Miguel, Amblard, Barceló & Madella (eds.) Advances in Computational Social Science and Social Simulation
Barcelona: Autònoma University of Barcelona, 2014, DDD repository <http://ddd.uab.cat/record/125597>

Rise, Fall and Abandonment in the Zambezi Plateau: An Agent-Based Model using the Canonical Theory

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***Abstract*—The Zambezi plateau region in Southern Africa has seen the rise and fall other several polities of different levels of complexity for many centuries before the arrival of Europeans and the beginning of the region's written history. One of the enduring questions this work raises is to explain the rise, fall and abandonment of large polities centered around large edifices with massive stone walls called "zimbabwes." The agent-based model presented here provides support for an explanation based on the Canonical Theory. In this theory, a succession of opportunities to engage in collective action by a polity strengthens or weakens the complexity of the polity. The main finding presented in the agent-based model is that group dynamics, centered on the collective feelings of loyalty to the group, can generate the macro level behavior that we see in the archeological record of Southern Africa.**

I. Introduction

THE MOTIVATION for this model is to explore how the Canonical "Fast Process" [1] can lead to polities dissolving with people moving to join larger, more advanced groupings.This process of abandonment exists in the archeological record of the Zambezi Plateau in present-day Zimbabwe.The process of abandonment is significant, especially in the case of the Zambezi Plateau, for two reasons: 1) it is important to establish how the first state-level polity in Africa came to be and why it disappeared, and 2) the abandonment and subsequent condition of Great Zimbabwe carries great weight in historical and modern Southern Africa [2, p. 771].

The walled enclosure of Great Zimbabwe supported a capital city for roughly 200 years, from 1275 CE to 1450 CE, based on the presence and absence of imported Chinese ceramics in the archeological record [3, p. 68]. After this date, Chinese blue-on-white porcelain is not found at Great Zimbabwe, but it is found at other important centers in Zimbabwe before and after this date. It is important to note that Collett, et al. disagree with Huffman on this point due to the presence of a large blue-on-white porcelain piece from the Ming Dynasty, 1488-1505 CE that is possibly related to Great Zimbabwe [4, p. 157]. However, Collett, et al. still use the term "abandoned" to describe Great Zimbabwe [4, p. 140].

Great Zimbabwe was not the first or only significant polity in the Zambezi Plateau. Pikirayi notes that prior to Great Zimbabwe, Mapungubwe "attained regional prominence during the thirteenth century, managing the resources of a territory that was equivalent to a state in both political and economic terms" [5, p. 3]. After the fall of Great Zimbabwe, the so-called "Zimbabwe Culture", "…marked by the presence of massive stone walls built in a variety of architectural styles," split into the northern and southwestern regions [5, p. 2-3].

Kim and Kusimba note that the first agrarian communities of the Zambezi plateau date to the first millenium CE and that "[t]he landscape …was dotted with temporary rockshelter settlements, semi-sedentary camps villages, and permanent settlements" [6, p. 137].

As can be seen, the sites of the Zambezi plateau have been the subject of significant archeological research; however, it has still been difficult to provide a theory of why this pattern of rise, fall and abandonment has occurred within the area. For example, Great Zimbabwe existed as a capital for a relatively short period of time, and when that period was over, it was seemingly cut off from receiving imports that had been coming to it from China. And rather than becoming a regional capital, or a noncapital, but still significant city, the site is treated as abandoned. This view of Great Zimbabwe helps explain how from the Portuguese arrival, which begins the written historical record, until the beginning of the twentieth century, there is a question of whether the site was even created by Africans [4, p. 140]. Even in the current day the site of Great Zimbabwe is treated with a distant reverence reserved for a hallowed, but forgotten place [2].

This paper examines how the Canonical Theory can provide an overarching theory to explain the process of rise and abandonment within the Zambezi plateau. This process can be explained by examining the interplay between group leadership and group loyalty during times of stress within the group. In this paper, I will present an agent-based model based on the Canonical Process that demonstrates how a social environment can evolve from something like what existed in the Zambezi plateau in the first millenium CE through the progression of larger and larger groupings. These larger groupings come about through a process of group dispersal by the individual agents, which serves as the significant collective action by the group.

