hardship but a distinct hatred of the regime going active, as well as Agents with high Hardship keeping silent because they love the regime.

5.4.17 Legitimacy Change each step

In certain cases a regime might lose supporters as time passes. For example the people of Egypt are pressing for reforms, and the longer they have to wait, the less satisfied they will become with the regime. This variable can be used to model such cases, and help decide when the breaking point is reached, by which a reform needs to be introduced, or the protests will start again.

5.4.18 Number of Frames

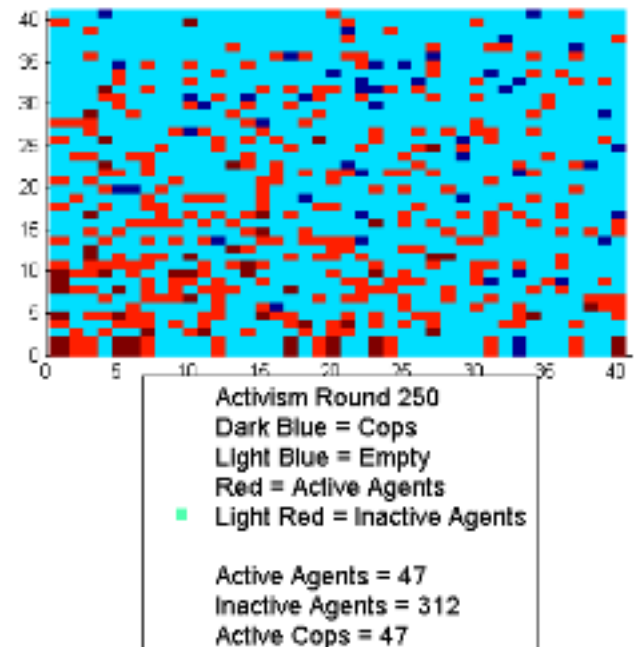
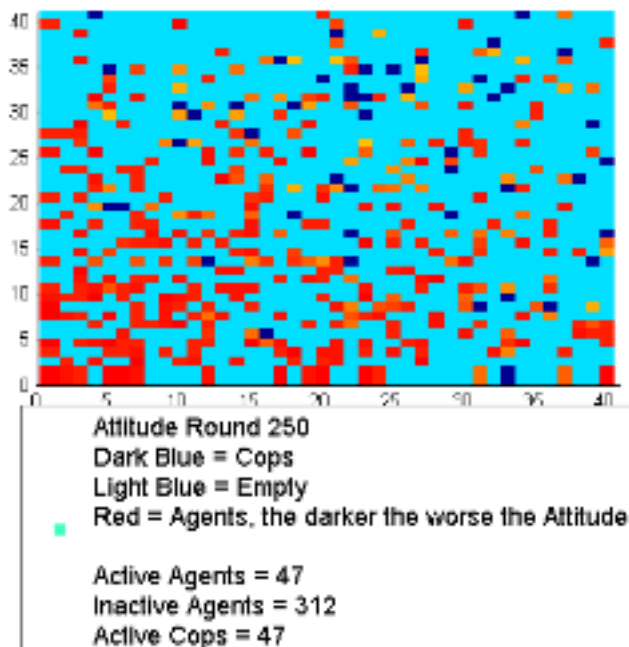
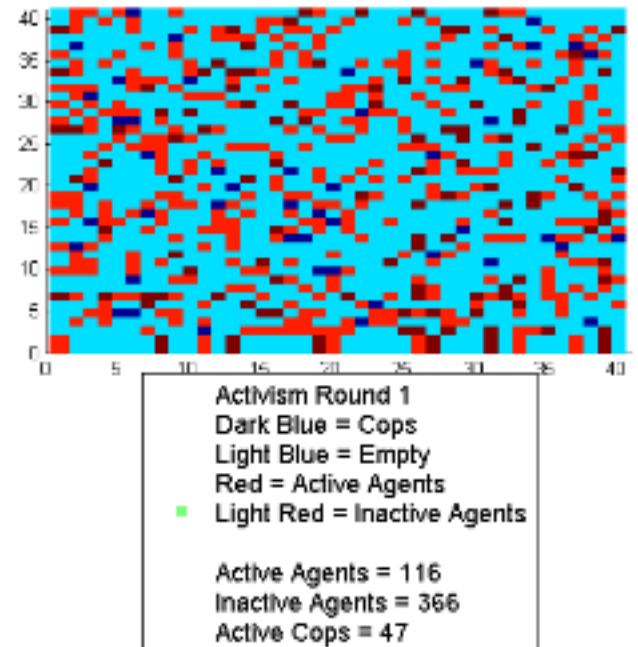
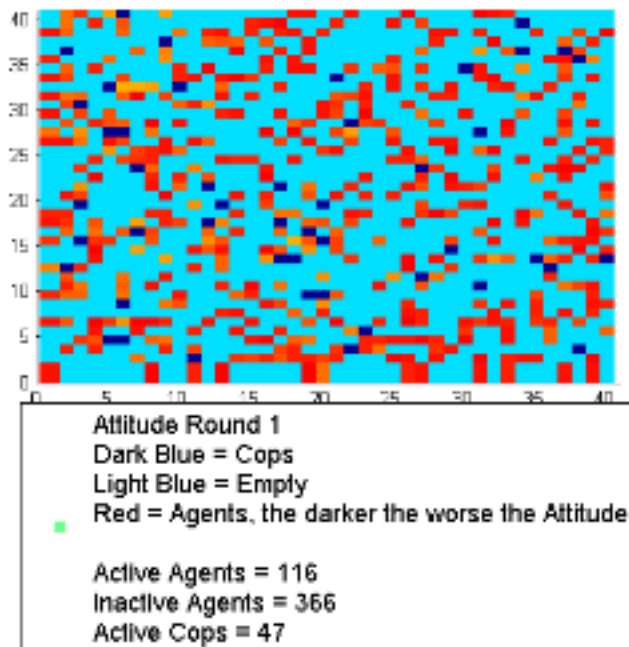
This variable does not have any influence on the computation itself, but governs how many steps are computed and archived.

5.4.19 Plot every X Frames

In case the number of frames is higher than five, one might want to consider not plotting each and every step, and this variable governs that.

6 Simulation Results and Discussion

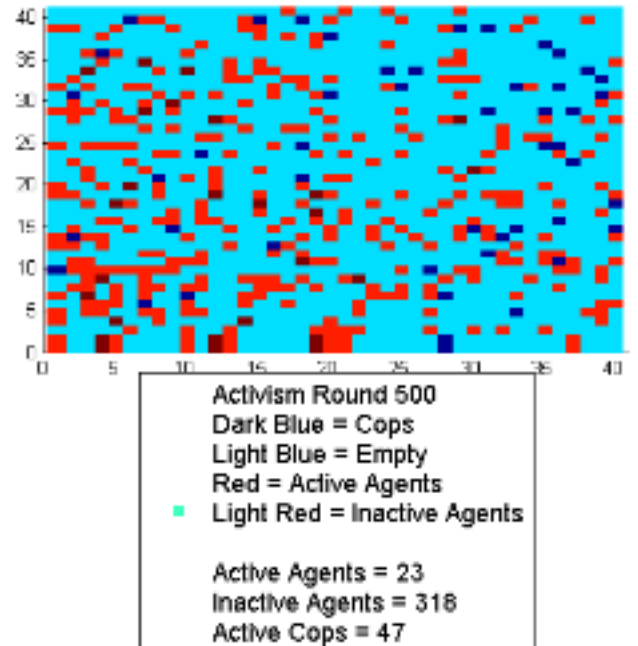
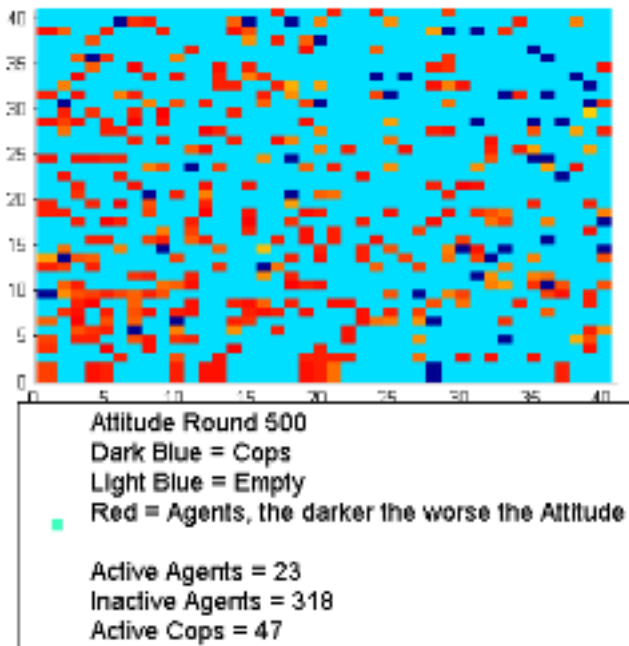
6.1 Comparison of Epstein Model with our Model

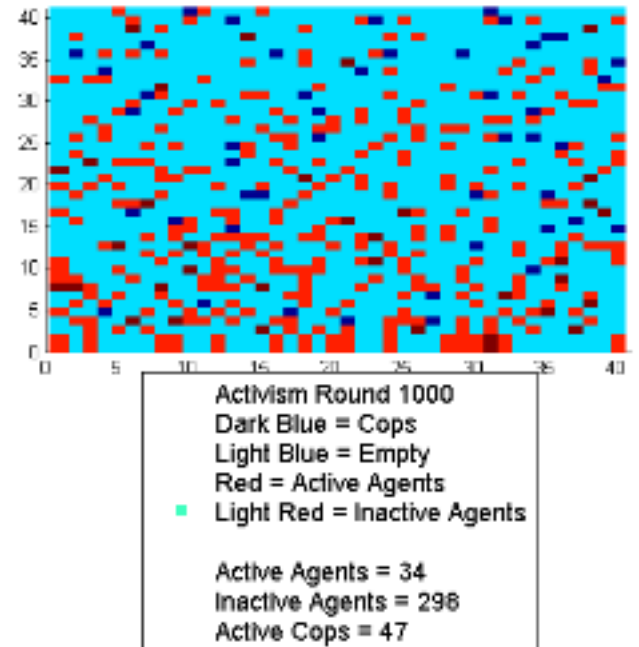
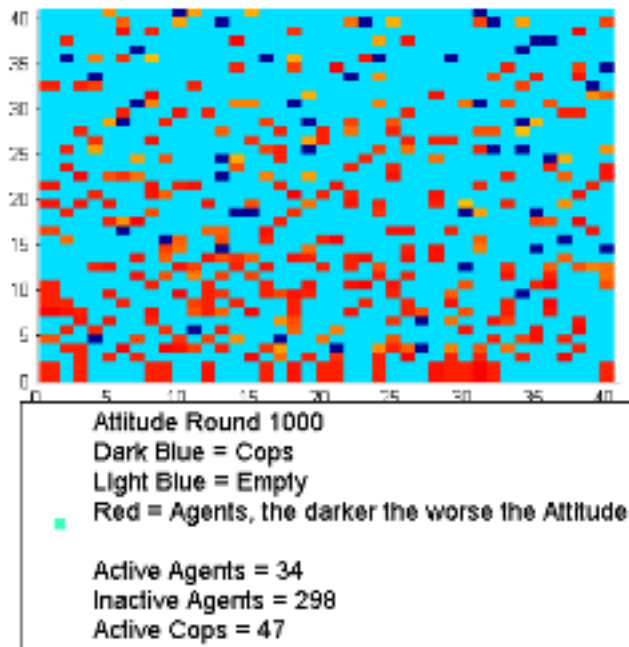
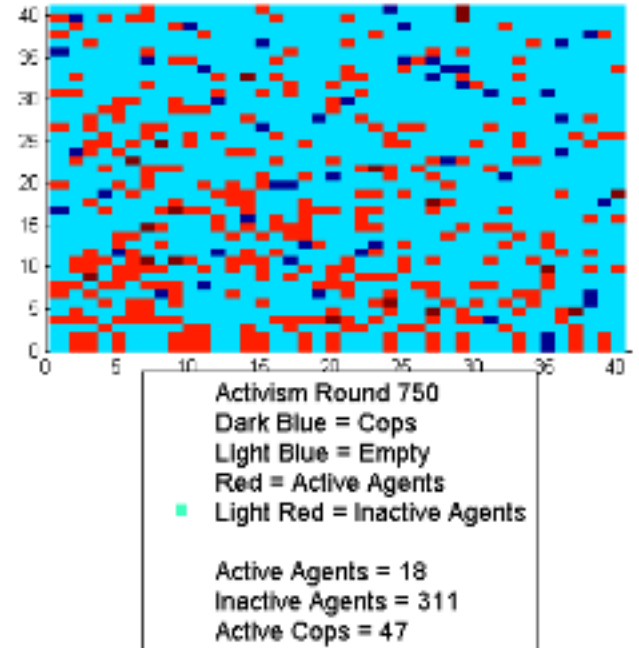
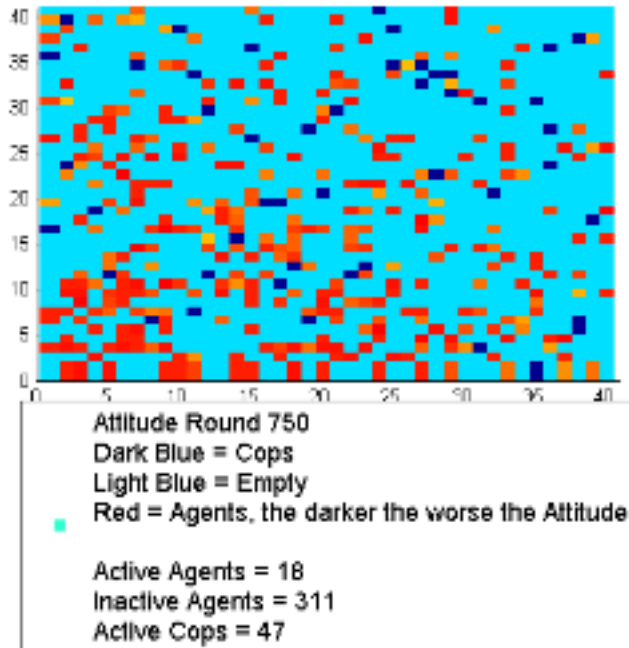


