USING THE PRINCIPLE OF LEAST ACTION TO FRAME THE PHYSICS OF HUMAN BEHAVIOR: AN EXTRAPOLATE UP APPROACH

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ABSTRACT

Our thinking and modeling of animal action is intertwined with some manner of intention, purpose, teleology, or goal – deliberate or otherwise. When operations research and game theory were deployed as tools and framework for understanding human decisions, the effort has been focused on justifying optimization, and axiomatizing reasonable human behavior. Breaking from this well-established tradition, we explore the limits of understanding of human behavior independent of reason and intention, and without having to justify optimization. Starting with the physical existence of humans as a core phenomenon, we swim against the customary current of the practice of modeling human behavior that starts and ends with our social-psychological attributes. In particular, we adopt from physics the principle of least action, and show that it can explain non-trivial aspects of human action before resorting to biological or social-psychological attributes to explain the remainder (which remains to be explored outside the physical core at the level of animate existence).

Keywords: principle of least action, human behavior, laws of physics

1. INTRODUCTION

What can we learn from framing human action in a path generated by moving from point A to point B in a state space? While three-dimensional physical space is the most familiar example, transformation or translation through any space of attributes can be viewed as a movement from A to B. Is it possible to structure this problem in a way that applies to a variety of contexts and conditions in which the movement might occur? Using the principle of least action, we hold optimization as a universal property of the physical universe rather than a faculty of the biological brain, and provide a framework for understanding a wide range of human behaviors based on minimal physical requirements. We explore the limits of a physics-based tool in providing a descriptive structure for the core—material—layer of humans. We confine our attention to this layer while cognizant of the two outer layers: biology and social-psychology. Through life, brain and mind, add understanding beyond the physics layer through non-optimization mechanisms. Exploration of these outer layers constitutes future directions within our framework.

In its current form, our proposed approach enters the longstanding debate over the applicability of optimization to theorizing about human behavior; instead of removing it from the theory, we suggest placing it at the very material core of the universe, independent of biology, cognition or intelligence.

2. A THREE-LAYER APPROACH TO HUMAN BEHAVIOR

Most explorations of human action start with our social-psychological attributes and circumstances that shaped us over a few million years. But social-psychology itself is undergirded by biology that has taken eons to develop. The biology, in turn, is built on the foundation of a physical universe with optimization as a fundamental organizing principle.

Animals being a part of the physical universe, the optimizing principle should also explain at least some of what the live organisms do, perhaps with inevitable error and noise. We can understand a good deal by analyzing the physical core of our existence that we share with the inanimate and animate worlds.

The next layer after the physical core is our biological existence that we share with the animal world. To the extent we think of ourselves as very special animals, the optimizing principle amended with our biology should partially explain what we do; though not as well as they explain the behavior of animals without all of our social-psychological endowments. When biological genetic endowments are added to physical properties for explaining human actions, the remainders can be viewed as error and noise.

Social-psychological factors should be used to explain and organize data about human behavior that cannot be explained...
by our physical and biological attributes that we share with inanimate and animal worlds. Even after using all three levels, some unexplained behavior will still, most likely, remain as error; we do not venture to explore beyond this point. The three layers of our humanly existence are depicted metaphorically in Figure 1.

**Figure 1: A three-layer schema for modeling human action**

In the economics tradition of modeling behavior, optimization emanates from human brain endowed with biological and social-psychological faculties. In physics, on the other hand, optimization is not driven by motivation or incentives; it is simply a fundamental property that governs the physical universe. Putting the physical existence of humans in the core of explanatory structure of sciences, we attempt to reverse the customary order in the practice of modeling human behavior. Maximization is a befitting tool for understanding the properties of matter and energy that pervade both inanimate and animate domains. We intend to show that it can explain a great deal of what humans do without including their biological or social-psychological attributes.

We plan to linger within the physical universe as long as possible, to fully exploit optimization as a mechanism to understand action, before resorting to the outer layers [1], [2]. Most difficult part of starting with physics is to suspend the role of intention and purpose—so essential to our self-image and human exceptionalism—until later. In virtually all academic training and schools of thought, animal action is intertwined with a manner of intention, purpose, teleology, or goal – deliberate or otherwise. So much so that when operations research and game theory were used as tools and framework for decision theory (von Neumann-Morgenstern 1944, [3]), the main effort has been on justifying the use of optimization techniques for axiomatizing reasonable human behavior. Never before, to the best of our knowledge, the goal has been set to explore just how much we can understand of human behavior independent of reason and intention, where there is no need to justify the use of optimization. It almost hurts our self-esteem to treat ourselves, howsoever tentatively, as a marble or a photon, stripped of intention and driven only by physical laws of nature. What is the precursor that launched the pursuit of this very quest.