II. Methodology

A. Agent-Based Model of Canonical Process

The methodology of this paper is based on the building and analysis of an agent-based model. In particular, the model was developed to implement a process for explaining the rise of social complexity called the Canonical Theory [1]. This theory describes a branching process that polities go through, where the polity follows particular branches when it experiences opportunities for collective action. As these opportunities come up again and again, the choices made by the polity can lead to greater, or lesser social complexity when examined on a longer time scale [1, p.138]. This "recursive" process [1, p.138] can happen relatively quickly, but the results and effects of it accumulate over time. This is key to the Canonical Theory which terms these the "fast" and "slow" processes [1, p.138].

The Canonical Theory provides a framework that ties together the micro-level activity by people in a society and the macro-level changes that a society goes through over long periods of time. This fits well with the goal of this paper, the examination of how individual-level choices can cause the startling effects that are seen in the archeological record around the rise and abandonment of sites in the Zambezi plateau. An agent-based model was chosen because one of the hallmarks of these types of models is that macro-level behavior in the model comes from the micro-level decisions of individual agents. In the current model, the agents represent individual people. Each individual can join a group of people, and each has a level or amount of two attributes: fealty and leadership. Fealty in this model is a measure of how attached or loyal one feels towards one's group in general and its leadership in particular. Fealty is a measure of attachement in that if it drops too low for the members of the group, they will seek to move onto another group with stronger leadership. All members in a group have a leadership score; however, when group decisions or measurements need to be made, only the individual with the highest leadership score counts as the group leader.

B. Model Details

The model is initialized with 100 groups, each with 50 members. This was chosen to represent a flat, undifferentiated setting as would exist prior to the origin of social complexity in the region. At the start, each agent is given a starting value for fealty and leadership. Both are taken from triangular distributions. Fealty randomly is assigned a value between 0 and 100, with a mode of 50. Leadership is assigned a value between 0 and 50 with a mode of 10. This is done to create an initial setting where high leadership is relatively rarer. Model input parameters set the payoff for an increase or decrease in fealty, which occurs as a result of collective action taken by the group. Runs of the agent-based model were made on a Macbook Pro with 4 processor cores. The model was created with Python 2.7.1 and the model allows for setting the fealty and leadership adjustments as input parameters; however, to clarify analysis, all runs are reported here with the same leadership adjustment parameter.

C. Model Action

The agent-based model runs as event loop where at each clock tick, each group of agents gets a chance to act on one or more of its behaviors. In this model, the event loop starts with the groups each deciding if some collective action should be undertaken. This is left as abstract within the current model. Collective action is "[w]hen a society correctly perceives and understands a given situational change, it may or may not be willing and able to undertake collective action …in response to such a change" [1, p.144]. Specifically, the group will undertake collective action if the average fealty score for the group is below 50. If the average fealty score is below 10, the group will disband and abandon their site, dispersing to other groups. Collective action is successful with differing probabilities depending on the quality of the group's leadership (25% with good leadership, 10% with poor leadership). If collective action is successful, each member's fealty is increased by some (differing) amount If collective action is unsuccessful, fealty for each member is decreased. Furthermore, leadership scores are adjusted as a result of some (but not all) of the collective action attempts.

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III. Results

The most significant result of the model is that the flat, homogenous set of groups quickly coalesce into a small number of much larger groupings, as seen in Fig. 1 and Fig. 2. This happens within the first 18 to 35 steps of the model. The model is set to begin with 100 groups, each with 50 members. Rapidly, this becomes between 1 and 13 groups with an average of between 384 and 5,000 members. No agents are born or die in this model, so the overall population remains the same. The speed with which the change in the model's society happens varies with different input parameters. It is interesting to note that the leadership scores have a positive linear relationship with the size of the group, even though it is only the score of the leader that is counted; that is, leadership scores are not additive among the group. Also, as the average number of groups increases, average fealty increases until between 5 and 6 groups, when average fealty decreases as number of groups get larger.

Additionally, the model shows a particular qualitative behavior in the movement of the average fealty levels during model runs. A fealty value is given to each agent at the start of the model in a triangular distribution between 0 and 100 with a mode of 50. The results from the model show that fealty quickly drops to relatively low values, becomes unstable, then recovers to a high value that stays stable for the rest of the model run. An example of this behavior is seen in Fig. 4. This happens at various beginning parameters and it happens at different speeds. One case behaves differently. Here (see Fig. 3), average fealty falls as before, rises to the starting level, then collapses to a very low value.