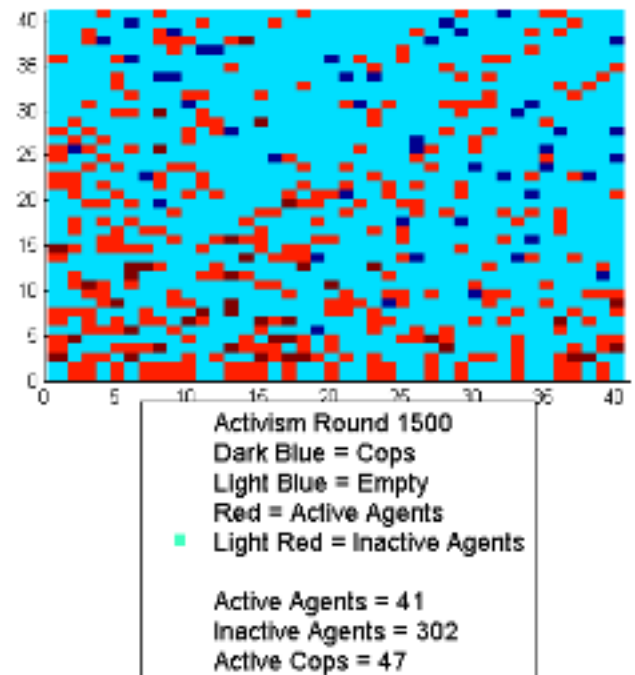
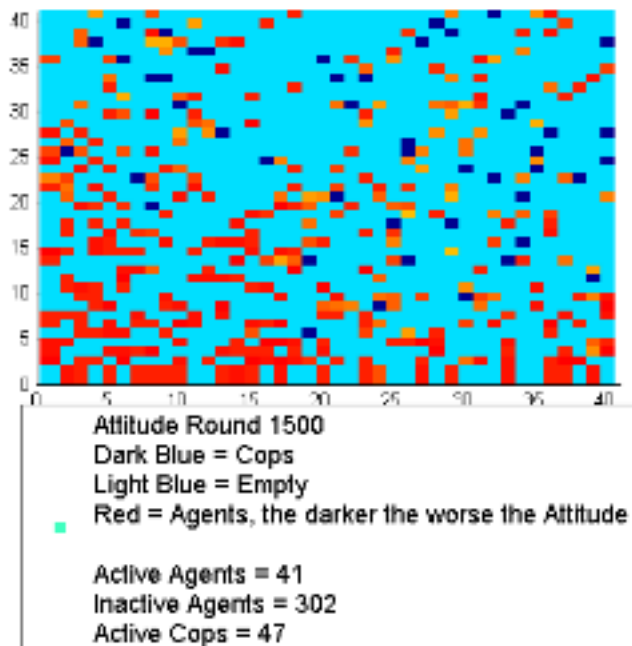
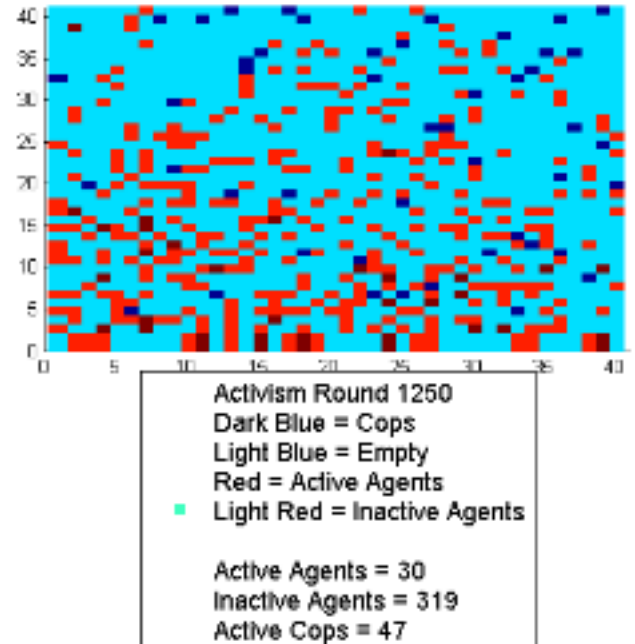
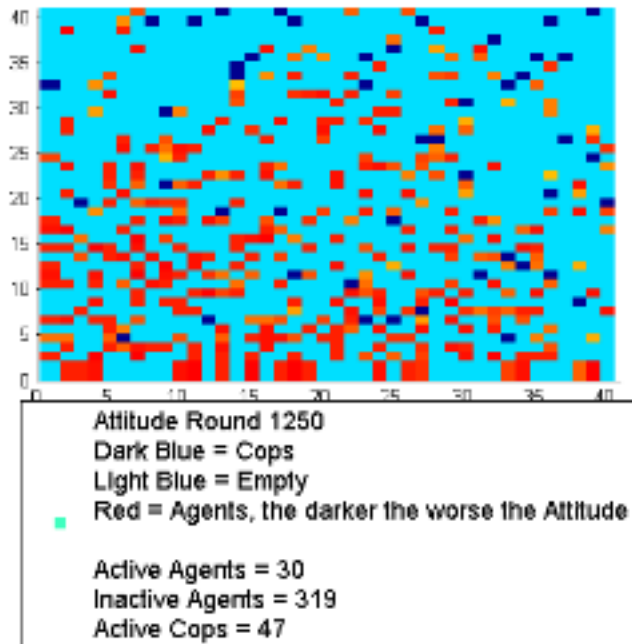
As in the Epstein model it can happen that the local cop to agent ratio drops too low and agents turn active. Later when the cops return the active agents disappear again either by arresting or turning inactive. A good example for that is round 250. Since there are no cops in one corner agents turn active. The simulation was done with the following input:

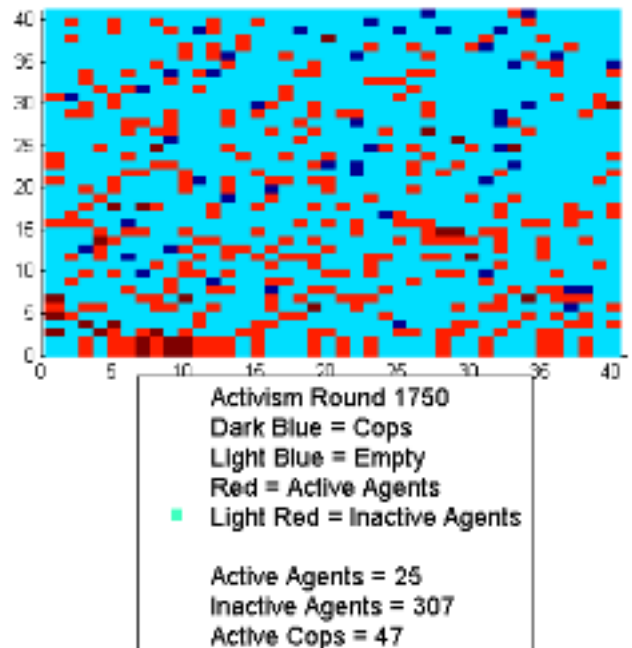
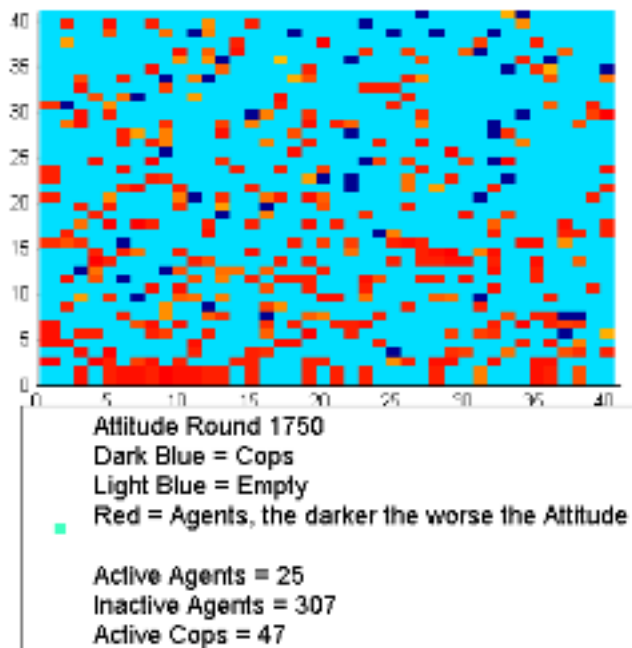
$L = 0.7$;
 $O_to_U_Ratio = 0.5$;
 $C_to_A_Ratio = 0.1$;
 $Jailterm_Min = 3$;
 $Jailterm_Max = 5$;
 $Activism_Threshold = 0.1$;
 $Vision_Min_Cops = 5$;
 $Vision_Max_Cops = 7$;
 $Vision_Min_Agent = 5$;
 $Vision_Max_Agent = 7$;

All the other variables have been set to 0.

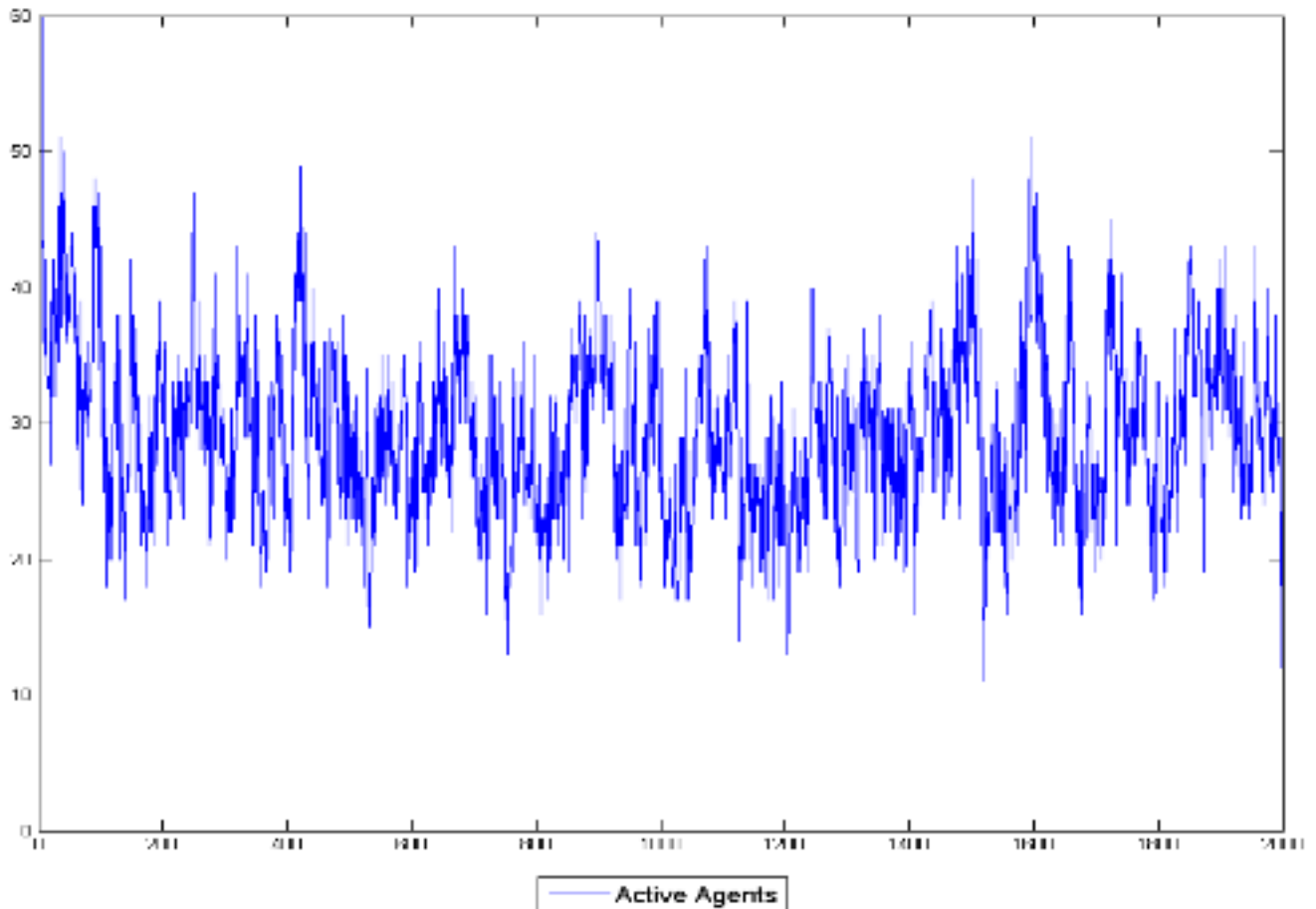


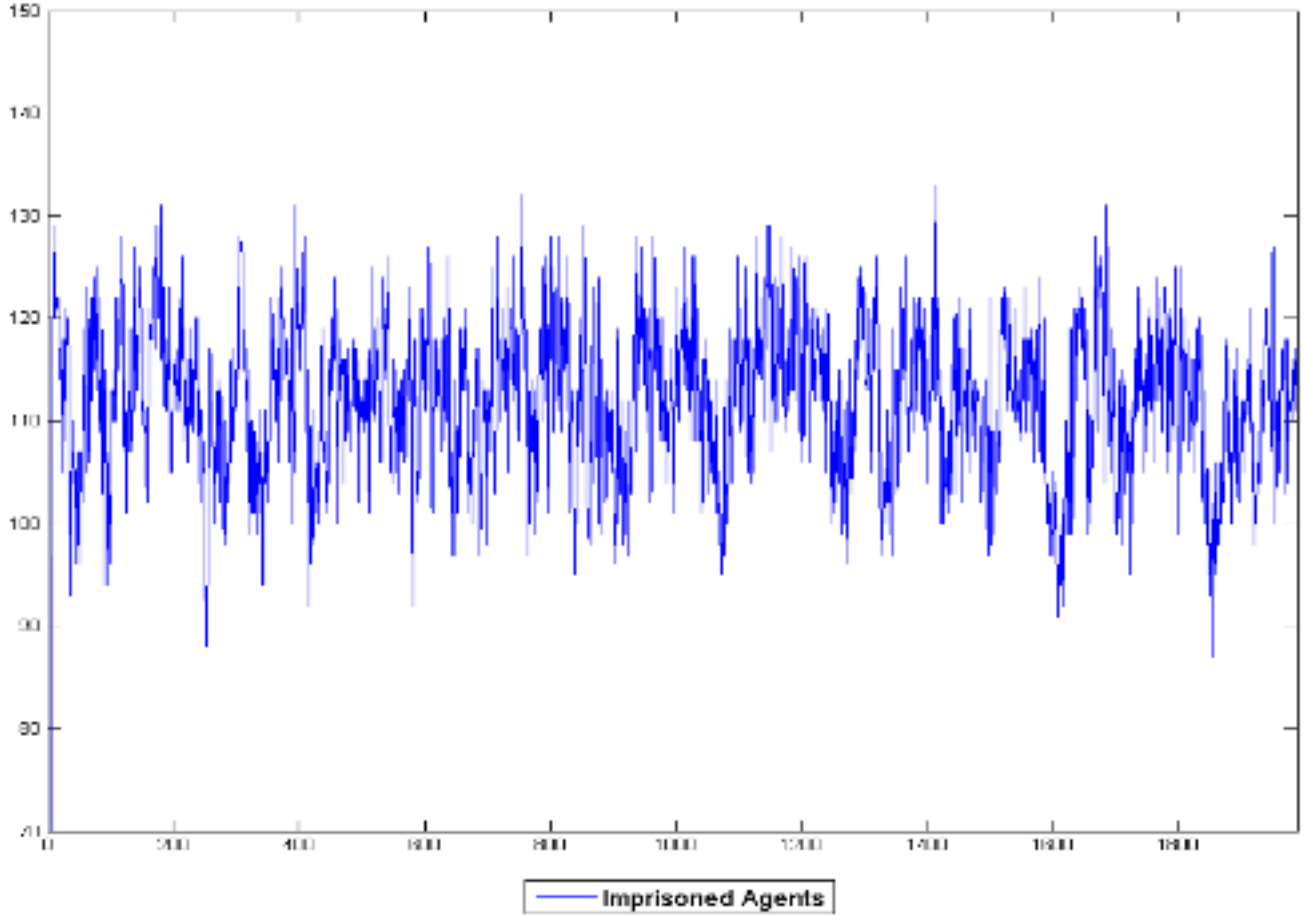






In the next graph we plot the number of active agents in every round. There is a sudden drop in the first couple of rounds: In the first round there are 116 active agents. But later the number of active agents is never larger than 60. Also can be observed that the number of active agents and the number of imprisoned agents affect each other. If the number of active agents is high the number of prisoner will probably be low and if only a few agents are active the prisoner will probably be full and vice versa.