2.1 What about intention?

Consider three cases depicted in Figure 2. The lifeguard rushing across a sandy beach and water to save a drowning child; the ants making their way from their hill to spilled sugar across smooth and coarse surfaces to reach sugar, and the photons travelling from the sun to hit the eye of a fish swimming under water—all three follow a kinked path (shown in red line) that obeys Fermat’s Principle of reaching the destination in minimum time, and not by minimum distance (the broken straight line). All three move from A to B to accomplish a task.

**Figure 2: Lifeguard reaching drowning swimmer, ants reaching for sugar, and sunbeam reaching a fish under water all follow a kinked path across two surfaces.**

Do the observable similarities among the human, ant, and photon behavior stem from some fundamental principle? Or is it simply a case of the same mathematical model that captures diverse but unrelated phenomena. Those who believe in free will, purpose, intention, and learning may associate such attributes to the lifeguard, and perhaps stretch it to the ants, but it would strain credulity to associate them with photons. How do we make sense of these phenomena? We wonder whether a principle of behavior, or law, can be extracted from simple physical similarities across very different contexts.

For modeling, we can add the dimension of time to the three-dimensional space, and solve for the path that optimizes time instead of distance; while the three paths in space look similar, the fourth dimension of time is the action element in each case. We return later to use this as a categorical element to be economized as action under the principle of least action [1].

In each case portrayed in Figure 2, the transition in the environment divides the path of action into two segments, with higher speed of movement in one. The actor follows this simple rule to get from A to B: choose a longer path in the faster segment. The speed in each fabric is proportional to the angles with the horizon, as captured in Snell’s law:

$$\frac{V_2}{V_1} = \sin(\theta_2)/\sin(\theta_1)$$

The entire action for inanimate photon, animal ant, and human lifeguard is understandable by using only the least action
principle of physics. Resort to social-psychological or biological attributes such as intention, learning, or genetic hard-wiring is not needed to achieve a basic understanding. And optimization is a proper method in this physical universe. Interestingly, a wide range of actions can be configured in this manner, as we will soon demonstrate. First, some definitions.

3. MOVING FROM A TO B: THE FIRST LENS OF A THEORY OF ACTION

An action can be defined with respect to the specifiability of the beginning state $A$ and the end state $B$ of the action. Viewed through a lens of specifiability (call it Lens 1), each state can be one of the two types, specifiable or non-specifiable from the viewpoint of the actor (not the modeler).

**Definition:** An action is a movement from state $A$ to state $B$, where $A$ and $B$ can be specifiable (denoted as $\bar{A}$ and $\bar{B}$) or non-specifiable (denoted as $\bar{A}$ and $\bar{B}$) states. A pair of beginning-end states $(A, B)$ constitutes a situation.

This working definition is the first in a series that allow thinking about actions in a general way. First, we examine action and inaction from a different angle to spell out the world-view produced by Lens 1. Considering a variety of configurations that combine different types of (specifiable and non-specifiable) $A$ and $B$, we choose from them a set of four situations with interesting interpretations as presented in Table 1. The situation of specifiable $A$ and specifiable $B$ in the last column, was the abovementioned subject of exploration of the core physical layer. That analysis was a special case of a larger set of general properties and generic characteristics of action.

Viewing action through Lens 1, as an actor, leads us to a set of four initial situations, summarized in Columns 1-4 of Table 1. With the exception of Situation (1), each situation represents a movement between a beginning $A$ and a distinct end $B$, where $A$ and $B$ are either specifiable or not. Situation (1) is inaction, whether or not the beginning and end are specifiable. Two cases of inaction can be deliberate (conscious) or not (unconscious).

<table>
<thead>
<tr>
<th>Situation: (1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A = \bar{B}$ [and $\bar{A} = \bar{B}$]</td>
<td>$\bar{A} \rightarrow \bar{B}$</td>
<td>$A \rightarrow B$</td>
<td>$\bar{A} \rightarrow B$</td>
</tr>
</tbody>
</table>

The best imaginable outcome is no change: Stability with “acceptable waves”

<table>
<thead>
<tr>
<th>whether specified or not</th>
<th>Unclear consequences</th>
<th>Use proxies for $B$; generate probable outcomes</th>
<th>Clear binary outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not started yet but end is in view with near-certainty about its characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Four initial situations that provide categories for certain combinations and states of $A$ and $B$.

