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Agent-Based Modeling

Proof of Concept - Final Project

I. Clearly present a research question to be answered by the model. Situate the contribution in the relevant literature, citing at least five peer-reviewed published sources. Explicitly discuss the social mechanism explored by the model.

Digital innovation increasingly operates as a mechanism of modern colonization. Michael Kwet defines the social mechanism *digital colonialism* as a structural form of domination enforced through centralized ownership of software, hardware, and network infrastructure **(Kwet 2018)**. This mechanism reproduces socio-political and economic power imbalances by entrenching technological dependencies, particularly in the Global South. In this project, I propose an agent-based model (ABM) to simulate this dynamic, drawing inspiration from existing models of innovation diffusion and augmenting them to reflect the cultural and infrastructural asymmetries that shape digital adoption and resistance, with an exploratory analysis of its effects on the digital divide.

Research Question: *"How does cultural infrastructure, resistance, and the digital divide affect the adoption and long-term sustainability of digital technologies diffused by a dominant technological superpower?"*

South Africa is used as a conceptual case study to contextualize the power asymmetries between digital superpowers (such as U.S.-based tech corporations) and less-resourced recipient cultures. Kwet illustrates how digital infrastructure rollout by Big Tech corporations often leads to surveillance, dependency, and extractive profit flows, thus reinforcing neocolonial dynamics rather than promoting equitable development **(Kwet, 2018)**.

Digital colonialism presents a unique socio-technical dynamic in which the global diffusion of digital technologies reinforces existing hierarchies between technologically dominant nations and more culturally and infrastructurally vulnerable societies. This relational connection, between digital superpowers and digitally dependent nations, forms the foundation for exploring how agent-based modeling (ABM) can simulate the mechanisms of innovation diffusion within a digitally colonized world.

Currently, AMBs exist around innovation diffusion to simulate technological adoption utilizing a utility function approach (similar to what I have laid out in the model's decision rule calculation for adoption). Kotthoff and Hamacher (2022) propose an alternative ABM that addresses a critical methodological gap for the Innovation Diffusion ABMs by introducing gradient-based optimization to iteratively calibrate individual agent behaviors using real data. While the proposed model will not implement in-depth real-world data due to the limited scope, the model serves as an example of how to adjust the decision parameters, enabling a more accurate depiction of innovation/adoption uptake among heterogeneous subgroups **(Kotthoff and Hamacher, 2022)**. Their presented ABM aims to simulate similar dynamics of

digital technology diffusion, particularly by modeling adoption decisions across societies with varying levels of infrastructure and individual resistance to change **(Kotthoff and Hamacher, 2022)**.

The proposed modeling approach draws from literature on innovation adoption in the Global South, particularly within agricultural and rural contexts, where disruptive technologies often fail due to misalignments with local culture, limited infrastructure, or resistance to imposed practices. Studies of agricultural innovation adoption in developing areas, specifically in the paper "Disruptive innovation in agriculture: Socio-cultural factors in technology adoption in the developing world" **(Curry et al., 2021)** emphasize that low adoption rates of technology are due to the incompatibility with "indigenous values, habits, socio-cultural institutions and ways of doing things that can make technology transfer challenging for farmers," **(Curry et al., 2021)**. This further echoes the correlation of cultural infrastructure alignment to the barriers of technology adoption, as well as the cultural risk and information gaps associated with adoption. Both Curry et al. and Kwet outline how tech products are deployed without regard to long-term cultural sustainability, instead reinforcing asymmetrical power relationships and undermining local autonomy.

Further reinforcing the relevance of the proposed model's cultural framing, recent digital transformation literature highlights how the interpretation and perceived utility of technological value are deeply shaped by institutional narratives and power structures. The framing theory applied to digital adoption, as defined by Frida Ivarsson (2022) in "Applying Framing Theory in Digital Transformation Research: Suggestions for Future Research," argues that technologies are not neutral objects but culturally coded interventions whose perceived benefits are contingent on alignment with local norms and values **(Ivarsson, 2022).** This research gives merit to incorporating the attributes of *perceived utility* and *neighborhood influence* into the model of digital colonialism, emphasizing the additional powers that contribute to technological interpretation.