As the number of groups declines, the leadership score of the remaining group leaders rise. A leadership value is given to each agent at the start of the model in a triangular distribution between 0 and 100 with a mode of 10. Few agents begin with high leadership scores. However, the successful leaders end model runs with leadership scores orders of magnitude higher than what they started with as in Fig. 5 and Fig. 6. This point can be shown with representative graphs of the evolution of leadership in two groups, a successful one (Fig. 8) and one that disbanded quickly (Fig. 7). These two groups also present representative examples of the change in membership (Fig. 9 and Fig. 10) and the group fealty level (Fig. 11 and Fig. 12).

IV. Discussion

This model demonstrates how a society of disparate, small groups might evolve into one with a few large groups in response to changes in how group member

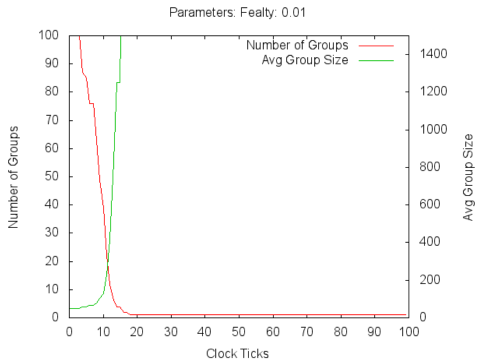

Fig. 1: Input parameters: Fealty, 0.01

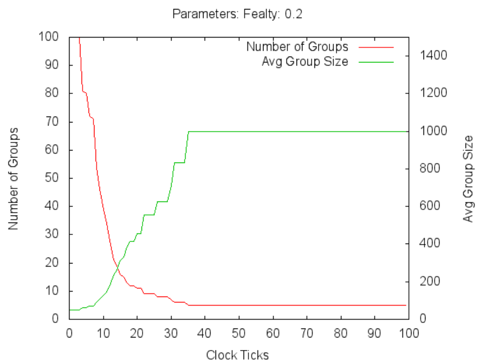

Fig. 2: Input parameters: Fealty, 0.2

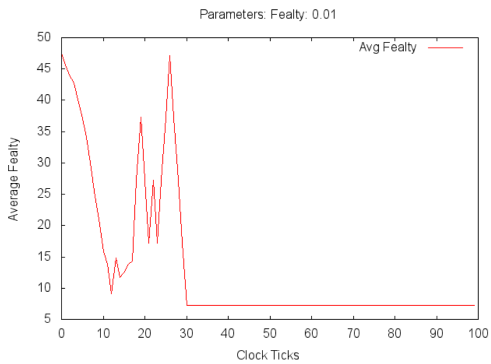

Fig. 3: Input parameters: Fealty, 0.01

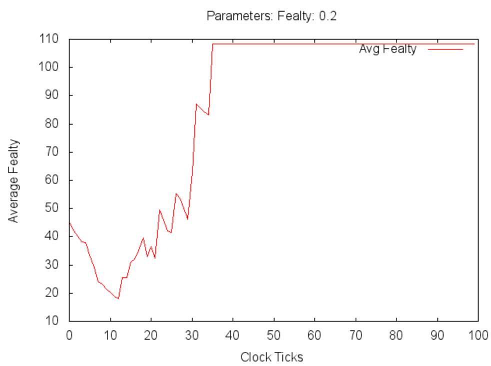

Fig. 4: Input parameters: Fealty, 0.2

TABLE I: Table of Model Results for Representative Fealty Adjustment Amounts

Fealty	Tick	Numb of Groups	Avg Size	Avg Fealty	Leadership Score
0.01	18	1	5000	27.285	5079.352
0.1	31	4	1250	77.730	1281.403
0.2	35	5	1000	108.317	1011.797
0.25	33	13	384	64.488	396.870
0.3	32	12	416	78.023	426.149

