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Civilization Defined

Abbey Perumpanani*
perumpanani@hotmail.com

Introduction

A civilization is a dynamical system† that supports endogenous cultural development through economic activity aggregated across elements of its data.

This paper proposes the aforementioned as an inclusive scientific definition that can bring about a convergence in the widely differing historical views on civilization. As this definition complies with the mathematical requirements of a definition, it will empower rigorous analytical approaches to study civilizations. The paper argues that all extant intensional historical definitions of civilization are partial implementations of the above definition.

I am a mathematician. In this paper I will describe what I see as a major and fundamental weakness in the historical approaches to study civilization — the absence of a scientifically credible, consensus definition of the term civilization. I will offer a mathematical solution to this historical problem.

Over recent decades, the term civilization has played an increasingly important role in structuring historical, political and economic thought. More recently it has even been suggested that our emerging world order is being morphed through a ‘clash of civilizations.’ Despite its academic significance, and its perceived importance as a determinant in global politics, the term civilization remains without a consensus definition. In a symposium organised by UNESCO, the historian Felipe Fernandez-Armesto provided a scholarly survey of the historical efforts to characterize civilization where he concluded that civilization “is a problematic concept because of its abuse, its ambiguities, its partisan connotations, and the arbitrary nature of the ways in which it is commonly characterized.”¹

For a person like me trained entirely in the sciences, this neglect of a consensus definition is difficult to comprehend. In any scientific exercise, definitions have a primacy which cannot be sidestepped. Yet historians, who have traditionally been the custodians of the term civilization, have for decades pursued a vibrant and prolific

* The author is an Indian physician and mathematician currently living and practicing medicine in Australia. After medical training in India, he received a PhD. in Mathematics from the University of Oxford, and he was then a Physician Fellow at Harvard Medical School. His research interests are in the molecular biology of cancer and in the analysis of partial differential equations. Email: perumpanani@hotmail.com
† A mathematical construct used to describe an entity that changes over time; the term is more elaborately described later in the paper.
industry in the study of civilizations without being stymied by the absence of a consensus definition. One of my earliest forays into history was reading *A History of Civilizations* by Fernand Braudel. I realized after reaching the end of the book that Braudel had, in fact, not offered any precise definition of the term which was the subject of his book.

This definitional crisis in Civilization Studies is a consequence not of the absence of plausible candidates, but rather arises from a surfeit of them. There are dozens, if not hundreds, of definitions of civilization around. I am told by the members of the International Society for the Comparative Study of Civilizations that they have made numerous previous attempts at their annual meetings to generate a consensus definition of civilization—without success. The problem of generating a consensus definition of civilization appears to be intractable from within the scope of historical methods. The absence of a consensus definition is not simply a matter of academic vexation, but one that has had consequences for the study of history. The ambiguity caused by the absence of a scientifically credible consensus definition of civilization has precluded the interdisciplinary development of the study of civilizations. While internal clarity is lacking within history on the definition of a civilization, it becomes impossible to develop external interactions with other disciplines to foster the interdisciplinary development of civilization studies.

This paper will use the mathematical paradigm of a definition to derive a definition of civilization by marrying the common elements in the historical perceptions of civilization with the theory of dynamical systems. This definition is based on the characterization of civilization as a "dynamical system"—an evolving entity driven by underlying processes within specified spatial and temporal boundaries.

Other areas of study which have previously been interpreted through dynamical systems theory — population biology, oncology, and economics, among others — have been dramatically transformed through a synergistic relationship with mathematics. Through such interactions a vast repertoire of tools has been developed to study dynamical systems. Formulating civilization as a dynamical system will allow the application of this powerful array of scientific tools to historical analysis, albeit with some discipline-specific differences. More importantly, the common language imposed by the theory of dynamical systems will help foster interdisciplinary dialogue between historians and mathematicians.

This definition provides the means for a scientific transformation of the study of history, and—if the trajectory in population biology is replicated—the development of "mathematical history."
Mathematical view of the historical definitions of civilization

In a mathematical sense, a definition determines the membership of a specific set through one of three mechanisms: intension, extension or recursion\(^3\).