Abdullah Alsaleh contributes literature that frames the impacts of technological advancements through the lenses of technological determinism, the digital divide, and the role technological advancements play in cultural development. Specifically, Alsaleh explores the dual nature of technology in both its to be a "catalyst for cultural change" and a driver to cultural homogenization, defined as "the loss of unique local traditions in favor of mainstream, globalized norms" **(Alsaleh, 2024**). Drawing on the *Actor-Network Theory (ANT), Media Archaeology, and Digital Cultural Semiotics*, Alsaleh emphasizes the risk of cultural erosion of technology deployed without regard for local context **(Alsaleh, 2024)**. Most importantly for this study, Alsaleh conceptualizes the identity of technology as both a tool and an active agent in cultural transformations, as explained by the actor-network theory. This theoretical framing directly informs the proposed model's initialization, where technology is implemented as an agent with distinct attributes. In a normative future application, the more complex, data-driven version of the proposed model would aid in exploring interventions to bridge the digital divide for equitable technological advancement. Collectively, this literature motivates the development of an ABM that does more than measure adoption rates—it simulates the lived tensions between adoption, resistance, and cultural survival under the conditions of digital colonialism.

II. Explain the model's function in sufficient detail that a reader could create code for it. Discuss operationalization: what do the agents represent?

The proposed model features two types of agents: Tech Superpower Agent and the Receiving Culture Agent. These agents represent a simplified abstraction of global dynamics in digital colonialism , where powerful entities (cultural, companies, or countries) disseminate technology and culturally distinct communities respond in varied ways.

Receiving Culture Agents

A. Decision Making

These agent's core decision-making is modeled around the decision to adopt a technology and evaluate its long-term cultural and infrastructure impacts. Similarly to the Innovation Diffusion ABM by Jotthoff and Hamamcher (2022), decision making is made on the calculation of adoptions were the Decision Rule is:

Adopt if *(Perceived Utility + Neighbor Influence - Cultural Resilience) > Adoption Threshold*

Where

Perceived Utility = (Infrastructure Strength / Implementation Cost) × Cultural Fit × Digital Access Score.

B. Attributes

The receiving culture agents are initialized with the following attributes: Cultural resistance (represents opposition to foreign technologies), infrastructure strength (ability to implement/sustain tech), adoption threshold (individual threshold needed to justify adoption), well-being (dynamic score tracking post-adoption effects) and digital access score (represents their position in the global digital divide and general connectivity). The last attribute is based on their decision making, which is first the decision to adopt the tech as a boolean state and the ban as a boolean state, updated when the agent observes a significant well-being decrease for itself or/country.

Tech Superpower Agents

A. Decision Making

The first decision attribute of this agent is the deployment policy, where the agents decide which recycling agents they will deploy the digital technology to, either all, some random amount of agents, or those with specific access scores.

B. Attributes

These agents attributes are a score of Tech Dominance representing their global influence and research which can decrease with increased resistance to their technology. Secondly, is the deployment policy attribute (customizable in the GUI) which implements the decision behavior.

Simulation Steps

Simulations run in discrete time steps, where at each step agents evaluate where to adopt a technology based on a utility function (if deployed to them) and agents may later on ban the technology if it causes negative impacts.

1. Adoption Phase
    - Each agent runs adoption rules based on attributes and neighbors.
2. Tracking Effects
    - After adoption:
        - Wellbeing and infrastructure increase or decline based on long-term impact.
        - Cultural resilience may degrade slightly on adoption.
3. Banning Phase (After X Time Steps)
    - After X time steps, agents reassess:
        - If wellbeing/infrastructure decline too much, they may ban the tech.
4. Extinction / Collapse
    - If wellbeing or infrastructure drops below a survival threshold, marked as collapsed → symbolic cultural "extinction".
5. Superpower Feedback
    - If Y% of the Receiving Agents ban or collapse:
        - Superpower loses 1 level in Tech Dominance.

Sources

I. Applying Framing Theory in Digital Transformation Research: Suggestions for Future Research
II. Calibrating Agent-Based Models of Innovation Diffusion with Gradients Download (Florian Kotthoffabc and Thomas Hamacherc)
III. Digital Colonialism: US Empire and the New Imperialism in the Global South
IV. Disruptive innovation in agriculture: Socio-cultural factors in technology adoption in the developing world
V. The impact of technological advancement on culture and society