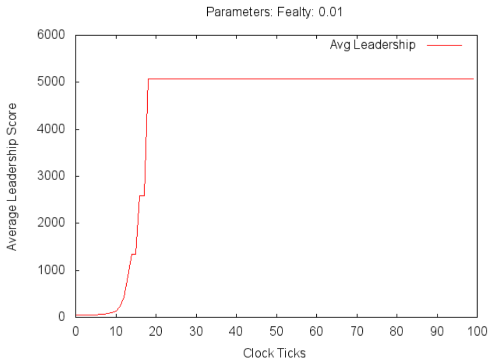

Fig. 5: Input parameters: Fealty, 0.01

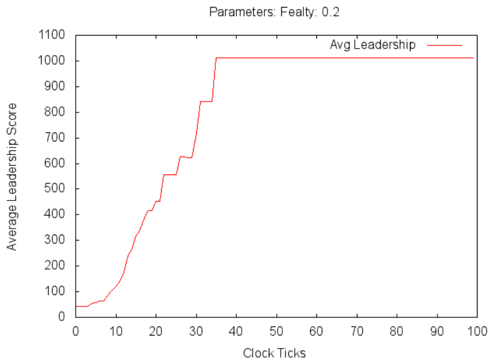

Fig. 6: Input parameters: Fealty, 0.2

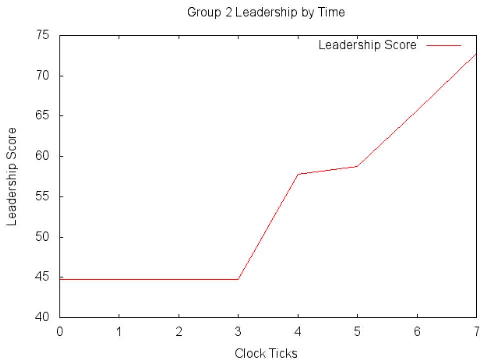

Fig. 7: Input parameters: Fealty, 0.25

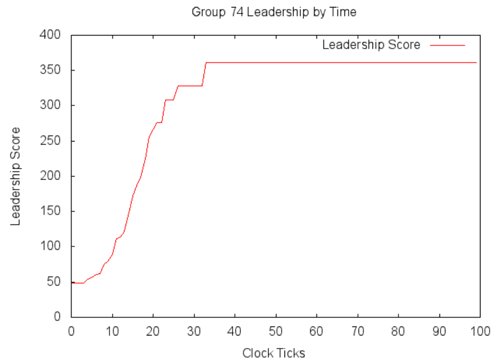

Fig. 8: Input parameters: Fealty, 0.25

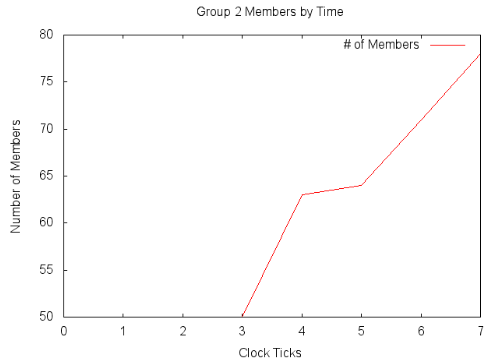

Fig. 9: Input parameters: Fealty, 0.25

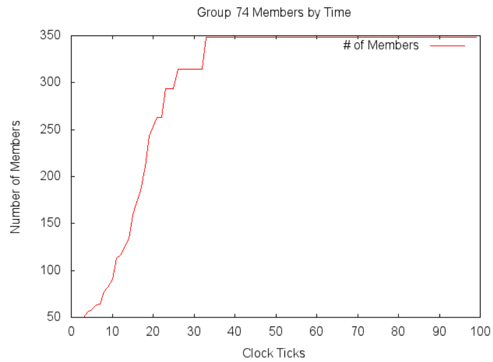

Fig. 10: Input parameters: Fealty, 0.25

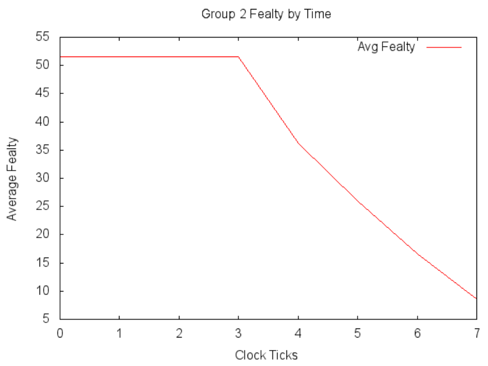

Fig. 11: Input parameters: Fealty, 0.25

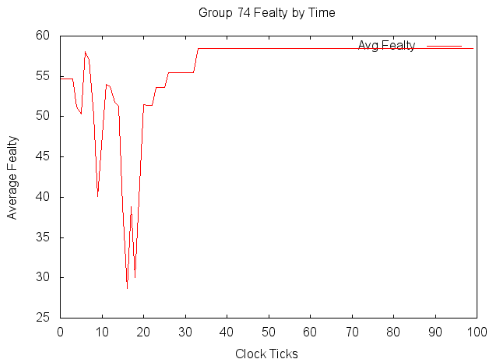

Fig. 12: Input parameters: Fealty, 0.25

perceive their group and its leadership. The key in the model, and in societies such as existed in the Zambezi plateau is the taking of a particular kind of collective action, that is, to abandon a group that is perceived to be unsuccessful and join another, more successful group.

