Modeling Social Evolution, Involution, and Indeterminacy: A Neutrosophic-Cultural Algorithm Approach

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Abstract: Neutrosophic Sociology, or Neutrosociology, is the study of sociology using neutrosophic scientific methods for understanding the dynamics of social systems within complex environments. When a social change occurs, the society evolves with respect to some parameters, regresses with respect to others, and remains the same or experiences an unclear change (indeterminacy) with respect to another set of parameters. This mirrors neutrosophic logic: true ($\mathcal{T}$), neutral or indeterminate ($\mathcal{I}$), and false ($\mathcal{F}$). The main concept of cultural algorithms is a generalization of the idea that evolution has at its base both racial learning within species and social learning within human societies. By employing a mathematical formulation that incorporates these theories, this study proposes a new framework, namely the Neutrosophic Theory of Cultural Evolution (NToCE), which analyzes how stakeholders can optimize their beliefs and actions in the face of uncertainty and conflicting interests. A real life scenario adopted from the neutrosophic social change due to technology as described in related bibliography, demonstrates the efficacy of this integrated neutrosophic framework in fostering collaborative decision-making, increasing flexibility, and promoting sustainability. The findings of our study reveal that adding neutrosophic principles into cultural algorithms considerably increases the robustness and resilience of social systems, allowing for more sophisticated modelling of stakeholder interactions and belief development.

Keywords: Neutrosociology; neutrosophic logic; cultural algorithms; social evolution; evolutionary computation; decision-making.

1. Introduction

The social environment is highly subjective, with conflicting trends and perspectives. The researcher's social model reflects a significant degree of "how I'd like to be," indicating a lack of consensus on social norms. Humans are capable of both unconscious and conscious evaluations of their surroundings. In a world that is constantly changing in terms of sociological conditions and interactions between individuals and social groups, we need theories and models that are adaptive, flexible, and dynamic in response.

Starting from this perspective, Professor Smarandache introduced Neutrosophic Sociology, or Neutrosociology, which is the study of sociology using neutrosophic scientific methods to understand the dynamics of social systems within complex environments [1]. He observed that the vast social data encountered in sociology is screened with indeterminacy: it is vague, incomplete, contradictory, hybrid, biased, ignorant, redundant, superfluous, meaningless, ambiguous, and unclear. Building on this observation, he suggested that methods of neutrosophic logic, which deals with indeterminacy, could be utilized to effectively address social changes. Social change causes society to evolve in some social parameters, regress in others, and remain the same or be unclear (indeterminate) in yet another set of social parameters.

The Neutrosophic Theory of Evolution (NTE) [2], characterized by its main concepts of evolution, involution, and indeterminacy (or neutrality), has been successfully applied in evolutionary biology to describe the process of adaptation of a being (animal, human, or plant) to a new environment. Recently, it has also been extended to study the case of language evolution in certain social groups, showcasing how individuals adapt, regress, or maintain neutral traits during cross-cultural transitions [3]. These recent studies have clearly revealed the applicability of the Neutrosophic Theory of Evolution in interdisciplinary scientific fields.

Cultural Algorithms (CA) [4-5] are a type of evolutionary algorithm that integrates concepts from cultural evolution to enhance optimization processes. These processes support two functions of heredity: one occurs at the micro-evolutionary level in terms of behavioral or genetic traits, while the other acts at the macro-evolutionary level in terms of the so-called beliefs of the population. The two functions interact through a communication channel that allows individuals to modify the structure of the population's beliefs, and also predisposes the behavior of individuals in light of the individuals' beliefs. Thus, cultural algorithms have three basic components: a belief structure, a population structure, and a communication channel.

In this paper, we suggest a hybrid neutrosophic model, the Neutrosophic Theory of Cultural Evolution (NToCE), which provides a synergy between NTE and CA so that we can enhance the adaptability and flexibility of the optimization process. The cultural aspect adopts knowledge sharing and collaborative learning among individuals, while the neutrosophic perspective enables a more comprehensive evaluation of solutions by accommodating varying degrees of truth, falsity, and uncertainty. In order to test the applicability of our method we study a real life case study, adopted from the related bibliography of neutrosophic social change [1], is studied to analyze social change due to technology. In this case, our aim is to achieve a thorough understanding of how CAs combined with the NTE may aid stakeholder decision-making in a highly complex setting. We simulate the views and interactions of stakeholders to mimic the dynamics of evolution, involution, and indeterminacy in their decision-making processes.

1.1 Novelties

The current article suggests the Neutrosophic Theory of Cultural Evolution (NToCE) which is a novel optimization method built around the integration of neutrosophic Logic (NL), Neutrosophic Social Evolution (NSE) and Cultural Algorithms. The key innovations include:

1. The combination of aforesaid methodologies allows for more advanced modelling of complicated systems. Specifically, NL's ability to manage indeterminacy in complex systems, such as the social environment, when joined with CAs' adaptive learning, allows for flexible decision making. Furthermore, combining core NTE concepts (evolution, involution, and indeterminacy) with CAs enables the model to develop more effective strategies for addressing complex challenges, facilitating collaboration among diverse stakeholders, and strengthening the robustness of solutions in uncertain environments.
2. The model incorporates neutrosophic concepts into CAs to update belief vectors for evolution (T), indeterminacy (I), and involution (F), while simulating stakeholder interactions. This combination approach allows for real-time changes in societal views, which improves decision-making processes in complicated contexts.