- An intensional definition lays out a set of necessary and sufficient conditions for an entity to belong to the defined set. An entity can also be intensionally defined by first stating the broad category it belongs to and then distinguishing it by specific properties.
- An extensional definition involves a list which can simply be a set of instructive examples (ostensive) or an exhaustive listing (enumerative).
- A recursive definition states one (or a few) elements of the set and all things bearing a certain relationship to elements of the set are also defined as members of the set.

Convention demands that definitions avoid certain pitfalls. A definition must not comprise terms that are synonymous with it, which will make the definition circular. Definitions should not be too wide or too narrow and definitions should not be negative where they can be positive. Definitions should also try to avoid arbitrariness and obscurity, choosing to explain themselves in terms whose meanings are unambiguous.

Against this mathematical background of definitions, most historical definitions of civilization stack up poorly. I will illustrate errors in each type of definition by adducing examples chosen for their ability to showcase the class of error.

**Intensional definitions:** Arnold Toynbee, who was at the inaugural meeting of the International Society for the Comparative Study of Civilizations in Salzburg, despite the somewhat indecent corpulence of his works, was much more concise in his definition of civilization. He described the process of civilization as one where “mimesis is directed towards the future, the cake of custom is broken and society is in a dynamical motion”\(^4\).

Oswald Spengler argued that a culture did not become a civilization until it was already in decline. Then, it “suddenly hardens, it mortifies, its blood congeals, its force breaks down, and it becomes Civilization.”\(^5\)

These are intensional definitions, which, though poetic and evocative, in a mathematical sense are simply examples of obscurity and circularity.

**Extensional definitions:** Samuel Huntington enumerated a list of eight “major civilizations”\(^6\) but provided no clarity on why those on his select list were deemed "major," particularly because, by inference, the rest are being deemed minor. This is an extensional definition, plagued by obscurity and arbitrariness.
Recursive definitions: Kenneth Clark, the British historian who reputedly wept for fifteen minutes, overwhelmed by the favourable reception of his television series *Civilization*, finally concluded that he still did not know what *civilization* was, but thought he could recognize it when he saw it. Though, as a definition, this would appear vague, it is possibly the longest standing and the most commonly used method to define *civilization*.

Essentially, it is a recursive definition—societies displaying features reminiscent of the characteristics of their own societies are deemed “civilized”. It is through such a definition that the Greeks considered the Persians uncivilized, Romans called the Germanic tribes barbarian, and the Hindus referred to the foreigners as Mlechaas. These notions are nothing more than the manifestation of ethnocentric bias. Despite their ubiquity, such biases cannot pass for a definition.

While these examples were chosen—essentially for their egregiousness—in order to illustrate the types of errors, all the historical definitions of *civilization* that I have come across show similar types of errors, albeit to varying degrees.

**Interdisciplinary approach to defining civilization**

**Civilization from a mathematical point of view**

At a basic schematic level all *civilizations* have some common features (see Figure 1):

- they involve a group of people defined by certain *boundary conditions*—geographic, religious, or linguistic, for example;
- whose *initial state*, which we deem uncivilized, or proto-civilized;
- over an *interval of time*;
- through *interactions* between them, or the institutions they create;
- result in *developments* which are manifest on the surface.

![Figure 1: Schematic representation of a civilization](https://scholarsarchive.byu.edu/ccr/vol68/iss68/3)
So at a broad level, civilizations have a similar underlying architecture. It is this precise architecture that mathematicians call a dynamical system. From a mathematical point of view then, all civilizations have a common functional denominator—they are dynamical systems.

**Common elements in the historical definition of civilization**

Despite the variety in the historical definitions of civilization, a recurring theme in the majority of them is the identification of cultural developments as the *sine qua non* of civilization.

However, many of the judgments about cultural developments lie trapped within ethnocentric or racial biases. For example, Kenneth Clarke based his recognition of civilization on the ability to create and value works of art. However, he was dismissive of African works, which to him appeared to lack in confidence.