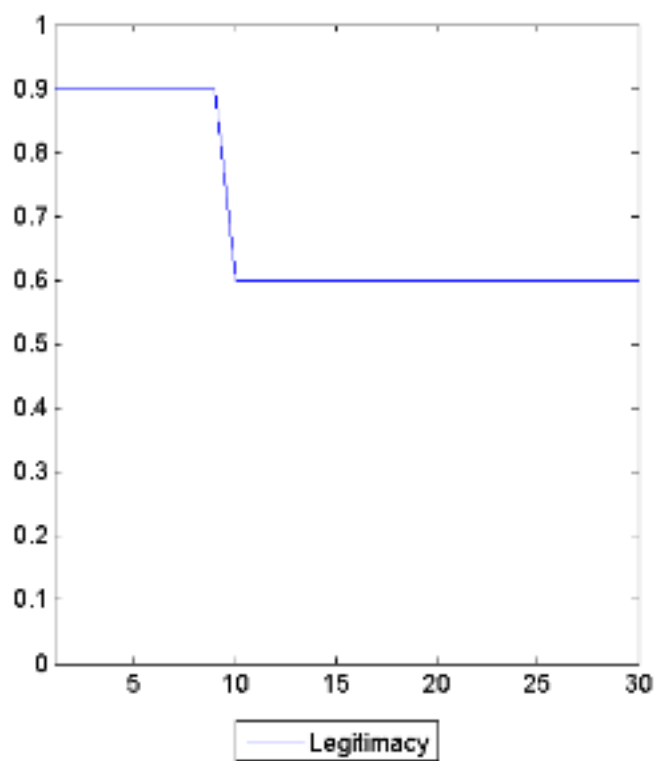
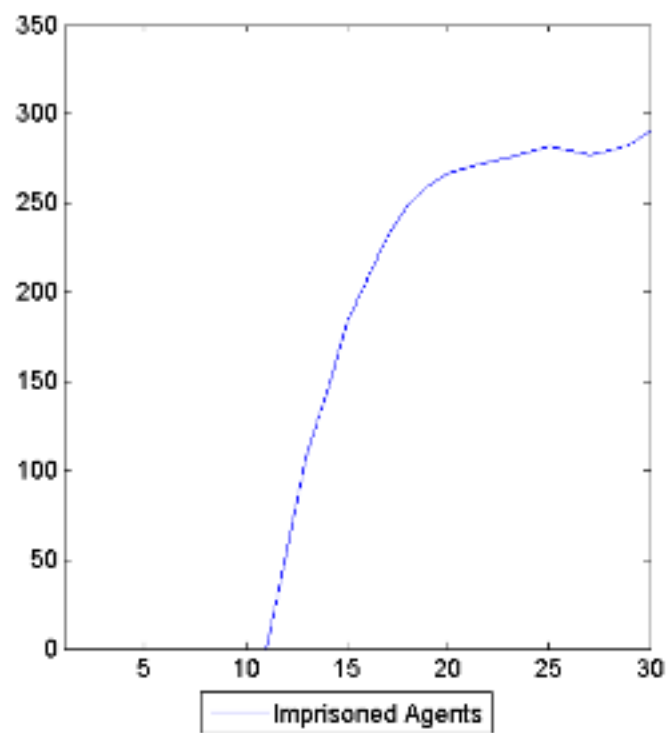
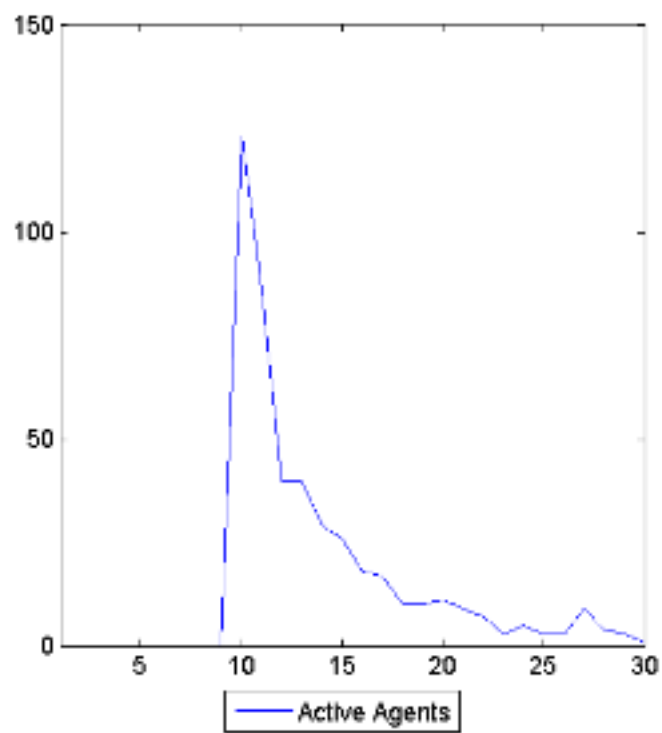


6.1.1 Salami Tactics of Corruption

As in the Epstein model we studied the influence of a Change in legitimacy. We looked at two cases: A sudden drop in legitimacy and a smoothly decay in legitimacy. Both cases happened in the real world. A very good example for a sudden legitimacy drop is Greece. After a protester was shot during a demonstration the public opinion suddenly dropped and the demonstration became even bigger. An example of a smoothly decay is Egypt. The system seemed to be quiet stable but the lack of a better future for a whole generation steadily decreased the legitimacy.

6.1.2 Sudden drop

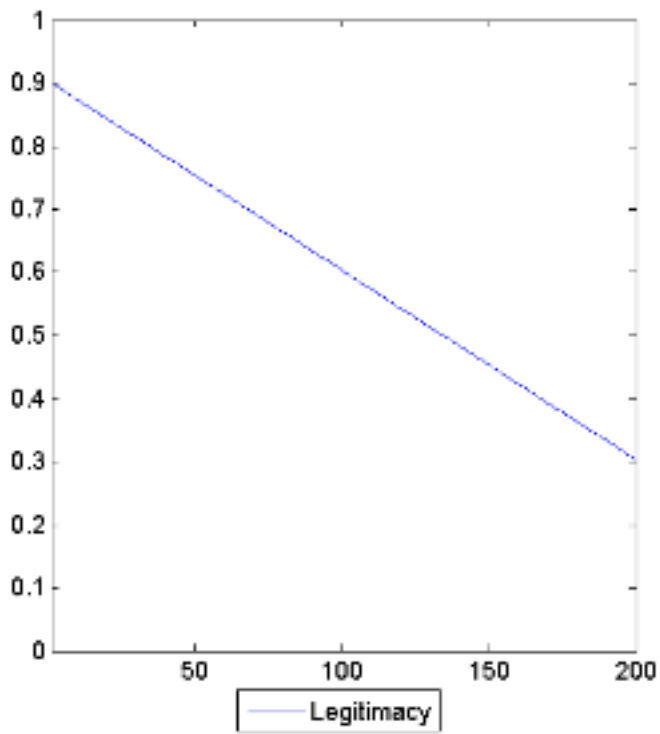
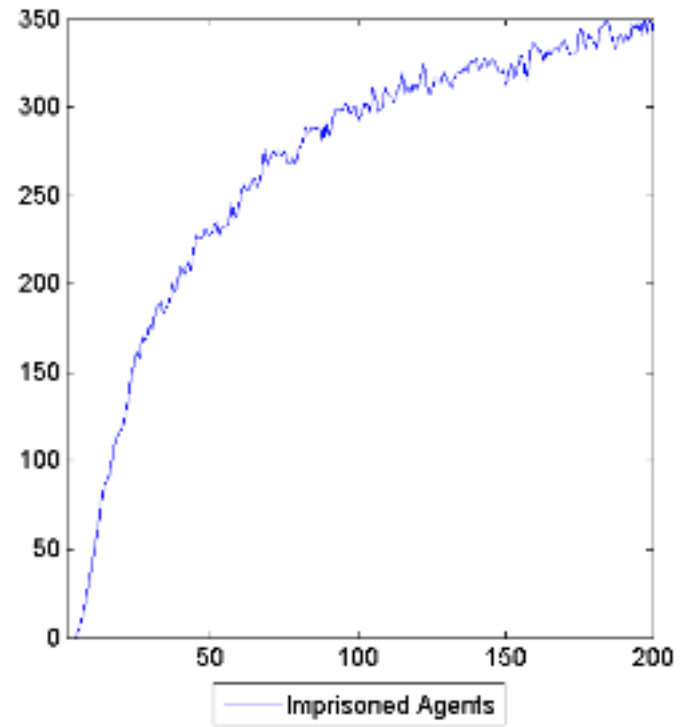
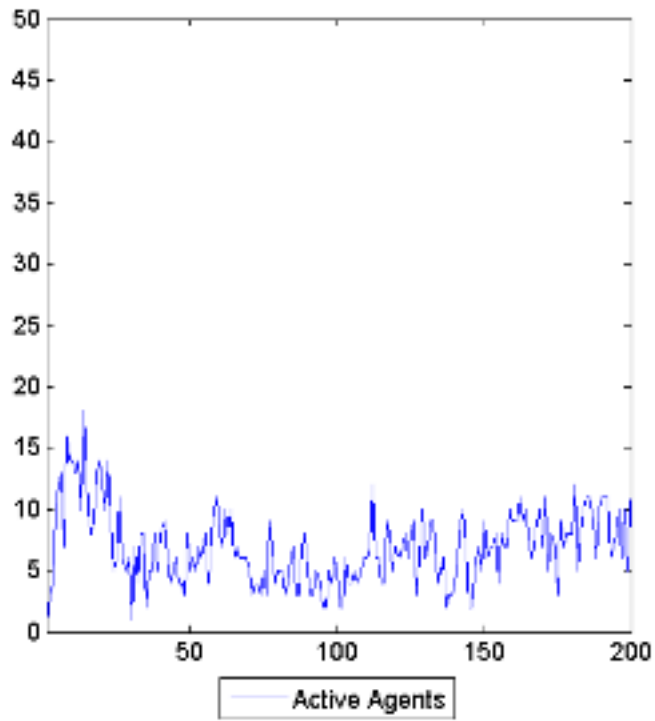
We started with a legitimacy of 0.9. Then in round 10 we reduced the legitimacy by -0.3. This leads to a sudden increase of the number of active agents. Since the central force is very strong (number of Cop/agents = 0.2) the number of active agents declines again and the prison gets full.



L=0.9
O_to_U_ratio=0.5
C_to_A_Ratio=0.2
Jailterm =(8,25)
Activism_Treshold=0.1
Vision=7

6.1.3 Linear decrease

In this case all the parameters are exactly the same as above. The only difference is the Legitimacy. Instead of a sudden drop we reduced the legitimacy round by $-0.6/200$. In this case we dont observe a peak in the number of active agents. Since the central force is strong and the prison terms rather long the cops can handle the situation.



$L=0.9$
 $O_to_U_ratio=0.5$
 $C_to_A_Ratio=0.2$
 $Jailterm = (8, 25)$

Activism.Treshold=0.1
Vision=7

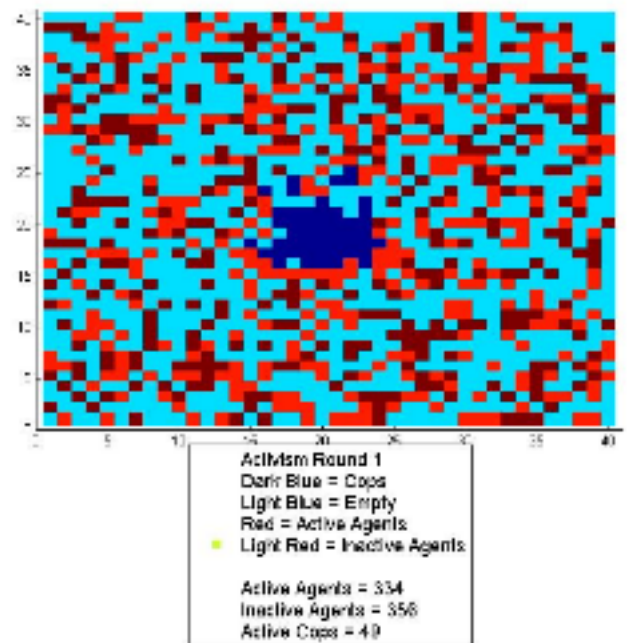
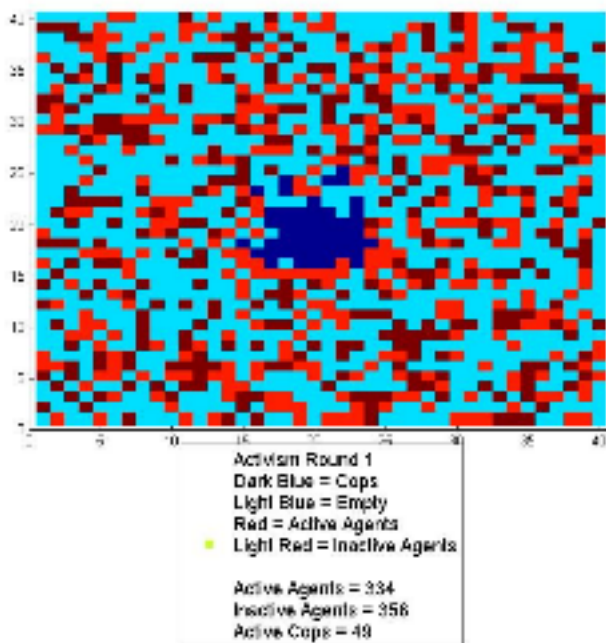
6.2 Influence of Cop Distribution

We wondered what would change if we would let star the cop in the middle instead of randomly distributed and how does the influence of the starting position of the cops depends on their view.