1.2 Contributions

1. The introduction of NToCE is an important theoretical advance. It associates NL with CAs to better manage the complexity and uncertainties of social evolution, hence filling a research gap in the modelling of indeterminate social systems.
2. The study proposes a new algorithm for updating stakeholder beliefs through iterative procedures, enabling continuous adaptation in complex and changing social situations. This helps to advancing approaches for modelling dynamic decision-making processes in uncertain scenarios.
3. The practical application, highlighted in our study, assessing the societal impacts of Internet and mobile technologies contributes to both academic knowledge and a practical understanding of technological disruptions in society.

1.3 Structure of the paper

In the next section, we present the fundamental formulations that are used to build our hybrid neutrosophic model. Section 3 applies our proposed model to a real word case study. This case focuses on the widespread adoption of Internet and mobile technologies and explores their impact on social dynamics, including the processes of social evolution, involution, and indeterminacy. In Section 4 we inquire into a detailed evaluation of the results, highlighting their significance for understanding social adaptation and decision-making in uncertain environments. Subsequently, in Section 5, we perform an assessment analysis, comparing the performance of the proposed NToCE model to other neutrosophic approaches such as Neutrosophic Cognitive Maps (NCMs), Neutrosophic Soft Sets (NSS), and Neutrosophic Analytic Hierarchy Process (N-AHP). This research highlights the NToCE approach's benefits, notably its iterative belief update process and dynamic flexibility. Finally, Section 6 provides a comprehensive summary of the insights gained from the development and application of the Neutrosophic Theory of Cultural Evolution (NToCE).

2. Materials and Methods

2.1 Neutrosophic Logic

Neutrosophic Logic (NL) is an extension of classical and fuzzy logic, introduced by Smarandache [6]. It provides a framework for dealing with indeterminate, imprecise, and inconsistent information by incorporating a third truth value called indeterminacy. In neutrosophic logic, a concept A is T% true, I% indeterminate, and F% false, with (T, I, F) $\in$ $]^-0, 1^+[^3$, where $]^-0, 1^+[$ is an interval of hyperreals.

Definition 1 [7] Let $\mathcal{X}$ be a space of points (objects), with a generic element in $\mathcal{X}$ denoted by x. A single-valued neutrosophic set (SVNS) $\mathcal{A}$ in $\mathcal{X}$ is characterized by truth membership function T_A, indeterminacy membership function I_A, and falsity membership function F_A. For each point x in $\mathcal{X}$, $T_A(x)$, $I_A(x)$, $F_A(x) \in [0, 1]$.

Then, a simplification of the neutrosophic set $\mathcal{A}$, which is a subclass of neutrosophic sets, is denoted by $\mathcal{A} = \{\langle x, T(x), I(x), F(x)\rangle \mid x \in \mathcal{X}\}$

2.2 Neutrosophic Cultural Algorithms

The CAs is a class of computational models derived from observing the cultural evolution process in nature [4]. The CA has three major components: a population space, a belief space, and a protocol that describes how knowledge is exchanged between the first two components. The population space can support any population-based computational model, such as Genetic Algorithms, and Evolutionary Programming. The basic framework that will be used in the context of our model is the following:

- *Population Space*
  Each individual i has a belief vector $B_i = (T_i, I_i, F_i)$ (1)
  where each component represents a distinct aspect of their beliefs.
- *Belief Space*

The belief space stores the best (or optimal) values of T,I,F discovered by the population: $T_{optimal}, I_{optimal}, F_{optimal}$

- *Belief Update*

The beliefs of the population are influenced by both their interaction with each other and the best values stored in the belief space.

$$T_i^{new} = T_i + \lambda * (T_{optimal} - T_i) \quad (2)$$

$$I_i^{new} = I_i + \mu * (I_{optimal} - I_i) \quad (3)$$

$$F_i^{new} = F_i + \nu * (F_{optimal} - F_i) \quad (4)$$

Where:

λ, μ, ν are adjustment factors that control the influence of the optimal beliefs on the population.

2.3 Neutrosophic Theory of Cultural Evolution

In this subsection we adopt the ideas from Neutrosophic Sociology and transform them into a suitable mathematical framework tailored for the needs of our proposed methodology.

The NTE characterizes the dynamics beliefs of individuals using three key components: Evolution (T), Indeterminacy (I), and Involution (F). These components evolve as individuals interact and make decisions regarding a common goal.

We define the belief vector B_i for each individual i as $B_i = (T_i, I_i, F_i)$ where:

T_i is the degree of evolution (positive change or support)

I_i is the degree of indeterminacy (uncertainty or neutrality) and

F_i is the degree of involution (negative change or opposition)

The belief vector is updated iteratively to reflect changes in individual's attitudes based on interactions and external influences as follows:

$$T_{new} = T_{current} + \alpha * (T_{optimal} - T_{current}) \quad (5)$$

$$I_{new} = I_{current} + \beta * (I_{optimal} - I_{current}) \quad (6)$$

$$F_{new} = F_{current} + \gamma * (F_{optimal} - F_{current}) \quad (7)$$

Where:

α, β, γ are influence factors that determine how much weight is given to the evolution, indeterminacy, and involution during the belief update process.

$T_{optimal}, I_{optimal}, F_{optimal}$ are the ideal target values for each belief component and are derived based on the goals of the system examined.

Eq. (5) – (7) are updated iteratively until a termination condition is met. A convergence threshold (ϵ) is commonly used to specify the termination condition. This threshold is a small positive value that shows how near the present beliefs must be to the ideal beliefs before the algorithm stops.

A common choice for (ϵ) might be a small value such as 0.001 or 0.01, depending on the precision required.