Situation (2), not customarily referred to as an action, could be imagination or dreams. Viewed through Lens 1, a dream has no specifiable beginning, but has a specific end. Whether or not action will be taken to arrive at the specifiable end does not pertain to the situation.2

Situation (3) characterizes major and mostly infrequent actions in the course of life, where the beginning is specifiable but the end is not, because completing the action does not coincide with completion of its effect. Examples are life partner and career choice.3 For each option regarding such choices we face a binary outcome of reject/accept with vague, unknown or unknowable consequences. On that note, the categorization in Table 1 can also be understood in terms of the type of goal applicable to an action. Pursuing this angle of inquiry, one can propose potential labels for the end state of an action: in-sight vs. imaginable goals; end-in-view vs. emerging; visible vs. yet-to-be-known consequences. To choose the most fitting label, it is necessary to distinguish between ends and goals, where the two do not necessarily coincide. For instance, the end can be offering or accepting a marriage proposal, where the goal is to live happily or to avoid loneliness later in life. This aspect can be further probed by exploring Situation (3), but this distinction is not pursued in the current paper. Neither do we focus on valuation and its change during and after an action, while remaining cognizant that the value of a choice may change (endowment effect on one hand, and Cost & Choice [5] argument on the other) once it has been made, implemented, and the consequences are realized. In this sense, the value of an end is fixed here, as constitutes its sole content.

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1 We invite the reader to use this definition to configure a subject matter in their respective discipline to see that action, defined in this manner, represents the central subject matter of many scientific disciplines.

2 The point might be raised that once action is taken to achieve the envisioned end, this action can be captured as a realization of Situation (4). Our inclination is to leave space for cases where acting on a wish is realized, but specification of the beginning is ad hoc.

3 It seems that this form of individual choice has a counterpart in corporations: project finance. That is the long-term financing of infrastructure based on projected cash flow instead of the balance sheet of the sponsors.
Situation (4) corresponds to the most common form of action, which is viewed through Lens 1 as moving from a specifiable beginning to a specifiable end. This is the only form in which a modeler’s view can be technically operationalized. Exploring the path of action in this situation constitutes the main body of the present paper after this section. Notice that animated cases such as catching a ball still comfortably fit in Situation, because for instance a more elaborate system can calculate the trajectory, and thus it remains exogenous.

What about the reason for and cause of an action? For instance, if an advertisement induces one to buy the advertised item, this person’s action appears to fall under situation (4). However, one can say the person is in situation (1), conscious or unconscious, until the advertisement is activated and attended to, then moves to situation (4), and makes a choice to purchase or not to. Moving between situations, can be represented as in Table 1’ that combines the same beginning-end pairs in the situations of inaction with action.

Table 1’- Categorizing action and inaction by specifiability of the beginning and the end.

<table>
<thead>
<tr>
<th>A: beginning</th>
<th>Specifiable: ( \hat{A} )</th>
<th>Non-specifiable: ( \check{A} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>B: end</td>
<td>Least Action (physics)</td>
<td>May never start (wishes)</td>
</tr>
<tr>
<td>Specifiable: ( \hat{B} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-specifiable: ( \check{B} )</td>
<td>Unknowable consequences (ambiguity)</td>
<td>Stay put (undisturbed default)</td>
</tr>
</tbody>
</table>

To illustrate this, let us return to physics principle of least action, and locate it in the space of Lens 1. For actions that fall in Lens 1-Situation (4) of Table 1 goal equals end. In addition, we can include the specifiable inaction from Lens1-Situation (1) in the same physics-based category to account for no-action. This combination can be generated in a variation of Table 1 configuration: Table 1’. Here, Cell (1,1) in Table 1’ contains the combined situations (4) and (1). Thus, we define Situation (i)’ as Situation (i) amended by corresponding inaction. That is (4)’= (4) + (\( \hat{A} = \check{B} \) = [ (\( \hat{A} \rightarrow \hat{B} \)) +(\( \check{A} = \check{B} \))].

This two-by-two structure generates four distinct categories of actions. This configuration combines situations same of beginning-end pairs whether or not an action has materialized. This contingency table format may prove useful in empirical testing of the ideas presented in this paper. Notice that the core or layer 1 of our three-layer approach in the previous section (Figure 1) is in the top left cell of this table, where \( A \) and \( B \) are both specifiable.

4. SUMMARY AND CONCLUDING REMARKS

We introduced a three-layer approach to human action, starting with physics at the core. This raises concern about the role of intention in actions, which we addressed next. We used the principle of least action as a structure for configuration of human actions without reference to biological or social-psychological attributes. This exercise ameliorates the common practice of providing justification for applicability of physical laws to non-physical attributes of the animate universe.

We posed a new question: How much of observed human behavior can be understood and organized within the optimization domain of physics sans biology and higher faculties. We observe that the same kinked line path left behind by unanimated and animated objects moving across two different fabrics to arrive at an end obeys one Snell Law, which itself is a case of the path of least action principle with time as the optimized argument. We propose adopting this principle as a framework for describing different types of human behavior by specifying (i) an optimization argument, which we called the action element, (ii) elements external to optimization, otherwise determined exogenous to the action, and a corresponding resulting path (See examples in [1]). This layer-1 analysis allowed us to describe important aspects of behavior without involving biological and cognitive elements variable. The advantage of our analysis is that it obviates the need to justify optimization, or to build a process for doing so; it pervades the inanimate physical universe.

ACKNOWLEDGEMENTS

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REFERENCES