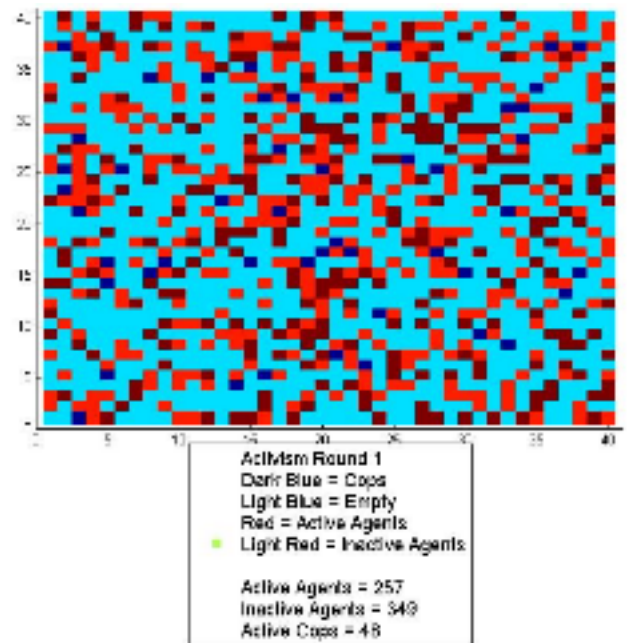
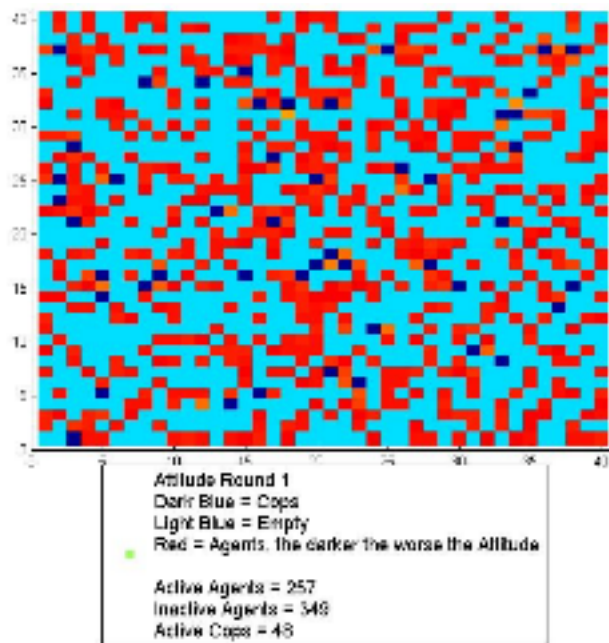
The idea is the following: In the beginning 49 cops are stationed in the middle of the field. Then they spread out and suppress the demonstrations. The question is now: How many rounds does it takes until the cops starting in the middle are as successful as the ones starting randomly.

The following plot shows the field in the first round and in the 100 round.

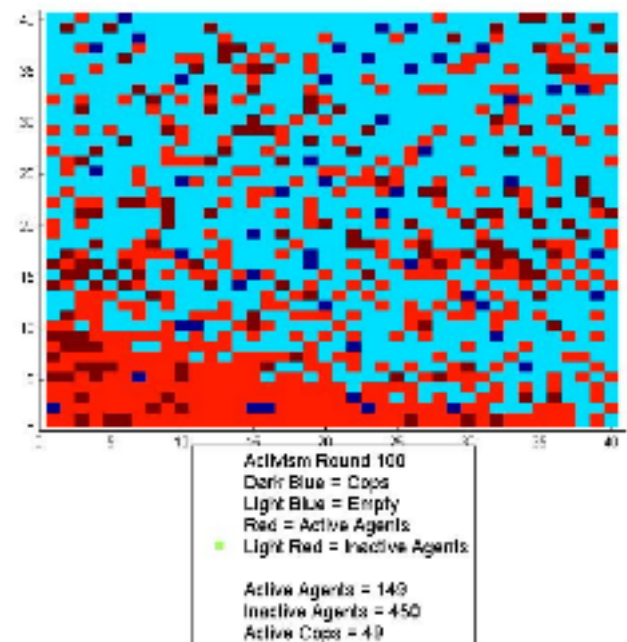
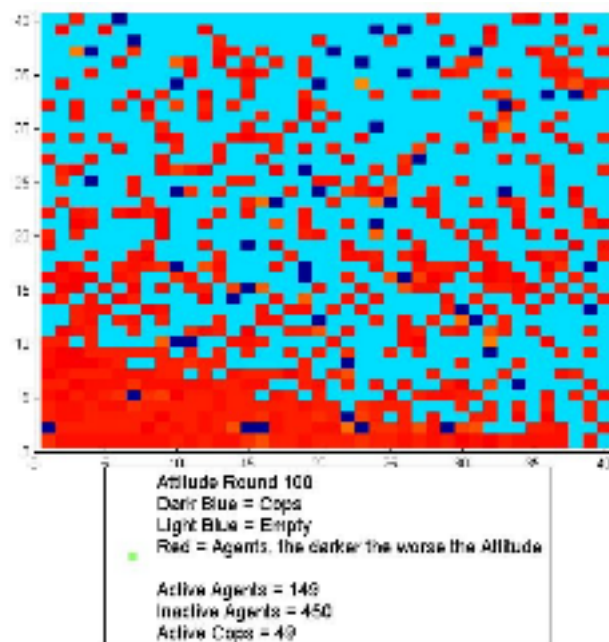
Centre



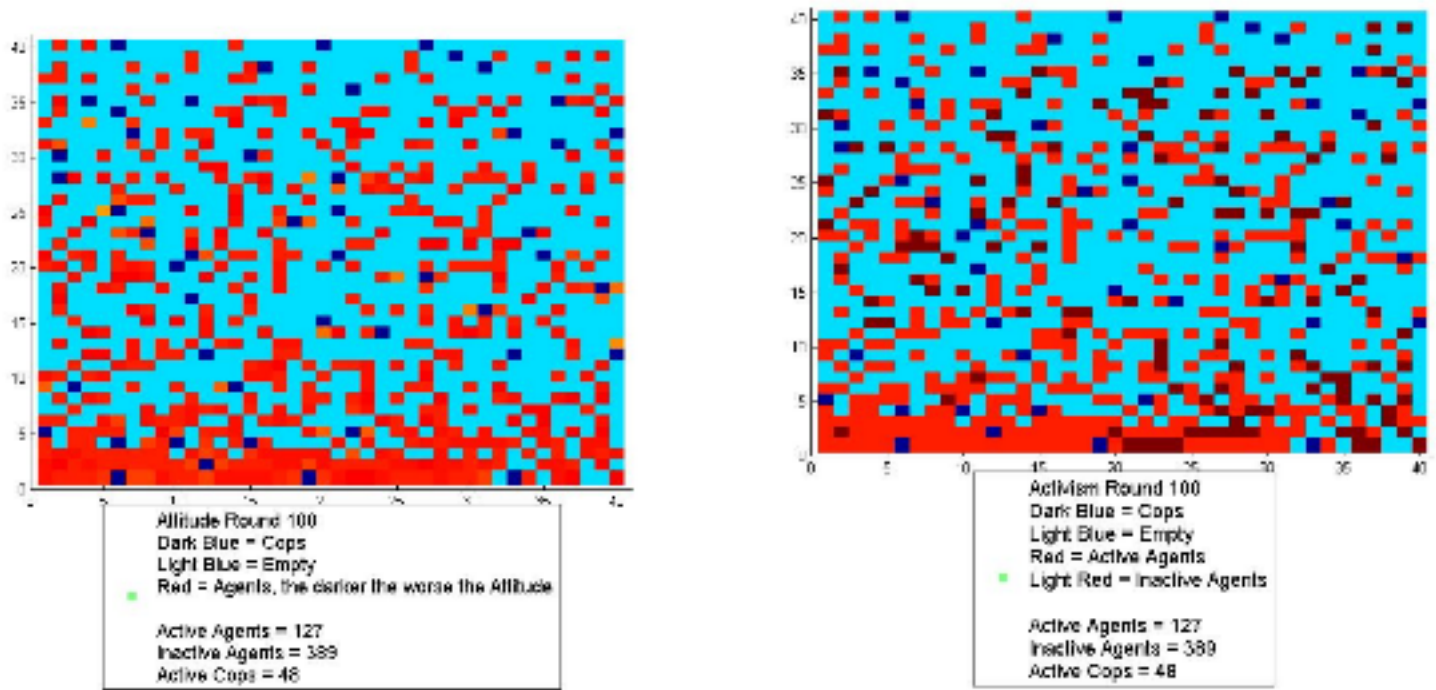
Random



Centre



Random



There's clearly a big difference in the first round, but after 100 rounds the plots looks alike. We run the simulation with the following parameters:

$L=0.8$

$O_to_U_Ratio = 0.7$

Jail = (3,6)

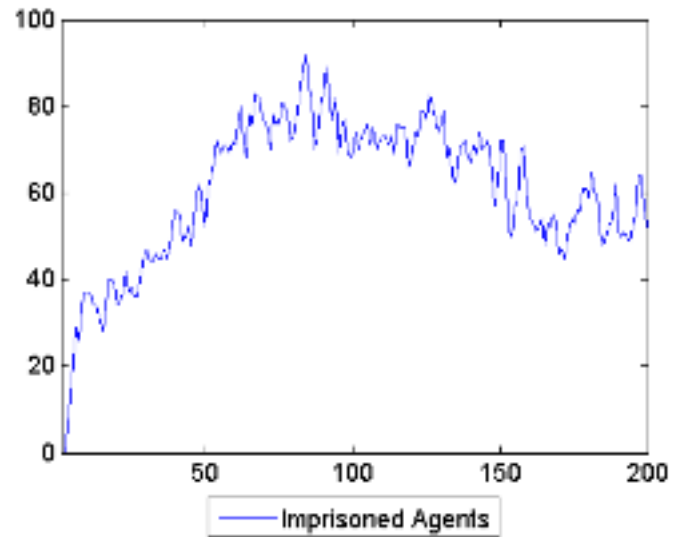
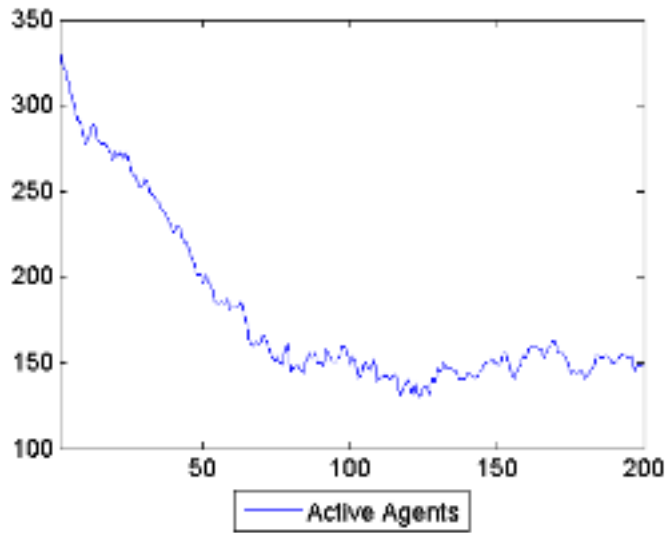
Activism_threshold=0.1

Vision = (1,3)

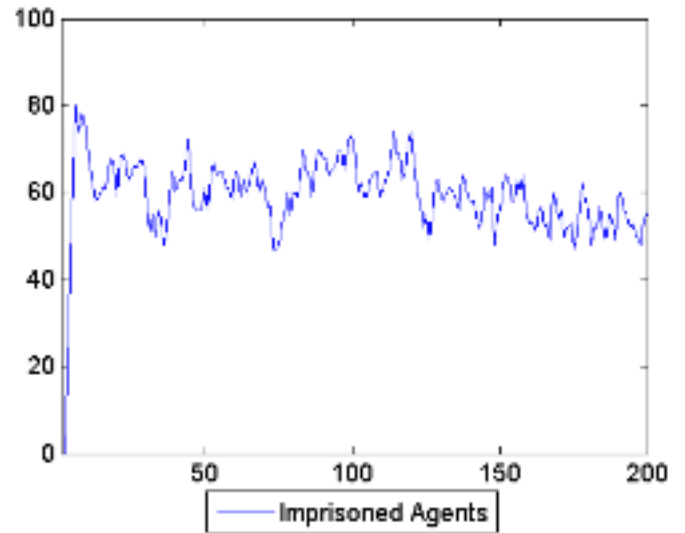
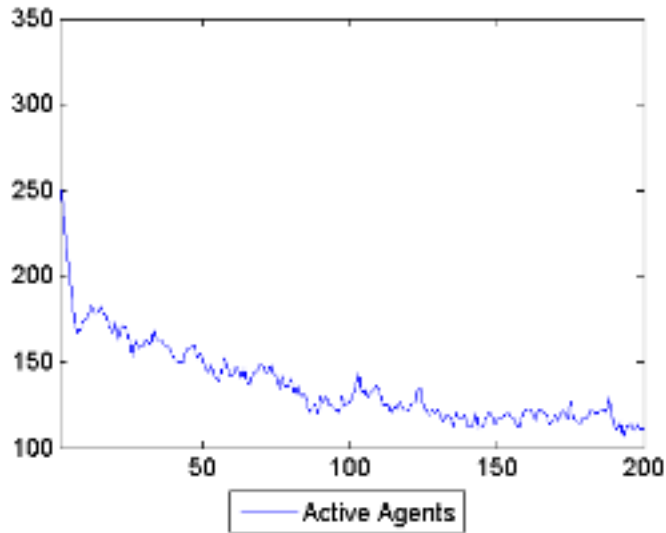
In the case of randomly distributed cops we set the $C_to_A_Ratio$ to 0.0743. So expected value of cops is 49 as in the case of cops starting in the centre.

In the following two graphs we clearly see that the cops starting in the middle are less successful in suppressing active agents and filling up the prison.