Model runs result in a few large groups even though groups and group leadership get more than one chance to improve the overall feeling of loyalty to the leadership. Groups must, at each clock tick, reexamine the need for collective action, and this examination is largely independent of that history of the group. Though this is more forgiving than the real world, it is still enough to cause the failure of some groups and the rise of large groups. Comparing Fig. 11 with Fig. 12 we see that one group suffered a significant fall in the average feelings of loyalty, but then saw that it recovered, due to successful collective actions and the addition of members from failed groups.

Results were largely expected given the importance of membership in groups with strong leaders. However, it is surprising how few groups remain in the stable system, and it is surprising the speed at which the system coalesces. This needs further investigation; however, it may be due to the fact that the model does not take into account any dampening effects in regards to communications among group members and between groups. In the archeological and historical record, long distance communications are known to, of course, take time. Furthermore, the model could be extended to add activation and decay effects to the behavior of the agents. This would make the slow process more realistically "slow".

Leadership is strongly, positively related to group size, but not to average fealty within the group. The preferred group size, by average fealty is around 1000, while the average fealty is quite low when everyone is in one large group. However, leadership scores continue to rise as groups get larger. This is counterintuitive. Leadership is expected to vary in the same way as average fealty, assuming a direct link between leadership and positive group feelings. This is an area that would need to be explored as the model is extended; however, it may also bring to light the problem of when group dynamics fail even in the presence of adequate leadership.

It is interesting that in most runs of the model, average fealty declines at the beginning of the model run, only to (sometimes) recover and rise. This is due to the fact that collective action succeeds only 25% of the time with good leadership, and only 10% of the time with poor leadership. This means that most agents will experience failed collective action more often that successful collective action. However, as groups begin to disband to join stronger groups, group leader scores go up, which increases the overall chance of experiencing successful collective actions.

A. *Further Model Development*

This model could be developed further in a number of ways. As constructed, the role of environment factors are not taken into account. These could be global factors that are beyond group control or they could play more of a role in instigating collective action. Furthermore, environment may affect different groups in different ways. The model could be extended to place the relatively homogenous in size groupings in locally distinct environments. This is supported by work done in analyzing the clustering of farming community archeological sites in the Zimbabwean plateau by Sinclair and Lundmark, as described by Sinclair et al., who note "[t]here remains a strong impression that environmental factors of topography, soils and rainfall play an important role in the localization of southern clusters as a whole, but it seems clear that cluster spacing and internal organization within clusters is much more the result of social and political factors" [7, p. 709]. This model is currently constructed without geographic detail; however, we know that geography plays a very important part in the prehistory of the Zambezi plateau.

V. Summary

The Zambezi plateau region in Southern Africa has seen the rise and fall other several polities of different levels of complexity for many centuries before the arrival of Europeans and the beginning of the region's written history. Much archeological work has been done to recover this past. One of the enduring questions this work raises is to explain the rise, fall and abandonment of large polities centered around large edifices with massive stone walls called "zimbabwes". Several of these survive to the present day, the largest of which is called Great Zimbabwe near present-day Masvingo, Zimbabwe. The Great ZImbabwe period, lasting only 200 years was proceeded by Mapungubwe and succeeded by zimbabwes built to the north and southwest of the Great ZImbabwe site. Given the success of these states, what causes them to fail is such a way that the sites can be considered not just in decline but abandoned?

The agent-based model presented here provides support for an explanation based on the Canonical Theory. In this theory, a succession of opportunities to engage in collective action by a polity strengthens or weakens the complexity of the polity. This so-called "fast process" over time creates larger structural changes in which the effects of collective action within the fast process accumulate into a polity at a different level of complexity.

This model demonstrates that how a society can change its complexity over time through the individual fast-process type decisions made by group members. In the model, groups rose, declined and disbanded as the feelings of loyalty and attachment to the group rose and fell. These feelings were effected by the success or failure of collective action, and the probability of success was dependent in part on the strength of the group leader.

The main finding presented here is that group dynamics, centered on the collective feelings of loyalty to the group, can generate the macro level behavior that we see in the archeological record of Southern Africa. This has implications on the benefits of further investigation into the ideologies and imagery around views of group leadership and loyalty of the people of the zimbabwes of Southern Africa.

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