Such subjective biases can be exorcised from the judgment of cultural developments by partitioning all human interactions and developments into two groups:

- those that are primarily related to subsistence or profit are "economic", and
- anything else, which is not done with an economic motive, is "cultural"

This segmentation represents a *mutually exclusive and completely exhaustive* (MECE) description of all human interactions and developments.

**An interdisciplinary definition of civilization**

Now by marrying the implicit historical assumption in civilization studies and the mathematical theory of dynamical systems, we can conclude that a civilization is a dynamical system that supports endogenous cultural developments through economic interactions aggregated across elements of its data.

![Figure 2: The Dynamical Systems View of Civilization](image)
Two of the terms in this definition—"dynamical system" and "data"—need clarification.

A "dynamical system" is a mathematical construct that models interactions which convert the initial state of an entity into developments within a defined boundary over a specified period of time. Within this broad definition any time-dependent entity can be characterized as a dynamical system.

- The human heart is a dynamical system—through the interaction of electrical and mechanical processes the state of the heart is continuously being modified, albeit repetitively.
- The stock market is a dynamical system, where the prices of financial instruments are being modulated through the interaction of speculative and economic forces.

Dynamical systems, as modeling tools, are very versatile. They can be used to study everything from molecular dynamics on an atomic scale to planetary interactions on a cosmic scale; from boundary layers that happen in a flash of the eye, to phenomena such as evolution with aeonic spans. It is a powerful and flexible tool, and one that has dramatically transformed many an area of study.

There are three elements that define a dynamical system: the initial conditions, the boundary conditions and the interactions between its elements. They are collectively referred to as the "data." Once these three elements are specified, we have a complete definition of the dynamical system. If the data of the dynamical system is adequately specified then it is called a “well determined” system; if not it is called "under-determined".

A definition such as the above opens up a door which will allow us to connect the worlds of history and of mathematics by building a mathematical formulation of a civilization, in the form of a family of equations. The details are technical; for the purposes of this paper I will keep the discussion to a conceptual level.

We can say about the economy that:

\[
\frac{\partial E}{\partial t} = f(E,C) - \nabla g(E).E.C + \frac{\partial E}{\partial x}.
\]

And if we called \( E \) a measure of economic development, and \( C \) a measure of the cultural development, then we can represent the above equation more concisely using mathematical notation as
We can write a similar equation for cultural developments.

$$\frac{\partial C}{\partial t} = f_c(x, t) - \nabla g_c(x, t),$$

Here $f_e$ and $f_c$ are the functions representing the interactions of economic and cultural developments and $\nabla$ is the divergence operator representing spatial movement of economic and cultural developments and $x$ and $t$ are independent variables measuring space and time. The initial and boundary conditions are determined by the choice of civilization and together they represent a full description of a civilization as a dynamical system.

**Advantages of the mathematical definition**

By positing the idea of civilization within the paradigm of dynamical systems we can connect the study of civilizations, and history in general, with the large array of analytical approaches available to study dynamical systems. The application of such techniques has revolutionized our understanding of many previously intractable problems: the spread of cancer, the development of economies, climate change, and ecological sustainability. I will provide a few examples of the application of such techniques to the study of history.

1. **Metrics:** Transparent and objective metrics of civilization-related phenomena can be implemented through the computation of maxima, minima, areas under the curve, averages, medians etc. Such metrics can be used to compare and hierarchize civilizations in a scientific fashion. If, for instance, Samuel Huntington's description of "Major Civilizations" was underwritten by such metrics, then it would be amenable to meaningful scientific discussion and disputation—in its absence, it can be argued as simply being an opinion, albeit from a reputed scholar.

2. **Measures:** The metrics that describe civilizations can be combined to generate measures of civilization (weighted sum of metrics). Mathematically these measures can be represented as

$$A = \sum_{i=1}^{n} g_i e_i + \sum_{k=1}^{m} h_k c_k$$

Where $A$ is a measure, $e_i(x,t) = \text{Economic developments}$ and $c_k(x,t) = \text{Cultural developments}$; and $g_i$, and $h_i$ are weighted functions such as Maxima, Minima, area under the curve, average, median, etc.