Centre

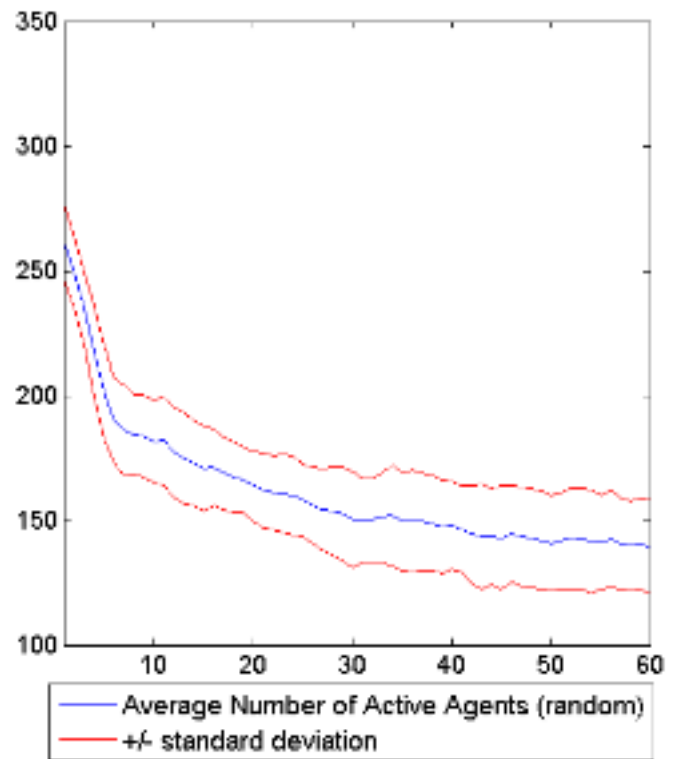
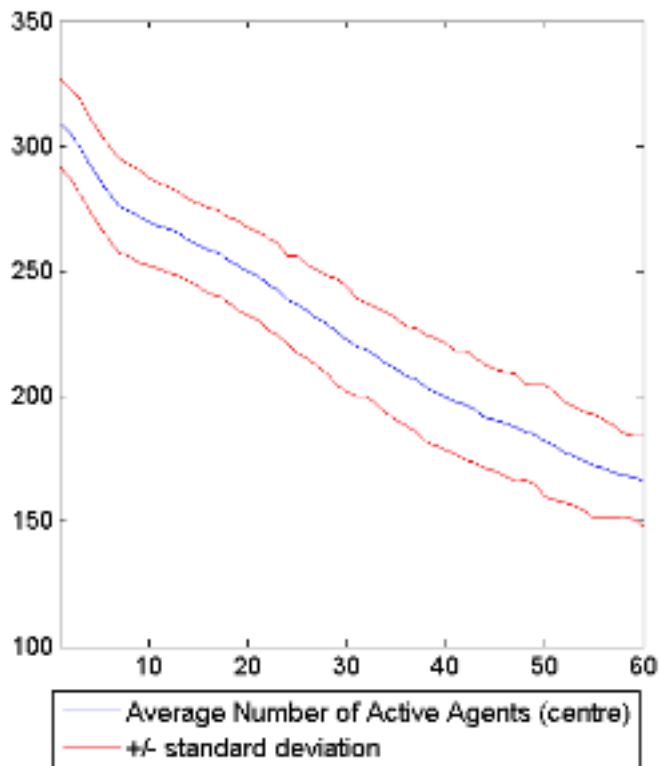


Random

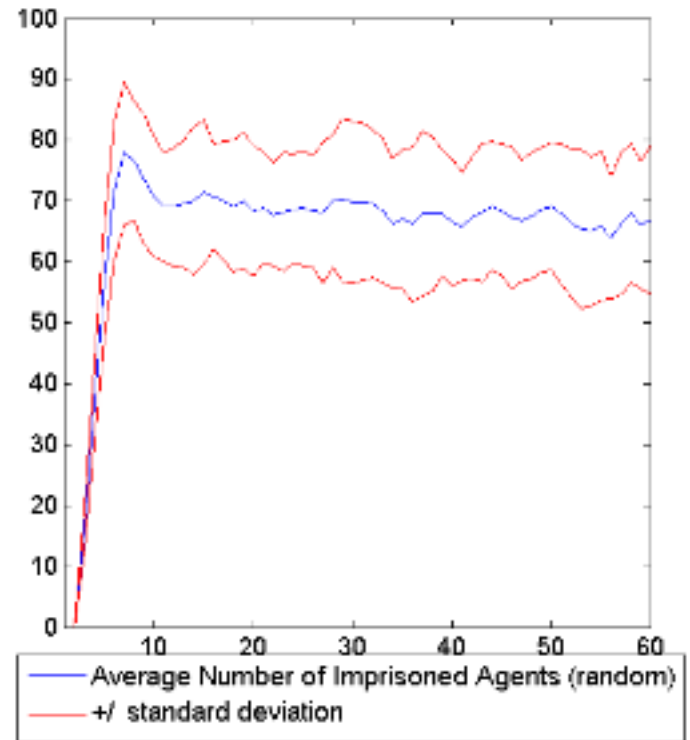
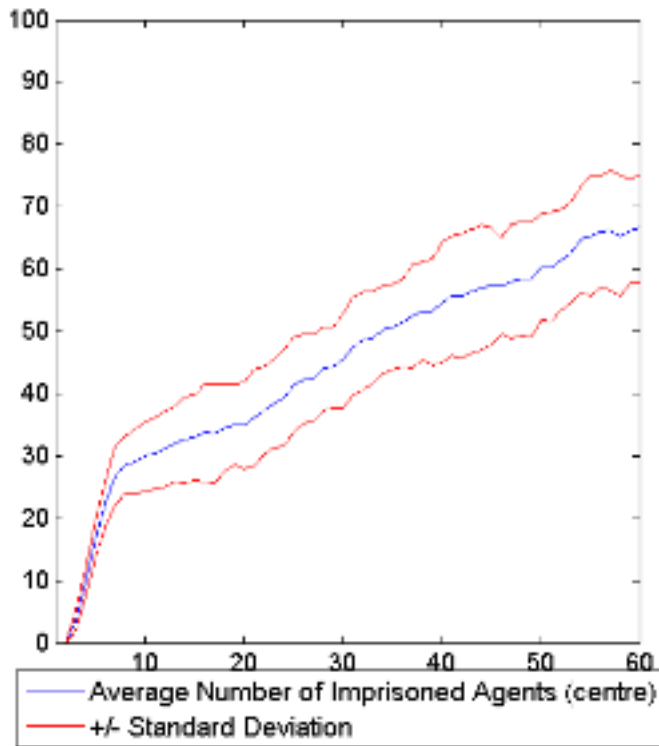


To get a more accurate result we took the mean and standard deviation of the number of active agents and the number of active agents over 30 runs of the simulations. We did that for 3 different tips of view ranges:

6.2.1 View randomly distributed in (1,3)

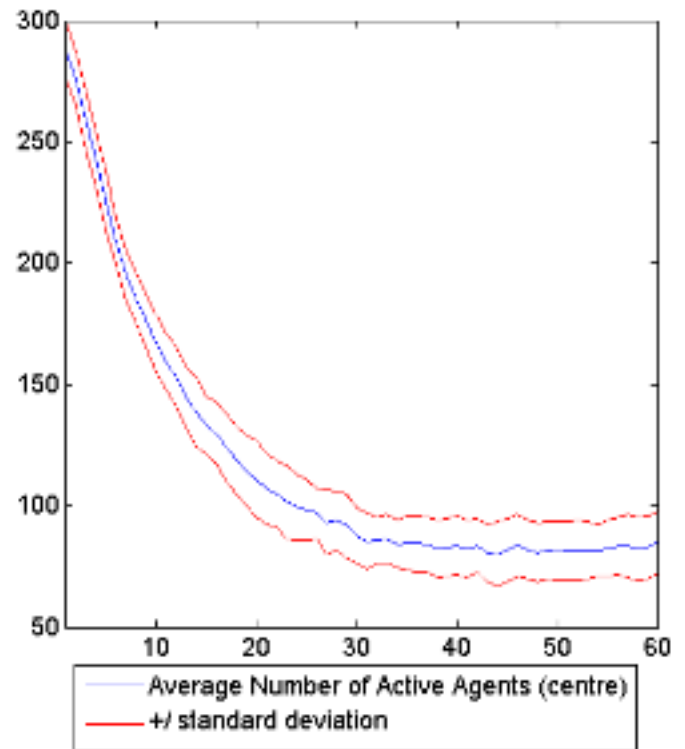
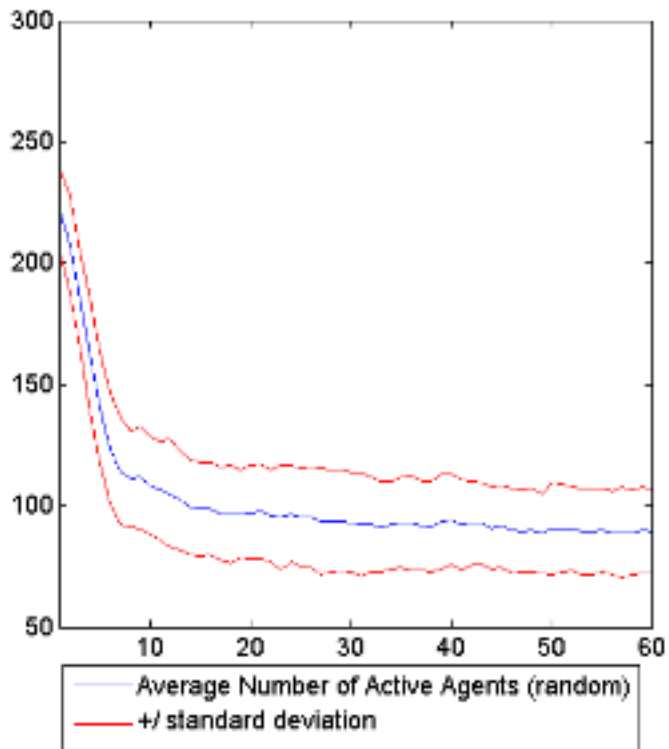


After 60 rounds the cops starting in the middle are still clearly less successful in suppressing active agents than randomly distributed cops. Also the shapes of the curves doesn't look alike

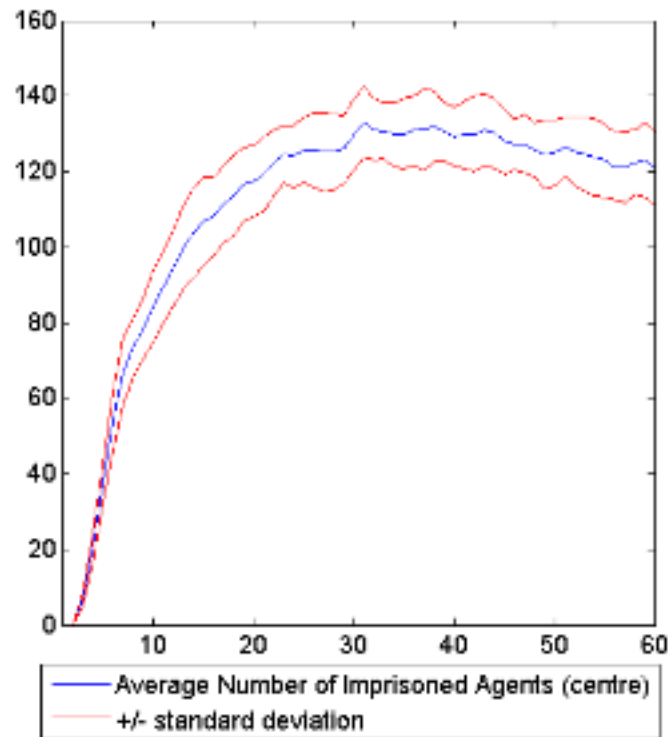
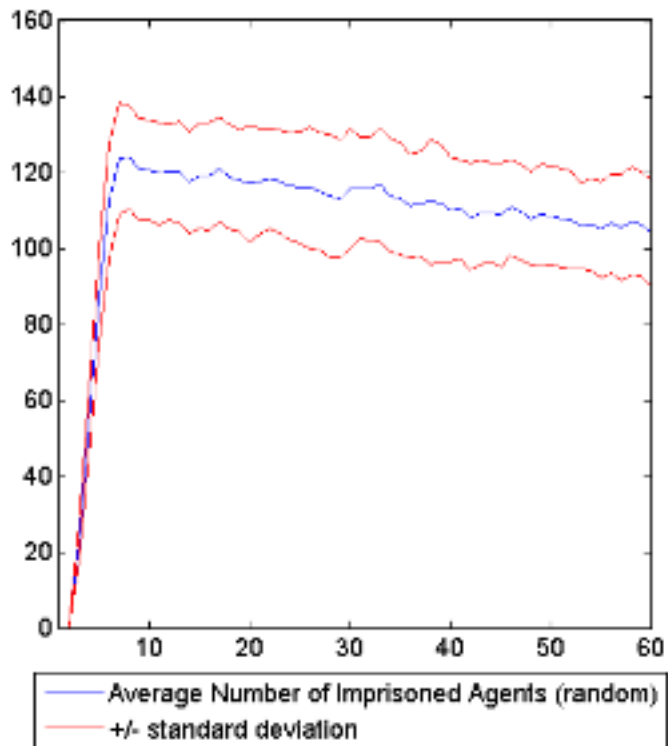


The cops on the middle need 60 rounds until they finally have imprisoned as many agents as the randomly distributed cops.