Next we define the *fitness* function, which is mainly used in evolutionary computation algorithms. In Neutrosophic Social Evolution, the goal is to maximize evolution, minimize involution and minimize indeterminacy. In this light, the fitness function will be used in our model as a measure of how well the current state of beliefs (represented by T, I, and F) of individuals align with the ideal target values. It can be defined as:

$$Fitness\ B_i = w_T * T_i - w_I * I_i - w_F * F_i \quad (8)$$

Where:

w_T, w_I, w_F are weights reflecting the importance of evolution, indeterminacy, and involution and allow to adjust the influence of each belief component in the fitness equation. In order to calculate the weights given in the above equation we could engage the population with sample questions like:

- How significant do you believe the positive influence of technology (evolution) is on society?
- How significant do you perceive the uncertainties associated with technology (indeterminacy)?
- How concerned are you about the negative implications of technology (involution)?

To summarize, Figure 1 depicts the algorithmic structure of the proposed method:

Neutrosophic Theory of Cultural Evolution (NToCE)

1. Initialize:

- Set initial belief vectors for each stakeholder group $B_i = (T_i, I_i, F_i)$
- Define optimal belief values $T_{optimal}, I_{optimal}, F_{optimal}$
- Set adjustment factors (α, β, γ) for belief updates.
- Set termination condition threshold (ϵ).

2. For each stakeholder group, calculate initial belief values:

B_i^{init} $T_{current}$, $I_{current}$, $F_{current}$

3. Update belief vectors iteratively:

- While the termination condition (ϵ) is not met, do:
  - For each stakeholder group:

$T_{new} = T_{current} + \alpha * (T_{optimal} - T_{current})$

$I_{new} = I_{current} + \beta * (I_{optimal} - I_{current})$

$F_{new} = F_{current} + \gamma * (F_{optimal} - F_{current})$

4. Convergence check:

- Check if the belief vector components (T, I, F) for each stakeholder group are within the termination threshold ϵ
- If convergence is achieved ($|T_{new} - T_{optimal}| < \epsilon$ and similar for I and F), terminate the algorithm

5. Calculate fitness values for each stakeholder group:

- $Fitness\ B_i = w_T{*}T_i - w_I{*}I_i - w_F{*}F_i$

6. Output final belief vectors and fitness values:

- Return the final belief vectors ($B_i = (T_i, I_i, F_i)$) after convergence
- Output fitness values for each stakeholder group

Figure 1. Algorithmic structure of NToCE

Remark: In step 5 of above proposed algorithm we could integrate a penalty function ($P(B_i)$) into the fitness values calculated to reduce the chance for illegal solutions to be reproduced by our algorithm: (i) a penalty could discourage certain behaviors or attitudes that are not desirable or ideal in the context of cultural development, (ii) the penalty function could assist in ensuring that the final belief values remain feasible, which is especially significant in situations when beliefs must adhere to certain ethical or cultural norms. This could be achieved by calculating the evaluation function as:

$Fitness\ B_i = w_T{*}T_i - w_I{*}I_i - w_F{*}F_i - P(B_i)$

where $P(B_i)$ would identify the constraints or undesirable behaviors that require penalties.

3. Results

In this section, we will apply our proposed method, Neutrosophic Theory of Cultural Evolution (NToCE), to a real-life case study, originating from related literature [1], concerning the societal implications of Internet and mobile technologies for various stakeholder groups. Specifically, we will examine how various groups—such as tech enthusiasts, privacy activists, and the business sector—change their views about the advantages, uncertainties, and threats connected with technology breakthroughs, using actual facts to guide the belief updating process. This will show how NToCE may represent social development, indeterminacy, and involution as a result of continual technology advancements. The data sources used for current scenario were adapted from real datasets [8-15]. For a figurative representation of related surveys, the interested reader is referred to the Appendix of the paper.

In order to derive the neutrosophic values from the corresponding datasets, we follow the next formulas to quantify the initial beliefs of population groups, based on counting positive, uncertain, and negative responses for components T, I and F (Table 1). This comes in align with the definition of a concept in NL, i.e. a concept A is T% true, I% indeterminate, and F% false with (T, I, F) $\in$ $]^{-}0, 1^{+}[$ [3].

Table 1. Formulas for deriving T, I and F components

Component	Formula
Truth (T)	$T = \frac{Positive\ responses}{Total\ responses}$
Indeterminacy (I)	$I = \frac{Uncertain\ or\ contradictory\ responses}{Total\ responses}$
Falsehood (F)	$F = \frac{Negative\ responses}{Total\ responses}$

Based on Table 1, we derive next table (Table 2) which summarizes the data used for calculating the initial belief vectors for each stakeholder group.

Table 2. Datasets for stakeholder groups for initial belief [8-15]

Stakeholder Group	Component	Value	Data
Tech Enthusiasts (TE)	Truth	0.8	81% of Americans believe mobile devices have improved their lives [8]
	Indeterminacy	0.3	53% uncertainty about long-term economic impacts of technology [10]
	Falsehood	0.1	79% concern about privacy, but low concern for tech enthusiasts [9].
Privacy Advocates (PA)	Truth	0.6	Lower trust in technology's benefits for privacy-conscious individuals [8]
	Indeterminacy	0.5[1]	79% concerned about data privacy and surveillance [9]
	Falsehood	0.4	400% increase in cybercrime during the pandemic [11]
Business Sector (BS)	Truth	0.7	Mixed views on technology's economic benefits, 53% uncertainty [10]
	Indeterminacy	0.4	53% of business leaders uncertain about technology's long-term benefits [10]
	Falsehood	0.3	Concerns about job displacement and automation risks [12]

From Table 2, we can derive the belief vector of our population as in Eq. (1):