In the manner after the sciences these measures could be named through descriptors or eponymously after their authors or famous historians. For instance, the Body Mass index (BMI) is used by doctors to predict the risk of
cardiovascular disease; the *Reynolds number* in fluid mechanics is used to predict the possibility of turbulent flow. A rich and vibrant area of study involving civilizational measures can be used to inform historical judgments and direct policy decisions.

3. Expansion of the scope of *civilization* studies: The dynamical system approach will provide a more flexible interpretation of *civilization* which will enable a wider inclusivity than is currently the case. Within the dynamical systems characterization, *civilizations* can be defined based on any of the three elements of the data,

- Based on the initial conditions: for example, as pre-Columbian or post-Reformation;
- Based on their boundary conditions: for example, as Western, Indian, Islamic or Riverine, and,
- Based on their interactions: for example, as industrial, agricultural, or informational.

And by transposing the three elements of the data on each other, we can define an even greater array of *civilizations*—potentially thousands of distinct *civilizations*. This will make *civilization* studies a much richer and more exciting area.

While neither the term *civilization* nor the term *culture* has a precise scientific definition, an implicit hierarchy is imposed through these terms. Larger entities which are easily recognized through ethnocentric views are called “*civilizations*”; others less easily recognized thus are simply referred to as “cultures”. Yet this difference within the current historiographical frameworks is entirely arbitrary. As Felipe Fernandez-Armesto noted, all definitions of *civilization* "belong to a conjugation which goes, 'I am civilized, you belong to a culture, he is a barbarian.'"¹⁰ There is little reason for us not to refer to the Medieval Kochi civilization, the Pitjantjatjara civilization, or the Bhutanese civilization.

Each of these entities qualitatively possesses the structural and functional elements seen in the more widely acknowledged *civilizations*. While spatial, temporal and quantitative differences may separate Bhutanese developments from the Egyptian *civilization*, for example, in most qualitative respects a direct one-to-one mapping is possible. The wider inclusivity of the dynamical system approach will not diminish the concept of a *civilization* any more than referring to a local fish-and-chips-shop as a *business* will detract from the same term being used for a large global corporation.

¹⁰https://scholarsarchive.byu.edu/ccr/vol68/iss68/3
4. Guide data collection: One of the turning points in historiography was von Ranke highlighting the importance of assiduous collection of data from primary sources\textsuperscript{11}. However, there are so many ways in which data can be collected and the premise behind the post-modernist critique of history as simply an ensemble of subjective perceptions is largely founded on this profusion of data. I face the same problem when dealing with my patients in the hospital, but when one knows what decision one is trying to make, the data that are relevant become self-evident. The characterization of a civilization as a dynamical system will allow us to interrogate the system for particular questions, questions that will make the data to be collected self-evident.

5. Evolution of hypotheses: I am sure many a learned historian, from periods of study and reflection, feel compelled by particular ideas. In history, however, there currently are no rigorous means to evolve these hunches into theories, laws or paradigms. In the sciences such ideas or hypotheses, as they are often called, have a well-trodden evolutionary trajectory through which they are either confirmed, negated or modified. This involves an iterative approach, where such hypotheses are prospectively simulated (forward modelling) to find out what inferences emerge. Reciprocally, the data pertaining to the system are simultaneously analyzed (backward modelling) to see how they compare with the findings of the prospective simulation. If the two agree, then we have a credible theory; if they don't, we either reject the hypothesis or modify it and iterate again. As this iterative process is repeated, through a hierarchy of models, we progressively get closer to the truth because of the convergent nature of the feedback loop between backward and forward modelling (see Figure 3). Good examples of this type of modelling in the sciences are the works of Tycho Brahe and Johannes Kepler\textsuperscript{12}.

Figure 3: The feedback loop between data analysis and process conjecture allows the study of dynamical systems to develop in a convergent fashion.
Discussion

Historically, and increasingly politically, civilization has been a divisive concept. The dynamical system formulation of civilization provides a scientific explanation for this divisiveness. A survey of the many available definitions of civilization (the International Society for the Comparative Study of Civilizations website lists 30 of them) shows that they are incomplete or partial (under-determined) implementations of the dynamical systems approach. None of them fully specify all the elements of the data -- the initial conditions, the boundary conditions and the interactions -- at the same time. A specific consequence of a system being underdetermined is that it allows multiple interpretations (solutions) and the difference between these interpretations cannot be analytically resolved.