6.2.2 View randomly distributed in (3-5)

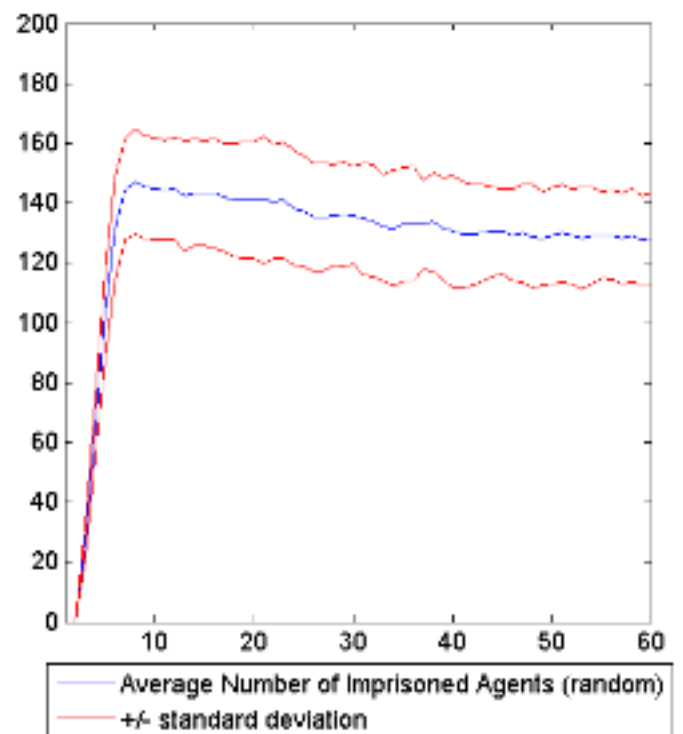
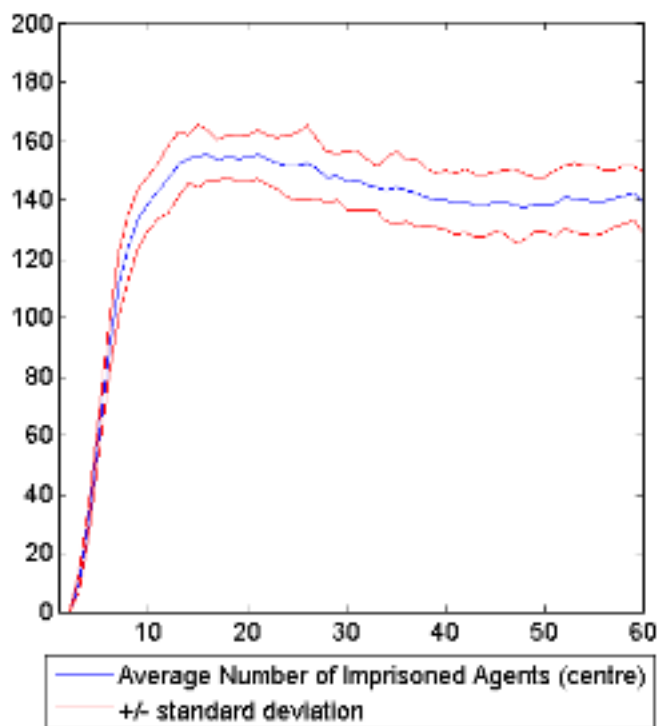
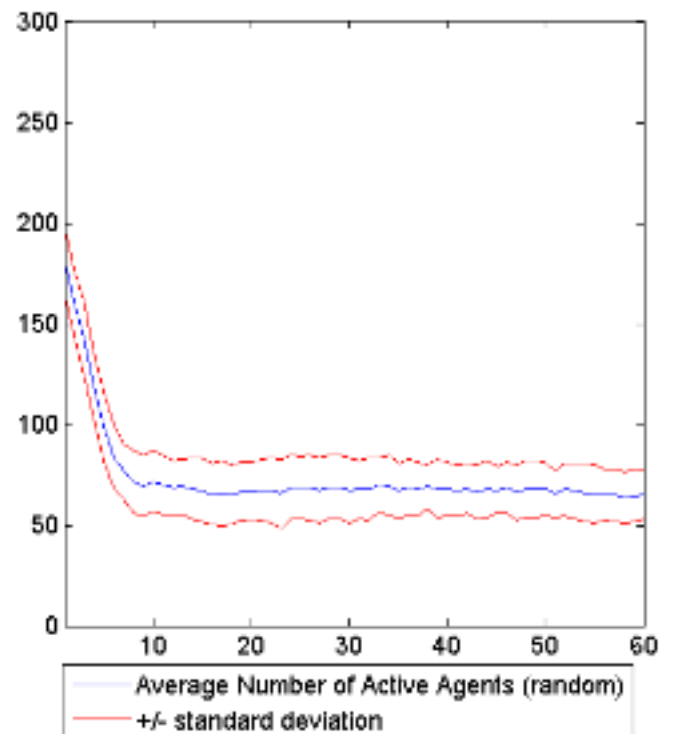
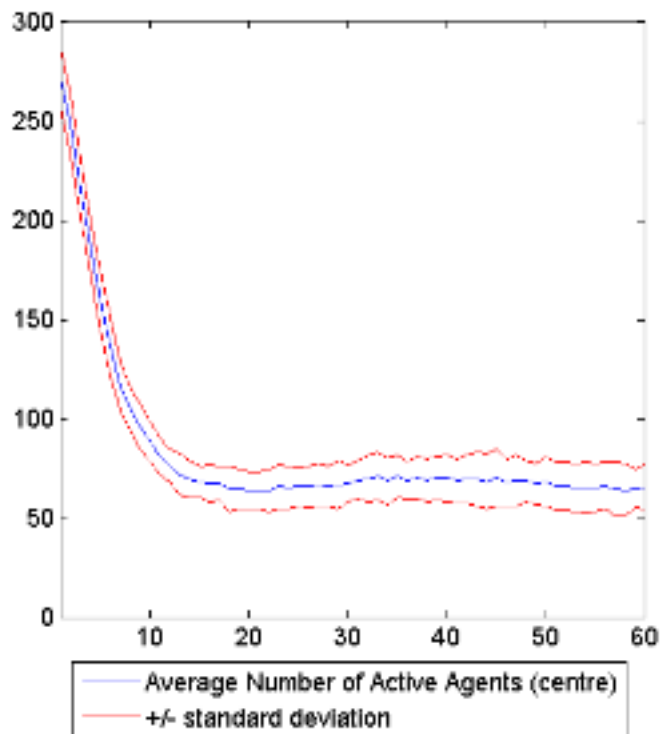


In this case it takes the cops starting in the middle about 25 rounds to get as successful in suppressing the active agents as the randomly distributed cops.



The curve in the random case after round 5 looks like the curve in the centre case after round 30. This holds also for the graph of active agents.

6.2.3 View randomly distributed in (5-7)



In this case the curves in the centre case shifted by about 5 rounds to the right looks like the curves in the random case. If we would increase the view even more the difference between the two cases would disappear completely. This is clear since we have only a 40×40 field. So after about 4 moves of length 10 a cop starting in the middle can reach every position in the field.

It is also very interesting how the whole system behaves: After a number of rounds depending on view, population density and cop density the average of the simulations gets constant.

6.3 Problems

6.3.1 View

We get a problem with our simulation if the view is very low and in the same time the population density is high. An Example for that are the plots of the field in the chapter Influence of Cop Distribution.

There we have a view in (1,3) and a ratio of 0.7 of occupied to unoccupied fields. After 100 rounds the people arent randomly distributed anymore. They sort of glue together in the corner. Since the view is small most of the people in this accumulation cant move at all.

6.3.2 Movement

Our agents and cops can only move left, right, up and down. This seems to be not very realistic. If only one cop is in a particular region the situation can be very unrealistic. But if many agents are in a particular area they can cover the whole area with their movement and the situation is similar to the case there the cops can move in all directions. So always place enough cops in the field. The same also holds for agents. Enough means at least more than 40.

7 Summary and Outlook

Summary and Outlook

We implemented the basic idea of the Epstein and added several extra variables to simulate things as active agents trying to kill a cop, agent killed while trying to kill a cop, a cop or an agent killed during imprisonment, legitimacy influenced by a deadly incident during imprisonment, a personal legitimacy for every agent and cop, cops being more human i.e. stop working or even defect if legitimacy is too low.

We compared our (basic) model in some simple cases with the Epstein model and got similar results. WE also studied the limitations of our model. We had a closer look on the influence of the starting position of the cops depending on their view. Very interesting was the fact that in a couple of cases the mean over several simulations became constant after a couple of rounds. It would be interesting to check if this happens always or if there exist cases where the average doesn't get constant but maybe behaves periodic.

8 References

Modeling civil violence: An agent-based computational approach, Eppstein 2002

9 Appendix A: Proposal

Document Version: 4

Group Name: creative!

Group participants names : Florian Besser, Fabian Mönkeberg, David Schwarz

General Introduction

During the course of human history, regime changes have often occurred by civilians taking up arms. This “civil violence” also happens right now in Syria, and a similar movement has just been successful in Libya and Egypt. These uprisings or rebellions have a big impact on our world, and an ever bigger impact on the people actually executing them. So it is imperative to be able to predict such changes, and that's exactly what we strive for: A clear model for civil violence, so that in the future we can better predict outcomes and aftermaths of these events.

Real world examples would be: Syria, Libya, Egypt, Russia, United States of America, even Switzerland etc.

(The canton Wallis had various unsuccessful uprisings until it was granted autonomy from Bern.)

Today, as taught in our schools, revolutions are formed by “normal” civilians, who are unhappy with their current situation. Somehow, this unhappy (but non-active) mob produces/elects a leader, who will then lead them into action. This now active mob will then have to fulfill certain tasks, such as taking up weapons against an oppressive military force, or a demonstration of force in form of a peaceful protest. On completion of these tasks, they can then form their own government according to their liking.

While the very first step (unhappy civilians) is often a requirement, the idea of a revolution forming and a revolution marching against the current system is not sophisticated enough. There are many factors which can catalyze or hinder the formation of a rebellion, as we are going to show.

The tactics which can be employed by a system that is under attack are also somewhat left out in our education, take the revolution in Egypt as an example: What would have happened if the government went “all out” on the protesters? Would the military rule have held another decade?

Fundamental Questions

Modifications of the model from Eppstein:

1. Different start conditions: some Cops are positioned in a casern (Soldier-cops) in the middle of the field. The rest is equidistributed (Police-cops).
2. Different distributions: the equidistribution for the level of hardship H or risk aversion R and over variables is not satisfying. To model the reality better, we want to use a distribution on $[0,1]$ similar to the Gaussian distribution centred at $\frac{1}{2}$.
3. Jail experience: The level of Risk aversion will rise during jailtime.
4. Agent leader: A new typ of agent. He will „lead“ the revolution. He’s able to increas the probability of Agents in an area around him to become active (by decreasing the level of Legitimacy L and decreasing the risk aversion R)
5. Copleader : New typ of cop. Modified by the ability of increasing the Level of Legitimacy L and the level of risk aversion R around him.
6. Intelligente Agents: active agents also move around. They have a higher change of moving towards a Leader and/or other agents (inside their visible area). This models the forming of a demonstration . This will change the cop /agent ratio and thereby decreas the risk for an active agent to be arrested.
7. Intelligente cops: Cops will have a higher change of moving towards active agents (inside their visible area). If they can` t see any active agents the Soldier-cops will have a higher chance of moving towards the casern in the middle of the field. The police-cops jus twill move randomly.

Questions:

- How does the results of the Eppstein Model differ from the result of the Model modified by 1 and 2?
- Does the outcome changes under a combination of Modifications 3-7? What influence do the modifications have ? Are there interesting cases ?
- How does the success rate of a revolution depend of the different Modifications ? Success of a revolution means that there are a certain number of active agents. The total success will be measured by the amount of successful revolutions in a certain time period. This correlates with the average waiting time between two successful revolutions.
- How does the amount of cops influence the total success in the different models ? What is the influence of the amount of military-cops and Police cops ? So are equidistributed cops better than centrally based cops? Will the probability for a revolution increase with the distance from the casern i.e. will active agents be likely far away from the casern ?
- Is a revolution successful because of its people or its leaders : Is there a significant higher probability for a successful revolution if there is an Agent Leader or not ?

Expected Results

A model that offers an improved algorithm to model uprisings and produce similar patterns as in real life.

References

Modeling civil violence: An agent-based computational approach,, Eppstein 2002

Project about « Civil Violence » from 2010

Research Methods

Agent-Based Model (Continuous Modeling would be possible)

10 Appendix B: Code

Listing from source file `Agent.m`

Listing 1: Agent

```
classdef Agent
    %Person Summary of AGENT
    % Detailed explanation goes here

    properties
        Hardship;
        Risk_Aversion;
        Vision;
        Jailt=0;
        Can_Move = true;
        Pers_Legitimacy;
        Effectiveness=1;
        Is_Active = false;
    end

    methods
        function obj = Agent(H, R, V, Leg, E)
            % class constructor
            obj.Hardship = H;
            obj.Risk_Aversion = R;
            obj.Vision = V;
            obj.Jailt=0;
            obj.Can_Move=true;
            obj.Pers_Legitimacy = Leg;
            obj.Effectiveness = E;
            obj.Is_Active = false;
        end

        function G = Grievance (this, L)
            G = this.Hardship*(1-min(1, max(0, L+
                this.Pers_Legitimacy)));
        end

        function P = Chance_of_Arrest (this, k, C, A)
            P = 1 - exp(-k*C/A);
        end

        function N = Net_Risk (this, P, J, alpha)
            N = this.Risk_Aversion*P*(J^alpha);
        end

        function N = Get_Type (this)
            N = 'Agent';
        end

        function N = Jailtime (this)
```

```

        N = this.Jailt;
    end
    function this = Set_Jailtime (this, J)
        this.Jailt = J;
    end
    function this = Set_Hardship (this, H)
        this.Hardship = H;
    end
    function b = Moveable (this)
        b = this.Can_Move;
    end
    function this = Set_Move (this, b)
        this.Can_Move = b;
    end
    function b = Active (this)
        b = this.Is_Active;
    end
    function this = Set_Active (this, b)
        this.Is_Active = b;
    end
end
end

```

Listing from source file Cop.m

Listing 2: Cop

```

classdef Cop
    %Person Summary of AGENT
    % Detailed explanation goes here

    properties
        Vision;
        Can_Move = true;
        Pers_Legitimacy;
        Effectiveness=1;
    end

    methods
        function obj = Cop(V, Leg, E)
            % class constructor
            obj.Vision = V;
            obj.Can_Move=true;
            obj.Pers_Legitimacy = Leg;
            obj.Effectiveness = E;
        end
        function N = Get_Type (this)
    end
end

```

```

        N = 'Cop';
    end
    function b = Moveable (this)
        b = this.Can_Move;
    end
    function this = Set_Move (this , b)
        this.Can_Move = b;
    end
end
end

```

Listing from source file `Display.m`

Listing 3: Display

```

%    FIX VALUES, CHANGE THESE IF NECESSARY

clear all;

side = 40;
%Side of the playfield

L = 0.9;
%Legitimacy of the Regime

O_to_U_Ratio = 0.5;
%Occupied Spaces to Unoccupied Spaces

C_to_A_Ratio = 0.1;
%Cops to Agents Ratio

Jailterm_Min = 3;
%Jailterm in Years

Jailterm_Max = 5;
%Jailterm in Years

Jailsentence = @( ) random( 'Uniform' , Jailterm_Min , Jailterm_Max , 1 , 1 );
%Jailsentence = @(x, y) random( 'Uniform' , x , y , 1 , 1 );

Better_Deterrent_of_Jailtime = 0;
%In Paper alpha=0

Better_Aggraviance_when_Agent_leaves_Jail = false;
Aggraviance = @( ) random( 'Uniform' , -0.5 , 0.5 , 1 , 1 );

Activism_Threshold = 0.1;

```

```

%If Grievance - Net Risk > Activism_Threshold -> Agent is active

Murder_threshold =1;
Murder_success_rate = 0.0;
Murder_assasin_death_rate = 0.0;
%If Grievance - Net Risk > Murder_threshold -> Agent kills Cops

Vision_Min_Cops = 6;
Vision_Max_Cops = 10;
Vision_Min_Agent = 6;
Vision_Max_Agent = 10;

Death = false;
Agent_Death_Chance = 0.0;
Agent_Death_Legitimacy_Penalty = 0.02;
Cop_Death_Chance = 0.00;
Cop_Death_Legitimacy_Boost = 0.03;
%Agents and Cops can die in Confrontations

Important_Land = false;
%Some spots of land are important
ID = 210;
Importance = 0;
ImportantFields{1} = Field(ID, Importance);

Important_People = false;
Important_Chance_Agents = 0.0;
Important_Effectiveness_Agents = 5;
Important_Chance_Cops = 0.0;
Important_Effectiveness_Cops = 5;
%Some people are important
%Important Agents count as "more" Agents, effectively making
%others rebell
%Important Cops count as "more" Cops, effectively silencing
%protest.
%Important People have extended Vision

Defective_Cops = false;
Legitimacy_Mod_Cop = 0.0;
Legitimacy_Threshold_Stop = 0.0;
Legitimacy_Threshold_Defect = 0.0;
%If a Cop's view of the Legitimacy drops too low, he may
%stop arresting, or defect.

Better_Legitimacy = false;
Legitimacy_Mod = 0.0;
%Agents all have a personal Legitimacy Modifier, which modifies
%the global Legitimacy.