B_{TE} = (0.8, 0.3, 0.1) (9)

B_{PA} = (0.6, 0.5, 0.4) (10)

B_{BS} = (0.7, 0.4, 0.3) (11)

[1] The adjustment from 79% concern to 0.5 indeterminacy reflects a process of normalization or contextual scaling, ensuring that the value fits within the neutrosophic model’s structure

We derive the optimal beliefs based on empirical data [8-15] from research on the impacts of technology. For example, the truth value can be supported by data showing that a large proportion of respondents believe that technology has significantly improved their lives or work, whereas the falsehood value can be influenced by concerns about technology's unintended consequences (e.g., privacy breaches or job losses). In this context, we get the following optimal values for social evolution, indeterminacy and involution respectively:

$T_{optimal}$ = 0.85, $I_{optimal}$ = 0.4 and $F_{optimal}$ = 0.2.

Next we update the belief vectors, for each population group using Eq. (2) - (4) where $\alpha = \beta = \gamma = 0.5$ (meaning that the process of updating beliefs for evolution (T), indeterminacy (I), and involution (F) is treated with equal importance) and taking into consideration Eq. (9) – (11).

- *Tech enthusiasts*

T_{new} = 0.8 + 0.5 * (0.85 − 0.8) = 0.825

I_{new} = 0.3 + 0.5 * (0.4–0.3) = 0.35

F_{new} = 0.1 + 0.5 * (0.2–0.1) = 0.15, so updated vector B_{TE} = (0.825, 0.35, 0.15) (12)

Following the same logic we get

- *Privacy Advocates*

B_{PA} = (0.725, 0.45, 0.3) (13)

- *Business Sector*

B_{BS} = (0.775, 0.4, 0.25) (14)

We proceed with Iteration 1 of our algorithm updating the beliefs of our population with current values as in Eq. (12) - (14) with $T_{current}$, $I_{current}$ and $F_{current}$ the updated values.

After iteration 1 we have:

B_{TE} = (0.8375, 0.375, 0.175)

B_{BS} = (0.7875, 0.425, 0.25) and

B_{PA} = (0.8125, 0.4, 0.25)

After three iterations we have at least one value (from T, I and F) below the threshold (0.001), so we can consider the algorithm to have converged with final beliefs:

B_{TE} = (0.846875, 0.39375, 0.19375)

B_{BS} = (0.834375, 0.40625, 0.2125) and

B_{PA} = (0.840625, 0.4, 0.2125)

Finally we calculate the fitness function for each stakeholder according to Eq. (8) where w_T= 1, w_I= 0.5 and w_F= 0.3. By assigning these values to the weight parameters we ensure that the alignment with desired outcomes is not overshadowed. The fitness values indicate how well each stakeholder's beliefs align with the desired outcomes.

$Fitness_{TE}$ = 0.591875

$Fitness_{PA}$ = 0.5675 and

$Fitness_{BS}$ = 0.576875

4. Applications

In the previous section, we utilized our method to study the societal implications of Internet and mobile technology regarding the evolution, indeterminacy, and involution of stakeholder beliefs. Next we list the main insights drawn from the results obtained.

1. The belief vectors for several stakeholder groups—tech enthusiasts, privacy activists, and business sector—show how their attitudes evolve in reaction to the effects of technology progress. The gradual convergence of these belief vectors via recurrent updates demonstrates how each group adjusts its perspectives on the positive, uncertain, and negative effects of technology. For example, tech enthusiasts who began with a strong conviction in the advantages of technology show a minor rise in indeterminacy and a moderate change in privacy concerns, indicating a more nuanced perspective of technological consequences.

2. The NToCE method updates belief vectors with weighted adjustment factors a, β, and γ, demonstrating how stakeholder views evolve towards optimal belief values based on real world data. The final convergence shows that, despite various initial perspectives, all groups arrive to an almost common understanding of the technological world.
3. The fitness function, which evaluates the alignment of each group's views with the intended social results, reveals that tech enthusiasts have the highest alignment, followed by the business sector and, ultimately, privacy activists. This result is consistent with the empirical data and indicates how each group prioritizes different aspects of technology's influence. The values of fitness function for each population group also acknowledges the positive impact of technology while also sharing concerns about privacy and job displacement. Another implication that could be made regarding the close values of fitness function between stakeholders is the possible balanced trade off in stakeholders' perceptions about technology.

5. Comparative analysis

Since there are no published results on the case study examined in this paper so as to directly compare the performance of our suggested method to other similar methodologies, the analysis conducted in this section will focus on the main features and characteristics of each approach, highlighting their advantages and disadvantages.

The methods chosen for comparative analysis (Table 3) in the context of our case study were selected due to their similar mathematical framework (neutrosophic), and their capability in addressing complex systems that involve uncertainty, evolving conditions, and multiple stakeholders.

Table 3. Methods for comparative analysis

Method	Components	Belief update mechanism	Convergence speed	Flexibility in handling indeterminacy	Key advantages
Neutrosophic Cognitive Maps [16-18]	Neutrosophic relationships (T,I,F)	Iterative	Moderate	High	Effective in representing dynamic systems
Neutrosophic Soft Sets [19-21]	T, I , F	Static	Slow	Limited	Handles uncertainty through soft set principles
Neutrosophic AHP [22-23]	Ranked decision criteria	No iterative Update	Moderate	Moderate	Useful for predefined decision-making criteria
NToCE	Evolution (T), Involution (F), Indeterminacy (I)	Iterative	Fast	High	Dynamic belief update and continuous adaptation

Based on the above comparative analysis, it is shown that NToCE demonstrates significant advantages over other neutrosophic approaches in dealing with complex systems, especially in dynamic and developing situations. One of the NToCE's key features is its iterative belief updating process, which is enhanced by cultural algorithms. This dynamic method enables the continuous adaption of stakeholder beliefs to reflect real-time changes in the social or technological environment. In contrast, approaches like Neutrosophic Soft Sets (NSS) and Neutrosophic Analytic Hierarchy Process (N-AHP) rely on static or non-iterative updates, which limit their ability to handle indeterminacy and evolving situations.