A simple algebraic example of an under-determined system is the case of two numbers, say x and y, whose sum is four. If that is all we know about the numbers, it would be impossible to resolve a debate between two disputants who argue that $x=3$ and $y=1$ or the other way around. No resolution is possible with any amount of arguments, unless additional information which makes the system well-determined is available, say, for instance, that $x$ is greater than $y$.

Many historical disputes have been caught up in such essentially unresolvable debates. They generate vibrant discussion and excitement, but being under-determined they are essentially unresolvable debates. For instance, Toynbee saw civilizations as the creative response of people to physical challenges imposed on them, in other words, a pattern imposed by geography. Accordingly, people faced with few challenges produce little civilization while those faced with insuperable challenges are crushed by it and have little opportunity to produce civilization. Only those faced with an optimal amount of challenge, according to Toynbee, go on to produce substantial civilizations.14

The Eskimos, for instance, had not proceeded beyond rudimentary culture because of the extreme adversity of their environment. On the other hand, in warmer climes, like in India, the environment posed few challenges and therefore did not provide the incentives required to produce complex civilizations. But in northern Europe, Toynbee observed that people were ideally matched with their environment and consequently went on to produce “high” civilization.14

Others have tried to explain the rise of Europe based on the organizing influence of ecclesiastical institutions, which through their organizing role in the community (regular mass times, for example) made the development of institutions, and hence the Industrial Revolution, possible.15

There is no way that these ideas as they stand can be formulated into well-determined models that can be pitched against each other and tested to see which one explains the
observed fact—the rise of Europe—better. Describing civilization as a well-determined dynamical system will foster a common framework within which objective analysis and constructive dialogue (and disputation) on the subject of civilization will become possible.

The dynamical system approach could have a significant impact on the course of historiography. Traditionally historians have regarded a degree of subjectivity as an inescapable part of the historical narrative, an idea that reached its zenith in the post-modernist view of history. The dynamical systems approach can be used to explain such a view as a logical consequence of traditional historiographies being under-determined. By creating a framework within which objectivity can progressively be enhanced through continued iteration, the dynamical systems approach provides an escape from the entrenched notions of subjectivity in the study of history and an effective counter to the essentially scientifically nihilistic post-modernist interpretation of history.

Not having a consensus definition of civilization is not merely a matter of academic vexation, but it is increasingly likely to have practical implications in the emerging world order. History provides the backdrop to many global discussions on political differences. While in a previous era the most contentious of such differences existed between nation states, increasingly the most inflammable differences now reside between civilizations. The existence of a consensually-agreed framework within which such discussions can be fostered will make the resolution of such differences more likely. In the absence of such a framework, misunderstandings are more likely to thrive and, with that, the downstream consequences of such misunderstandings.

The two disciplines—history and mathematics—have had very different evolutionary trajectories and have been separated for so long that connecting the two can pose a challenge. Historians and mathematicians think very differently. There are two ways in which the idea of dynamical systems can be implemented into history.

On the one hand historians could foray into mathematics and return to imbue history with its methods and attitudes. A more efficient approach, I believe, would be to open the door from the other side—to import from other disciplines academics with an interest in history, and to foster interactions through them. This will be more expedient than enjoining historians to rediscover tools for which the expertise already exists in mathematics. Such importation of academics, from other disciplines into history, has happened before, and to great success: von Ranke’s background in philology, for example, significantly energized his approach to history.

And should the engagement between the two disciplines be fully consummated, we should see the emergence of a new discipline, Mathematical History—a common platform to objectively discuss our shared past.
End Notes


2 Discussions with Professor Anthony M. Stevens-Arroyo, Professor Joseph Drew, and Professor Michael Andregg.


13 http://www.wmich.edu/iscsc/civilization.html