```

```

Each_Round_Legitimacy_Change = 0;

One_Time_Change = true;
One_Time_Legitimacy_Change = -0.3;
round_for_One_Time_Legitimacy_Change = 10;

Number_of_Frames = 30;
%Number of Rounds

Plot_every_X_Frames = 5;
%Only plot some of the rounds (1=Plot every Round)

k = 2.3;
%Constant so that 0.9 = 1 - exp(-k), see Paper

%Statistical Analysis
%AllReleases = [];
%AllAgentMoves = [];
%AllCopMoves = [];

    % First, we need to generate a Problem
    % OY, KEEP HANDS AWAY FROM CODE!

x = zeros(1, side*side+3);
y = zeros(1, side*side+3);

Prison{1} = Empty();

Colors_Attitude = zeros(1, side*side+3);
Colors_Activism = zeros(1, side*side+3);

for i=1:1:side

    for j=1:1:side

        x((i-1)*side + j) = i;
        y((i-1)*side + j) = j;

    if random('Uniform',0,1,1,1) > 1/(O_to_U_Ratio+1)

        if random('Uniform',0,1,1,1) > 1/(C_to_A_Ratio+1)
            %Cop
            V = floor(random('Uniform',Vision_Min_Cops,
                Vision_Max_Cops,1,1));
            if Defective_Cops

```

```

        Leg = random( 'Uniform' , -Legitimacy_Mod_Cop ,
            Legitimacy_Mod_Cop , 1 , 1 );
    else
        Leg = 0;
    end
    if random( 'Uniform' , 0 , 1 , 1 , 1 ) <
        Important_Chance_Cops
        E = Important_Effectiveness_Cops ;
        V = V*Important_Effectiveness_Cops ;
    else
        E = 1;
    end
    Playfield {(i-1)*side + j} = Cop(V, Leg, E);
else
    %Agent
    H = random( 'Uniform' , 0 , 1 , 1 , 1 );
    R = random( 'Uniform' , 0 , 1 , 1 , 1 );
    V = floor( random( 'Uniform' , Vision_Min_Agent ,
        Vision_Max_Agent , 1 , 1 ));
    if Better_Legitimacy
        Leg = random( 'Uniform' , -Legitimacy_Mod ,
            Legitimacy_Mod , 1 , 1 );
    else
        Leg = 0;
    end
    if random( 'Uniform' , 0 , 1 , 1 , 1 ) <
        Important_Chance_Agents
        E = Important_Effectiveness_Agents ;
        V = V*Important_Effectiveness_Agents ;
    else
        E = 1;
    end
    Playfield {(i-1)*side + j} = Agent(H, R, V, Leg, E);
end
else
    Playfield {(i-1)*side + j} = Empty();
end
end
end

%Dirty Hack for correct Colors
x(side*side+1) = -5;
x(side*side+2) = -5;
x(side*side+3) = -5;
y(side*side+1) = -5;

```

```

y(side*side+2) = -5;
y(side*side+3) = -5;
Colors_Attitude(side*side+1) = -5;
Colors_Attitude(side*side+2) = -3;
Colors_Attitude(side*side+3) = 1;
Colors_Activism(side*side+1) = -5;
Colors_Activism(side*side+2) = -3;
Colors_Activism(side*side+3) = 1;
    %    Then, we solve it!

%fig1=figure(1);
%winsize = get(fig1, 'Position ');
%winsize(1:2) = [0 0];

%Movie =moviein(Number_of_Frames,fig1,winsize);
%set(fig1, 'NextPlot ', 'replacechildren ');

Active_Agents_Array = zeros(1, Number_of_Frames);
Inactive_Agents_Array = zeros(1, Number_of_Frames);
Active_Cops_Array = zeros(1, Number_of_Frames);
Inactive_Cops_Array = zeros(1, Number_of_Frames);
Defected_Cops_Array = zeros(1, Number_of_Frames);
Murdered_Cops_Array = zeros(1, Number_of_Frames);

Prison_Population_Array = zeros(1, Number_of_Frames);
Legitimacy_Array = zeros(1, Number_of_Frames);

g = 0;
first=true;
figurecounter=1;

for h=1:Number_of_Frames

    %legitimicy-drop

    if (One_Time_Change &&
        h==round_for_One_Time_Legitimacy_Change)
        L =L + One_Time_Legitimacy_Change;
    end

    %Reset Moves

    for j=1:1:side*side
        A = Playfield{j};

        if strcmp(A.Get_Type(), 'Agent') ||
            strcmp(A.Get_Type(), 'Cop')

```



```

        A = A.Set_Move(true);

        Playfield{j} = A;

    end
end

% Release imprisoned

Prison_Population = 0;

for i=2:1:length(Prison)

    A = Prison{i};

    if strcmp(A.Get_Type(), 'Agent')

        A = A.Set_Jailtime(A.Jailtime() - 1);

        if A.Jailtime() <= 0
            A = A.Set_Jailtime(0);
            A = A.Set_Hardship(max(0, min(1, A.Hardship +
                Aggreivance())));

            EmptyFields = [];

            for j=1:1:side*side
                % Get all Empty Places
                if strcmp(Playfield{j}.Get_Type(), 'Empty')
                    EmptyFields(length(EmptyFields)+1) = j;
                end
            end

            EmptyFields = EmptyFields( randperm(
                length(EmptyFields)) );

            Release = select_field( EmptyFields,
                ImportantFields, side );
            %AllReleases(length(AllReleases)+1) = Release;

            Playfield{Release} = A;           %Actual Move
            Prison{i} = Empty();

        else

            Prison{i} = A;
            Prison_Population = Prison_Population + 1;
        end
    end
end

```

```

        end

    end
end

Prison_Population_Array(h) = Prison_Population;

%Move Cops / Agents

for i=1:1:side

    for j=1:1:side

        A = Playfield {(i-1)*side + j};

        if Defective_Cops && strcmp(A.Get_Type(), 'Cop')
            && A.Moveable() && L + A.Pers_Legitimacy <
                Legitimacy_Threshold_Defect
            %Check if Cop, and if he defects now
            H = random('Uniform',0,1,1,1);
            R = random('Uniform',0,1,1,1);
            A = Agent(H, R, A.Vision, A.Pers_Legitimacy,
                A.Effectiveness);
            Playfield {(i-1)*side + j} = A;

            Defected_Cops_Array(h) =
                Defected_Cops_Array(h)+1;
        end

        if (strcmp(A.Get_Type(), 'Agent') ||
            strcmp(A.Get_Type(), 'Cop')) && A.Moveable()

            %Move to unoccupied space, check if active

            AgentFields = [];

            if strcmp(A.Get_Type(), 'Cop') && (L +
                A.Pers_Legitimacy >
                Legitimacy_Threshold_Stop ||
                Defective_Cops == false) ||
                strcmp(A.Get_Type(), 'Agent') &&
                A.Grievance(L) > Murder_threshold
                %We have an active Cop, search for
                %active Agents for Arrest
                for k=1:1:A.Vision
                    % Get all agent Places

```

```

        if i > k && strcmp(
            Playfield{(i-1-k)*side + j}.
            Get_Type(), 'Agent') &&
            Playfield{(i-1-k)*side + j}.Is_Active
            AgentFields(length(AgentFields)+1)
                = (i-1-k)*side + j;
        end
        if i <= side-k && strcmp(
            Playfield{(i-1+k)*side + j}.
            Get_Type(), 'Agent') &&
            Playfield{(i-1+k)*side + j}.
            Is_Active
            AgentFields(length(AgentFields)+1)
                = (i-1+k)*side + j;
        end
        if j > k && strcmp(
            Playfield{(i-1)*side + j-k}.
            Get_Type(), 'Agent') &&
            Playfield{(i-1)*side + j-k}.
            Is_Active
            AgentFields(length(AgentFields)+1)
                = (i-1)*side + j-k;
        end
        if j <= side-k && strcmp(
            Playfield{(i-1)*side + j+k}.
            Get_Type(), 'Agent') &&
            Playfield{(i-1)*side + j+k}.
            Is_Active
            AgentFields(length(AgentFields)+1)
                = (i-1)*side + j+k;
        end
        AgentFields = AgentFields( randperm(
            length(AgentFields)) );
    end

    EmptyFields = [];

    if strcmp(A.Get_Type(), 'Agent') ||
        (strcmp(A.Get_Type(), 'Cop') &&
        length(AgentFields) == 0)
        %We have an Agent or a Cop who can't find
        %Agents to Arrest -> wander aimlessly
        for k=1:1:A.Vision
            % Get all Empty Places
            if i > k && strcmp(
                Playfield{(i-1-k)*side + j}.
                Get_Type(), 'Empty')

```

```

        EmptyFields(length(EmptyFields)+1)
            = (i-1-k)*side + j;
    end
    if i <= side-k && strcmp(
        Playfield{(i-1+k)*side + j}.
        Get_Type(), 'Empty')
        EmptyFields(length(EmptyFields)+1)
            = (i-1+k)*side + j;
    end
    if j > k && strcmp(
        Playfield{(i-1)*side + j-k}.
        Get_Type(), 'Empty')
        EmptyFields(length(EmptyFields)+1)
            = (i-1)*side + j-k;
    end
    if j <= side-k && strcmp(
        Playfield{(i-1)*side + j+k}.
        Get_Type(), 'Empty')
        EmptyFields(length(EmptyFields)+1)
            = (i-1)*side + j+k;
    end
    end
    EmptyFields = EmptyFields( randperm(
        length(EmptyFields)) );
end

CopFields = [];

if strcmp(A.Get_Type(), 'Agent') &&
    A.Grievance(L) > Murder_threshold
    %We have an Agent that is ready to kill,
    %search Assassination targets
    for k=1:1:A.Vision
        % Get all Empty Places
        if i > k && strcmp(
            Playfield{(i-1-k)*side + j}.
            Get_Type(), 'Cop')
            CopFields(length(CopFields)+1)
                = (i-1-k)*side + j;
        end
        if i <= side-k && strcmp(
            Playfield{(i-1+k)*side + j}.
            Get_Type(), 'Cop')
            CopFields(length(CopFields)+1)
                = (i-1+k)*side + j;
        end
        if j > k && strcmp(
            Playfield{(i-1)*side + j-k}.

```

```

        Get_Type(), 'Cop')
        CopFields(length(CopFields)+1)
            = (i-1)*side + j-k;
    end
    if j <= side-k && strcmp(
        Playfield{(i-1)*side + j+k}.
        Get_Type(), 'Cop')
        CopFields(length(CopFields)+1)
            = (i-1)*side + j+k;
    end
end

CopFields = CopFields( randperm(
    length(CopFields)) );
end

if strcmp(A.Get_Type(), 'Cop') &&
    length(AgentFields) >= 1
    %Our Cop has found some Agents to Arrest
    if random('Uniform',0,1,1,1) <
        Agent_Death_Chance
        %HE tried to arrest an Agent, but the
        %Agent died.
        L = L - Agent_Death_Legitimacy_Penalty;
        Arrest = select_field(AgentFields,
            ImportantFields, side );

        A = A.Set_Move(false);

        Playfield{(i-1)*side + j} = Empty();
        Playfield{Arrest} = A;
        %Free Cell
    elseif random('Uniform',0,1,1,1) <
        Cop_Death_Chance
        %He tried to arrest an Agent, but the
        %Cop died.
        L = L + Cop_Death_Legitimacy_Boost;
        Playfield{(i-1)*side + j} = Empty();
    else
        %Arrest successful
        Arrest = select_field( AgentFields,
            ImportantFields, side );
        ArrestedAgent = Playfield{Arrest};
        ArrestedAgent = ArrestedAgent.
        Set_Jailtime(Jailsentence());
        Prison{length(Prison)+1} =
            ArrestedAgent;
        %Jail
    end
end

```

```

        A = A.Set_Move( false );

        Playfield{(i-1)*side + j} = Empty();
        Playfield{Arrest} = A;
        %Free Cell
    end

    %AllCopMoves( length( AllCopMoves)+1) =
    %Arrest;

elseif length( CopFields) >= 1 && A.Grievance(L)
- A.Net_Risk( A.Chance_of_Arrest(k,
length( CopFields), length( AgentFields)),
Jailterm_Max, Better_Deterrent_of_Jailtime) >
Murder_threshold && random( 'Uniform',0,1,1,1)
< Murder_success_rate
    %Our Agent successfully murders a Cop
    GoTo = select_field( CopFields,
        ImportantFields, side );

    A = A.Set_Move( false );

    %AllAgentMoves( length( AllAgentMoves)+1) =
    %GoTo;

    Playfield{(i-1)*side + j} = Empty();
    Playfield{GoTo} = A;
    %Actual Move

    Murdered_Cops_Array(h) =
        Murdered_Cops_Array(h)+1;
elseif length( CopFields) >= 1 &&
    random( 'Uniform',0,1,1,1) >
    Murder_success_rate &&
    random( 'Uniform',0,1,1,1) <
    Murder_assasin_death_rate
    %Our Agent tries to murder a Cop,
    %but dies in the process
    Playfield{(i-1)*side + j} = Empty();
elseif length( EmptyFields) >= 1
    %Wander aimlessly
    GoTo = select_field( EmptyFields,
        ImportantFields, side );

    A = A.Set_Move( false );

    %AllAgentMoves( length( AllAgentMoves)+1) =