Moreover, the convergence speed of the NToCE model is considerably faster, with beliefs stabilizing within three iterations, whereas models like NSS and N-AHP often require more iterations and exhibit slower adaptation. The NToCE method's capacity to dynamically modify the balance of evolution (T), involution (F), and indeterminacy (I) guarantees that stakeholder viewpoints develop towards optimum belief states, which improves decision-making in uncertain and conflicting situations.

In terms of fitness value alignment, the NToCE method performs well, delivering a better level of alignment between stakeholder beliefs and desired results. This is primarily due to the employment of cultural algorithms, which enable stakeholder groups to share knowledge and collective learning. As a consequence, the NToCE model not only adapts fast but also gives more robust decision-making results when compared to systems like Neutrosophic Cognitive Maps (NCMs) or NSS, which handle uncertainty but lack the same level of real-time responsiveness and flexibility. A promising work regarding the inclusion of the concepts of evolution and dynamics of time in NCMs is described in [24], but still needs further testing validation in real life problems.

6. Conclusions

Parsons [25] believed that societies, like biological creatures, needed to adapt to changing circumstances in order to survive. His theory of social evolution proposes that civilizations that best adapt to their surroundings would be more effective in preserving stability and making advancements. This is related to Darwin's notion of "survival of the fittest," which states that the most adaptive or well-suited creatures survive and thrive. However, we are faced with so many social problems that we will never succeed in completely eliminating all the corruption from society. For example, in the context of this paper, technology increases people's wealth, but at the same time, it also diversifies, increases, and creates new kinds of social problems such as cyber-crimes, online identity theft, and electronic bullying. In this view, scholars [1,26] extended Parson's Social Evolution to the Neutrosophic Social Evolution. He claimed that social change causes society to evolve, as Parsons stated in his functionalism. However, this evolution only applies to certain social parameters, while other parameters may regress (involution). In some cases, society may remain the same or the change may be unclear (indeterminacy), as in neutrosophic logic: true (T), neutral or indeterminate (I), and false (F).

Commencing from this fundamental idea, this study examined the integration of Neutrosophic Logic and Cultural Algorithms to propose the Neutrosophic Theory of Cultural Evolution (NToCE), a novel approach to understanding and modelling social evolution in a complex driven society. The suggested approach captures not just positive or negative shifts in stakeholder perceptions, but also the inherent uncertainties that technology entails, such as privacy issues, job displacement, and cybercrime. Finally, our neutrosophic framework to cultural evolution provides a more comprehensive understanding of how societies can improve their decision-making processes in the face of uncertain outcomes.

The study models stakeholders' beliefs using three components: evolution (T), involution (F), and indeterminacy (I) to model changes in systems. When a social change occurs, it impacts society in various dimensions, leading to multiple degrees of evolution, involution, neutrality, and uncertainty across different social parameters. Future research could provide more granular definitions to capture refinements within each category by employing Refined Neutrosophic Evolution which is described by Refined Neutrosophic Logic [27-30]. In this model we could define multiple degrees of evolution ($\mathcal{T}_1$, $\mathcal{T}_2$, …, $\mathcal{T}_k$) to correspond a set of social parameters (e.g. technological, economic, educational etc.) to represent the extent of positive change across these various aspects of society. In the same logic we would have multiple degrees of involution ($\mathcal{F}_1$, $\mathcal{F}_2$, …, $\mathcal{F}_m$), degrees of neutralities ($\mathcal{I}_1$, $\mathcal{I}_2$, …, $\mathcal{I}_n$) referring to no significant change with respect to certain social parameters and degrees of indeterminacy ($\mathcal{I}_{n+1}$,

$\mathscr{I}_{n+2}$, …, $\mathscr{I}_{p}$) when referring to social parameters where it is unclear whether the changes represent evolution or involution.

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Conflicts of Interest: The authors declare no conflict of interest.

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Appendix A

A.1 Data figures

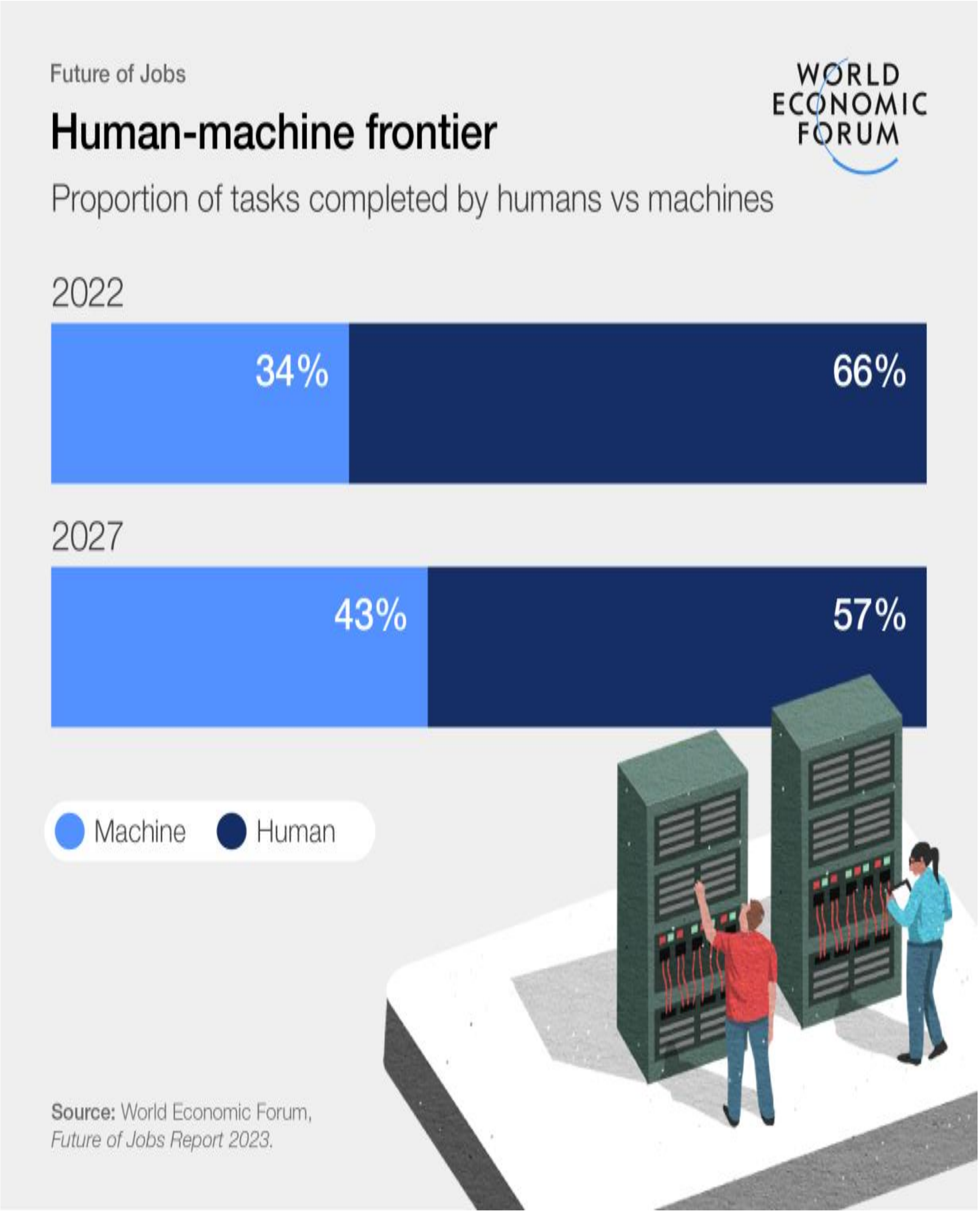

Figure A1. How tasks could be split between humans and machines in the coming years [14]