```

```

                                %GoTo;

                                Playfield{(i-1)*side + j} = Empty();
                                Playfield{GoTo} = A;                                %Actual Move
                                end

                                else
                                %Empty Square, do nothing
                                end

                                end

                                end

                                end

                                % Accomplish Actions for Agents & Cops
                                Active_Agents= 0;
                                Inactive_Agents = 0;
                                Active_Cops = 0;
                                Inactive_Cops = 0;

                                for i=1:1:side

                                for j=1:1:side

                                A = Playfield{(i-1)*side + j};

                                if strcmp(A.Get_Type(), 'Agent')

                                Cops = 0;
                                Agents = 1;

                                for k=1:1:A.Vision

                                if i > k && strcmp(
                                    Playfield{(i-1)*side + j - k*side}.
                                    Get_Type(), 'Agent')
                                    Agents = Agents+
                                        Playfield{(i-1)*side + j - k*side}.
                                        Effectiveness;
                                elseif i > k && strcmp(
                                    Playfield{(i-1)*side + j - k*side}.
                                    Get_Type(), 'Cop')
                                    Cops = Cops+
                                        Playfield{(i-1)*side + j - k*side}.
                                        Effectiveness;
                                end
                                if i <= side-k && strcmp(

```

```

        Playfield{(i-1)*side + j + k*side}.
        Get_Type(), 'Agent')
        Agents = Agents+
            Playfield{(i-1)*side + j + k*side}.
            Effectiveness;
    elseif i <= side-k && strcmp(
        Playfield{(i-1)*side + j + k*side}.
        Get_Type(), 'Cop')
        Cops = Cops+
            Playfield{(i-1)*side + j + k*side}.
            Effectiveness;
    end
    if j > k && strcmp(
        Playfield{(i-1)*side + j - k}.
        Get_Type(), 'Agent')
        Agents = Agents+
            Playfield{(i-1)*side + j - k}.
            Effectiveness;
    elseif j > k && strcmp(
        Playfield{(i-1)*side + j - k}.
        Get_Type(), 'Cop')
        Cops = Cops+
            Playfield{(i-1)*side + j - k}.
            Effectiveness;
    end
    if j <= side-k && strcmp(
        Playfield{(i-1)*side + j + k}.
        Get_Type(), 'Agent')
        Agents = Agents+
            Playfield{(i-1)*side + j + k}.
            Effectiveness;
    elseif j <= side-k && strcmp(
        Playfield{(i-1)*side + j + k}.
        Get_Type(), 'Cop')
        Cops = Cops+
            Playfield{(i-1)*side + j + k}.
            Effectiveness;
    end
end

end

Colors_Attitude((i-1)*side + j) = max(-1,
    A.Grievance(L) - A.Net_Risk(A.
        Chance_of_Arrest(k, Cops, Agents),
        Jailterm_Max, Better_Deterrent_of_Jailtime));
if A.Grievance(L) - A.Net_Risk(A.Chance_of_Arrest(
    k, Cops, Agents), Jailterm_Max,
    Better_Deterrent_of_Jailtime) >

```



```

        Activism_Threshold
        Colors_Activism((i-1)*side + j) = 1;
        A = A.Set_Active(true);
        Playfield{(i-1)*side + j} = A;

        Active_Agents = Active_Agents + 1;
    else
        Colors_Activism((i-1)*side + j) = 0;

        Inactive_Agents = Inactive_Agents + 1;
    end

elseif strcmp(A.Get_Type(), 'Cop')

    Colors_Attitude((i-1)*side + j) = -5;
    Colors_Activism((i-1)*side + j) = -5;

    if (L + A.Pers_Legitimacy >
        Legitimacy_Threshold_Stop ||
        Defective_Cops == false)
        Active_Cops = Active_Cops + 1;
    else
        Inactive_Cops = Inactive_Cops + 1;
    end

else

    Colors_Attitude((i-1)*side + j) = -3;
    Colors_Activism((i-1)*side + j) = -3;

end

end

end

Active_Agents_Array(h) = Active_Agents;
Inactive_Agents_Array(h) = Inactive_Agents;
Active_Cops_Array(h) = Active_Cops;
Inactive_Cops_Array(h) = Inactive_Cops;
Legitimacy_Array(h) = L;

L = max(0, min(1, L + Each_Round_Legitimacy_Change));

%Provide Feedback
h

if g == 0

```

```

    figx=figure(figurecounter);
    figurecounter = figurecounter+1;
    axes;
    scatter(x, y, 150, Colors_Attitude, 's', 'filled');
    legend([ 'Attitude_Round', num2str(h), 10,
            'Dark_Blue==Cops', 10, 'Light_Blue==Empty', 10,
            'Red==Agents, the darker the worse the Attitude',
            10,10, 'Active_Agents==', num2str(Active_Agents),
            10, 'Inactive_Agents==', num2str(Inactive_Agents),
            10, 'Active_Cops==', num2str(Active_Cops)] ,
            'Location','SouthOutside');
    axis([0 side+1 0 side+1]);

    figx=figure(figurecounter);
    figurecounter = figurecounter+1;
    axes;
    scatter(x, y, 150, Colors_Activism, 's', 'filled');
    legend([ 'Activism_Round', num2str(h), 10,
            'Dark_Blue==Cops', 10, 'Light_Blue==Empty', 10,
            'Red==Active_Agents', 10,
            'Light_Red==Inactive_Agents', 10,10,
            'Active_Agents==', num2str(Active_Agents), 10,
            'Inactive_Agents==', num2str(Inactive_Agents), 10,
            'Active_Cops==', num2str(Active_Cops)] ,
            'Location','SouthOutside');
    axis([0 side+1 0 side+1]);
    %Movie(:,i)=getframe(fig1, winsize);

    if h == 1 && Plot_every_X_Frames > 1
        g=Plot_every_X_Frames-1;
    else
        g=Plot_every_X_Frames;
    end
end

    g=g-1;

end

figx=figure(figurecounter);
figurecounter = figurecounter+1;
plot(1:Number_of_Frames, Active_Agents_Array);
axis([1 Number_of_Frames 0 side^2*(1-1/(O_to_U_Ratio+1))]);
legend('Active_Agents' , 'Location', 'SouthOutside');

figx=figure(figurecounter);
figurecounter = figurecounter+1;

```

```

plot (1: Number_of_Frames , Inactive_Agents_Array );
axis ([1 Number_of_Frames 0 side ^2*(1-1/(O_to_U_Ratio+1))]);
legend ( 'Inactive_Agents' , 'Location' , 'SouthOutside' );

figx=figure (figurecounter);
figurecounter = figurecounter+1;
plot (1: Number_of_Frames , Prison_Population_Array );
axis ([1 Number_of_Frames 0 side ^2*(1-1/(O_to_U_Ratio+1))]);
legend ( 'Imprisoned_Agents' , 'Location' , 'SouthOutside' );

%figx=figure (figurecounter);
%figurecounter = figurecounter+1;
%plot (1: Number_of_Frames , Active_Cops_Array );
%axis ([1 Number_of_Frames 0 side ^2*(1-1/(O_to_U_Ratio+1))]);
%legend ( 'Active Cops' , 'Location' , 'SouthOutside' );

%figx=figure (figurecounter);
%figurecounter = figurecounter+1;
%plot (1: Number_of_Frames , Inactive_Cops_Array );
%axis ([1 Number_of_Frames 0 side ^2*(1-1/(O_to_U_Ratio+1))]);
%legend ( 'Inactive Cops' , 'Location' , 'SouthOutside' );

%figx=figure (figurecounter);
%figurecounter = figurecounter+1;
%plot (1: Number_of_Frames , Defected_Cops_Array );
%axis ([1 Number_of_Frames 0 side ^2*(1-1/(O_to_U_Ratio+1))/25]);
%legend ( 'Defected Cops' , 'Location' , 'SouthOutside' );

%figx=figure (figurecounter);
%figurecounter = figurecounter+1;
%plot (1: Number_of_Frames , Murdered_Cops_Array );
%axis ([1 Number_of_Frames 0 side ^2*(1-1/(O_to_U_Ratio+1))/100]);
%legend ( 'Murdered Cops' , 'Location' , 'SouthOutside' );

figx=figure (figurecounter);
figurecounter = figurecounter+1;
plot (1: Number_of_Frames , Legitimacy_Array );
axis ([1 Number_of_Frames 0 1]);
legend ( 'Legitimacy' , 'Location' , 'SouthOutside' );

```

Listing from source file `Displaycentre.m`, changes only

Listing 4: Display

```

side = 40;
L = 0.8;
O_to_U_Ratio = 0.7;
C_to_A_Ratio = 0;

```

```

Jailterm_Min = 3;
Jailterm_Max = 6;
Jailsentence = @( ) random( 'Uniform' , Jailterm_Min , Jailterm_Max , 1 , 1 );
Better_Deterrent_of_Jailtime = 0;
Better_Aggreviance_when_Agent_leaves_Jail = false ;
Aggreviance = @( ) random( 'Uniform' , -0.5 , 0.5 , 1 , 1 );
Activism_Threshold = 0.1;
Murder_threshold = 1;
Murder_success_rate = 0.0;
Murder_assasin_death_rate = 0.0;
Vision_Min_Cops = 1;
Vision_Max_Cops = 3;
Vision_Min_Agent = 1;
Vision_Max_Agent = 3;
Death = false ;
Agent_Death_Chance = 0.0;
Agent_Death_Legitimacy_Penalty = 0.02;
Cop_Death_Chance = 0.00;
Cop_Death_Legitimacy_Boost = 0.03;
Important_Land = false ;
ID = 210;
Importance = 0;
ImportantFields{1} = Field(ID, Importance);
Important_People = false ;
Important_Chance_Agents = 0.0;
Important_Effectiveness_Agents = 5;
Important_Chance_Cops = 0.0;
Important_Effectiveness_Cops = 5;
Defective_Cops = false ;
Legitimacy_Mod_Cop = 0.0;
Legitimacy_Threshold_Stop = 0.0;
Legitimacy_Threshold_Defect = 0.0;
Better_Legitimacy = false ;
Legitimacy_Mod = 0.0;
Each_Round_Legitimacy_Change = 0;
Number_of_Frames=200;
Plot_every_X_Frames=67;

for i=17:1:23
    for j=17:1:23
        V = floor( random( 'Uniform' , Vision_Min_Cops , Vision_Max_Cops ,
            1 , 1 ));
            if Defective_Cops
                Leg = random( 'Uniform' , -Legitimacy_Mod_Cop ,
                    Legitimacy_Mod_Cop , 1 , 1 );
            else
                Leg = 0;
            end
    end
end

```

```

        if random('Uniform',0,1,1,1) < Important_Chance_Cops
            E = Important_Effectiveness_Cops;
            V = V*Important_Effectiveness_Cops;
        else
            E = 1;
        end
        Playfield{(i-1)*side + j} = Cop(V, Leg, E);
    end
end

```

Listing from source file `Displayline.m`, changes only

Listing 5: Display

```

side = 40;
L = 0.8;
O_to_U_Ratio = 0.7;
C_to_A_Ratio = 0.00;
Jailterm_Min = 3;
Jailterm_Max = 5;
Jailsentence = @( ) random('Uniform',Jailterm_Min,Jailterm_Max,1,1);
Better_Deterrent_of_Jailtime = 0;
Better_Aggreivance_when_Agent_leaves_Jail = false;
Aggreivance = @( ) random('Uniform',-0.5,0.5,1,1);
Activism_Threshold = 0.1;
Murder_threshold = 1;
Murder_success_rate = 0.0;
Murder_assasin_death_rate = 0.0;
Vision_Min_Cops = 1;
Vision_Max_Cops = 3;
Vision_Min_Agent = 1;
Vision_Max_Agent = 3;
Death = false;
Agent_Death_Chance = 0.0;
Agent_Death_Legitimacy_Penalty = 0.02;
Cop_Death_Chance = 0.00;
Cop_Death_Legitimacy_Boost = 0.03;
Important_Land = false;
ID = 210;
Importance = 0;
ImportantFields{1} = Field(ID, Importance);
Important_People = false;
Important_Chance_Agents = 0.0;
Important_Effectiveness_Agents = 5;
Important_Chance_Cops = 0.0;
Important_Effectiveness_Cops = 5;
Defective_Cops = false;
Legitimacy_Mod_Cop = 0.0;

```

```

Legitimacy_Threshold_Stop = 0.0;
Legitimacy_Threshold_Defect = 0.0;
Better_Legitimacy = false;
Legitimacy_Mod = 0.0;
Each_Round_Legitimacy_Change = 0;
Number_of_Frames = 200;
Plot_every_X_Frames = 50;

for i=20:1:20
    for j=1:1:40
        V = floor(random( 'Uniform' , Vision_Min_Cops , Vision_Max_Cops ,
            1,1));
        if Defective_Cops
            Leg = random( 'Uniform' , -Legitimacy_Mod_Cop ,
                Legitimacy_Mod_Cop , 1 , 1);
        else
            Leg = 0;
        end
        if random( 'Uniform' , 0,1,1,1) < Important_Chance_Cops
            E = Important_Effectiveness_Cops;
            V = V*Important_Effectiveness_Cops;
        else
            E = 1;
        end
        Playfield {(i-1)*side + j} = Cop(V, Leg, E);
    end
end
end

```

Listing from source file `Empty.m`

Listing 6: Empty

```

classdef Empty
    %Person Summary of EMPTY
    % Detailed explanation goes here

    properties
        Vision=0;
    end

    methods
        function obj = Empty()
            % class constructor
            Vision = 0;
        end

        function N = Get_Type (this)
            N = 'Empty';
        end
    end
end

```

```

        end
    end
end

```

Listing from source file `Field.m`

Listing 7: Field

```

classdef Field
    %Person Summary of FIELD
    % Detailed explanation goes here

    properties
        Importance = 0;
        ID;
    end

    methods
        function obj = Field(d, I)
            % class constructor
            obj.ID = d;
            obj.Importance = I;
        end
    end
end

```

Listing from source file `select_field.m`

Listing 8: `select_field`

```

function field = select_field( fields, important_places, side )
% SelectField Summary of this function goes here
% Detailed explanation goes here

%field = fields( round(random('Uniform',0.5,length(fields)+
%0.499,1,1)) );
maxfield = 0;
maximportance = 0;

for i=1:length(fields)

    i_y = ceil(fields(i)/side);
    i_x = fields(i) - ((i_y-1) * side);

    for j=1:length(important_places)
        j_y = ceil(important_places{j}.ID/side);
    end
end

```

```

        j_x = important_places{j}.ID - ((j_y-1) * side);

        importance = 1/sqrt((i_y - j_y)^2 + (i_x - j_x)^2 +
            1) * important_places{j}.Importance;

        if (importance >= maximportance)
            maximportance = importance;
            maxfield = i;
        end
    end
end

field = fields(maxfield);

end

```