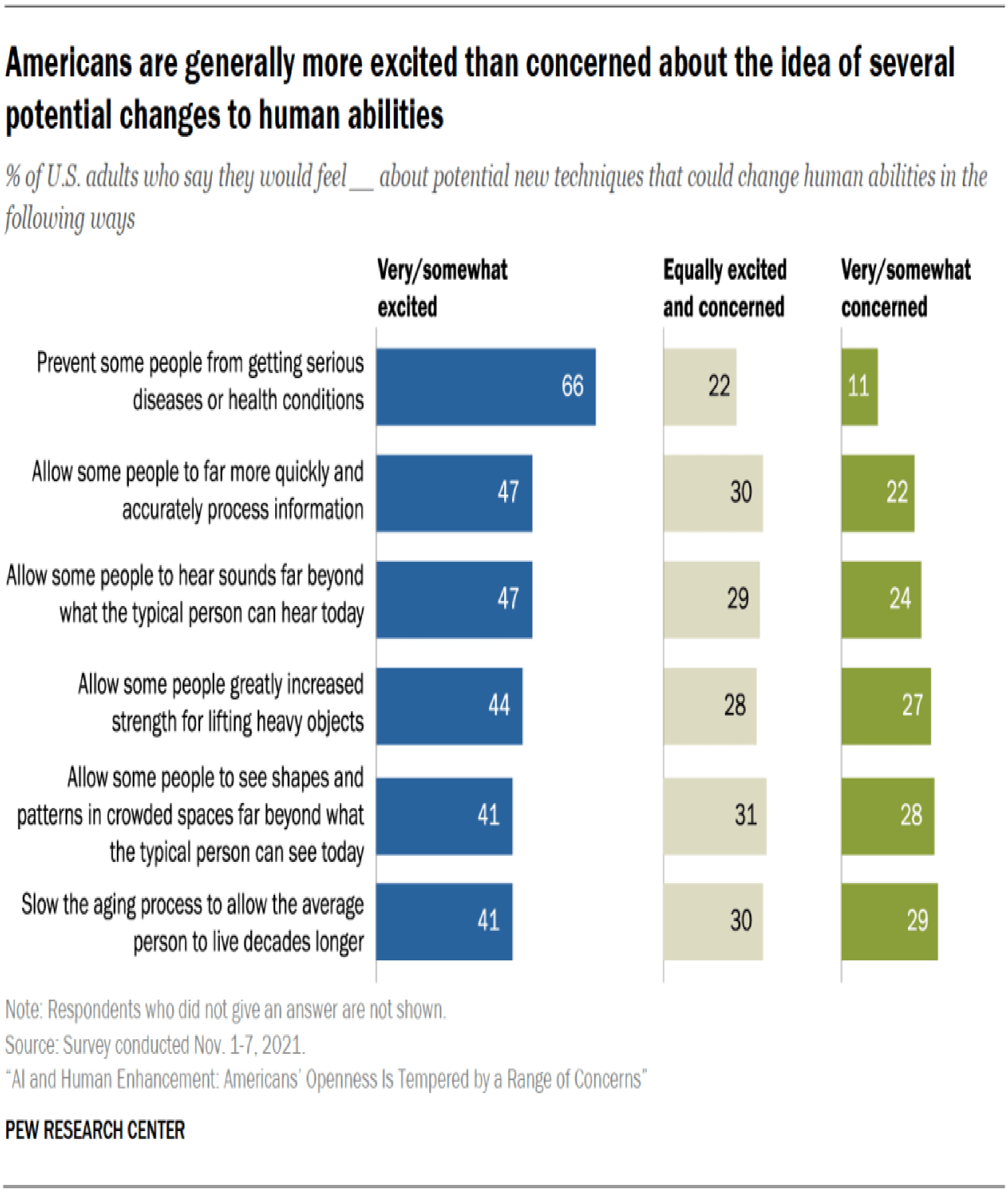

Figure A2. AI and human enhancement [8]

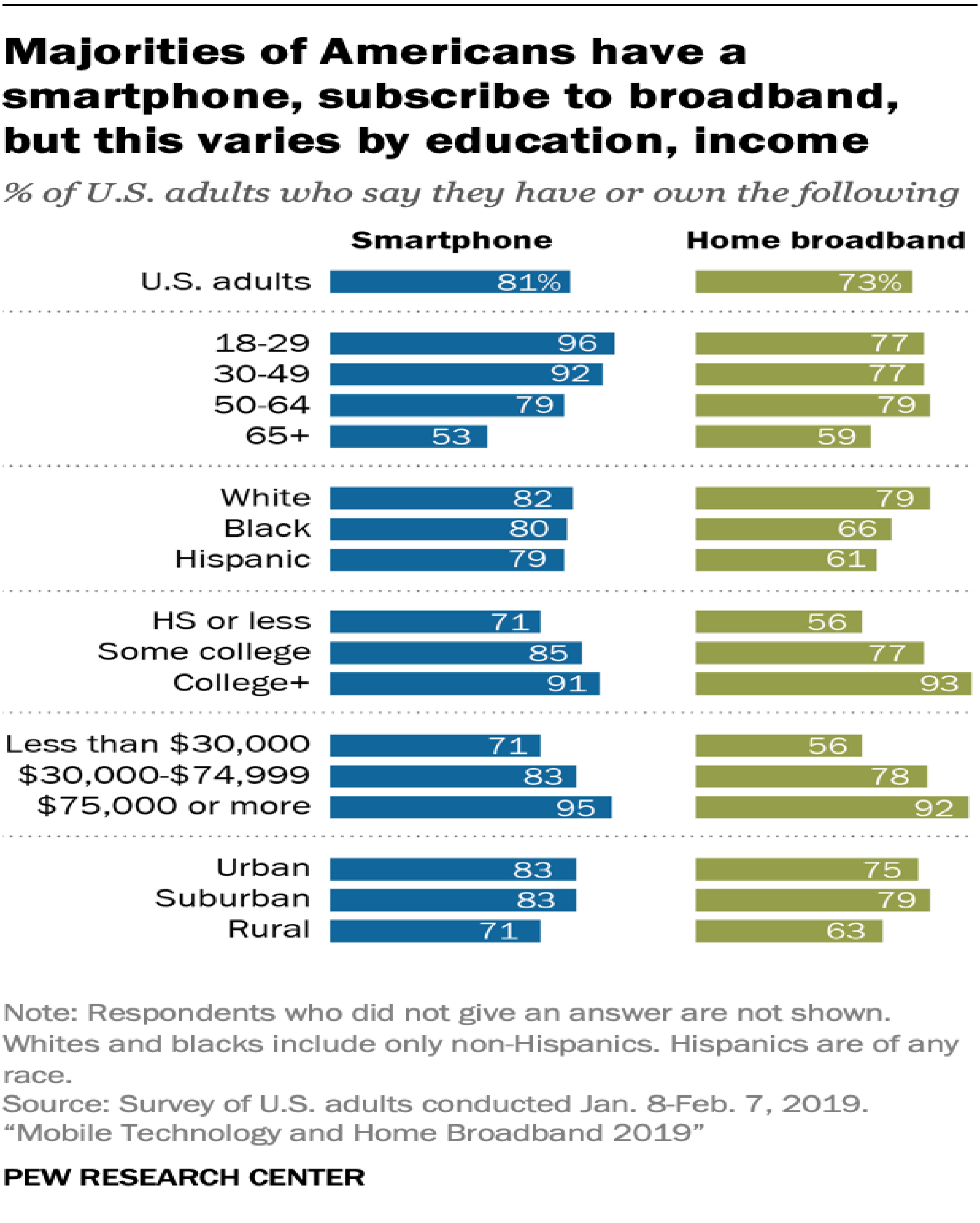

Figure A3. Mobile technology and broadband [8]

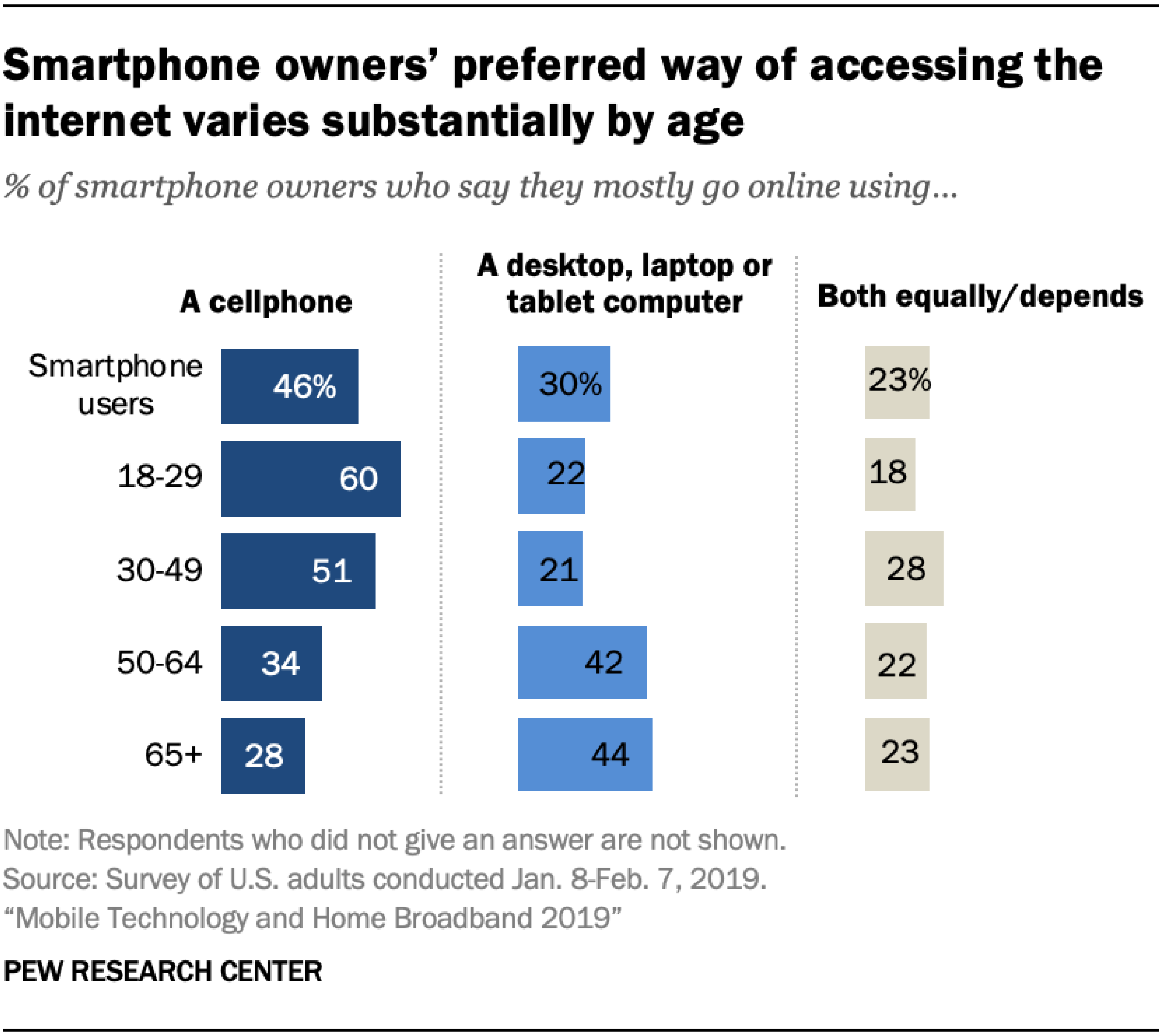

Figure A4. Smartphone preferred way of accessing the Internet [8]

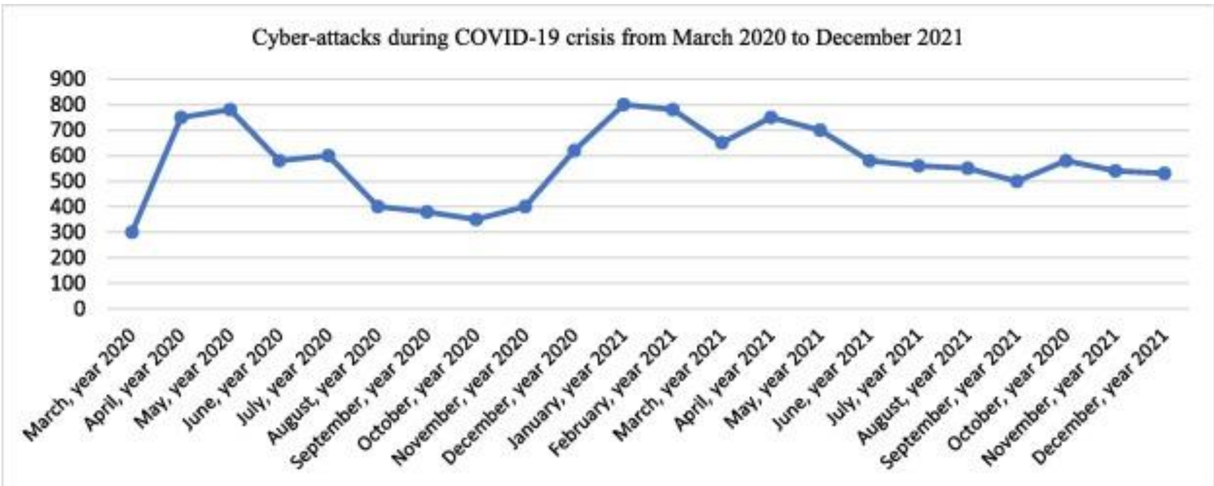

Figure A5. Cyber-attacks during the COVID-19 crisis between March 2020 and December 2021 [15]

Figure A6. Mass Surveillance of Personal Data [9]

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