Nature of individual exploration in blockchain-governed virtual environments

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Extended Abstract

The internet created a digital space of information from diverse web pages (*1*), providing the opportunity for information seekers to build their own digital knowledge library. Analysis of the web ecosystem revealed key insights on human behavior pertaining to knowledge diffusion (*2*), consumer purchasing patterns (*3*), and online search behavior (*4*). While the internet is primarily focused on providing access to information and communication, blockchain-governed environments enable a new form of online experience focused on building a unique individual identity (*5*), designing virtual worlds (*6*), and trading Non-Fungible Tokens (NFT) (*7*).

The maturity of blockchain technology and its applications creates a web ecosystem that is open and accessible to all participants, and continues to push the boundaries of possibility in the metaverse, and hence greatly reducing the barriers between digital and physical realities. Importantly, the metaverse invokes an internet experience with radical transparency, and offers unprecedented opportunities to quantify and understand the forces, mechanisms, and hidden networks that shape human behavior on the metaverse.

In this work, we study human behavior in two distinct contexts of the metaverse, and identify the patterns pertaining to individual exploration in blockchain environments, and importantly demonstrate the role of network effects in shaping user experiences online.

(1) Physical mobility. We collect physical mobility data from Decentraland, one of the first decentralized blockchain-run metaverse, launched in 2019. The metaverse is built on a symmetrical layout of 90,601 land (parcels), each of size 16 by 16 metres, and allows users to traverse through land parcels in the metaverse. First data collection process lasted from March 15, 2022 to Aug 6, 2022, extracting data from a single data server, resulting in 81,563 users and 110,416,682 displacements (D1). To ensure that the data is not affected by irregularities from a single data server, we collect and curate data from multiple data servers from Aug 7,2022 to September 19, 2022, capturing 141,226,580 movements by 94,149 users and (D2). We use this data to construct individual mobility in the physical space (Fig 1 A).

(2) Contract mobility. On the Ethereum blockchain, each individual NFT is minted according to the specifications of a unique smart contract, providing trading standards and specifications such as creator royalty mechanisms, creating a meaningful association between the NFT and the contract. Each individual then uses the contract to purchase the underlying NFT, similar to how collectors purchase art from specific galleries. We extract the NFT purchases of individuals from two chains: (a) Ethereum, finding 1,165,310 NFTs from 23,827 contracts collected by 14,732 (9%) users, (b) Polygon, an Ethereum side-chain that enables faster and cheaper transactions, providing 3,112,300 NFTs from 54,918 contracts by 41,870 (25%) users. We use this data to construct the temporal journey of NFT purchases of an individual across multiple contracts (Fig 1 B).

As a first step, we examine the total number of users that are distributed across individuals lands and contracts. We find that visitation is highly concentrated: a few lands and contracts receive majority of the visitors, indicating heterogeneous visibility patterns, well-approximated as a powerlaw, $P(S) \propto N^{-\alpha}$, where $\alpha_{D1} = 1.98$, and $\alpha_{D2} = 1.92$ in the physical mobility (Fig 1 C), and $\alpha_{eth} = 2.07$ in contract mobility (Fig 1D). Further, when looking at individual exploration patterns over time measured as the number of unique lands and contracts visited over time following, $S(t) \propto t^{\beta}$, where $\beta_t = 0.65$ in the physical mobility space (Fig 1 E), and $\beta_{eth} = 0.57$ in the contract mobility space (Fig 1 F), suggesting a sublinear scaling in exploration patterns. Interestingly, contracts have a 63% customer retention rate on Ethereum, indicating that users tend to repeatedly purchase same contract, similar to the "lock-in" effects found in browsing.

We find that users tend to develop a preference towards a few lands, spending most of their time there (Fig 1 G), and users allocate more than 50% of their NFTs in four contracts (Fig 1 H). As a result, the individual flux in exploration, characterized by mean visitation frequency, f, and dispersion,σ, follows $\sigma_{\langle f \rangle} \propto \langle f \rangle^{\beta}$, where $\beta = 0.91$ in the physical mobility space (Fig 1 I), and $\beta = 0.98$ in the contract mobility space (Fig 1 J), indicating a sub-linear scaling. Since $\beta \sim 1$ it shows that users who visit the metaverse a lot tend to disproportionately allocate their time and resources across lands and contracts.

To better understand individual behavior in the metaverse, we characterize the jump distance in mobility across both systems. In the physical space, δ_r, measured by the manhattan distance between the two consecutive instances, and in the contract space, $d(a,b)$, measured as the shortest distance between two contracts. Across both systems, we find that individuals rarely make big jumps across locations (Fig 1 K) and contracts (Fig 1 L), suggesting short travel patterns. Contradictory, the favorite locations tends to located farther from each other suggesting the importance of teleportation in the physical space (Fig 1 M). In the contract space, users tend to distribute their investments in contracts that are located close to each other (Fig 1 N), measured as the average shortest shortest distance between all explored contracts, $D = \frac{1}{|C|}\sum_{a,b \in C} d(a,b)$, significantly lower compared to the random exploration while preserving size and degree ($z = -1.4$, $p < 0.1$)..

Overall, we find strong similarities in mobility patterns across the physical and contract space in the metaverse. Specifically, we find that user participation is highly concentrated to a few key lands and contracts, suggesting the importance of network effects in the metaverse. At an individual level, we find that users tend to return to the previously explored lands or contracts, and spend disproportionate resources and time towards that, indicating the importance of "lock-in" effect in blockchain-run environments.

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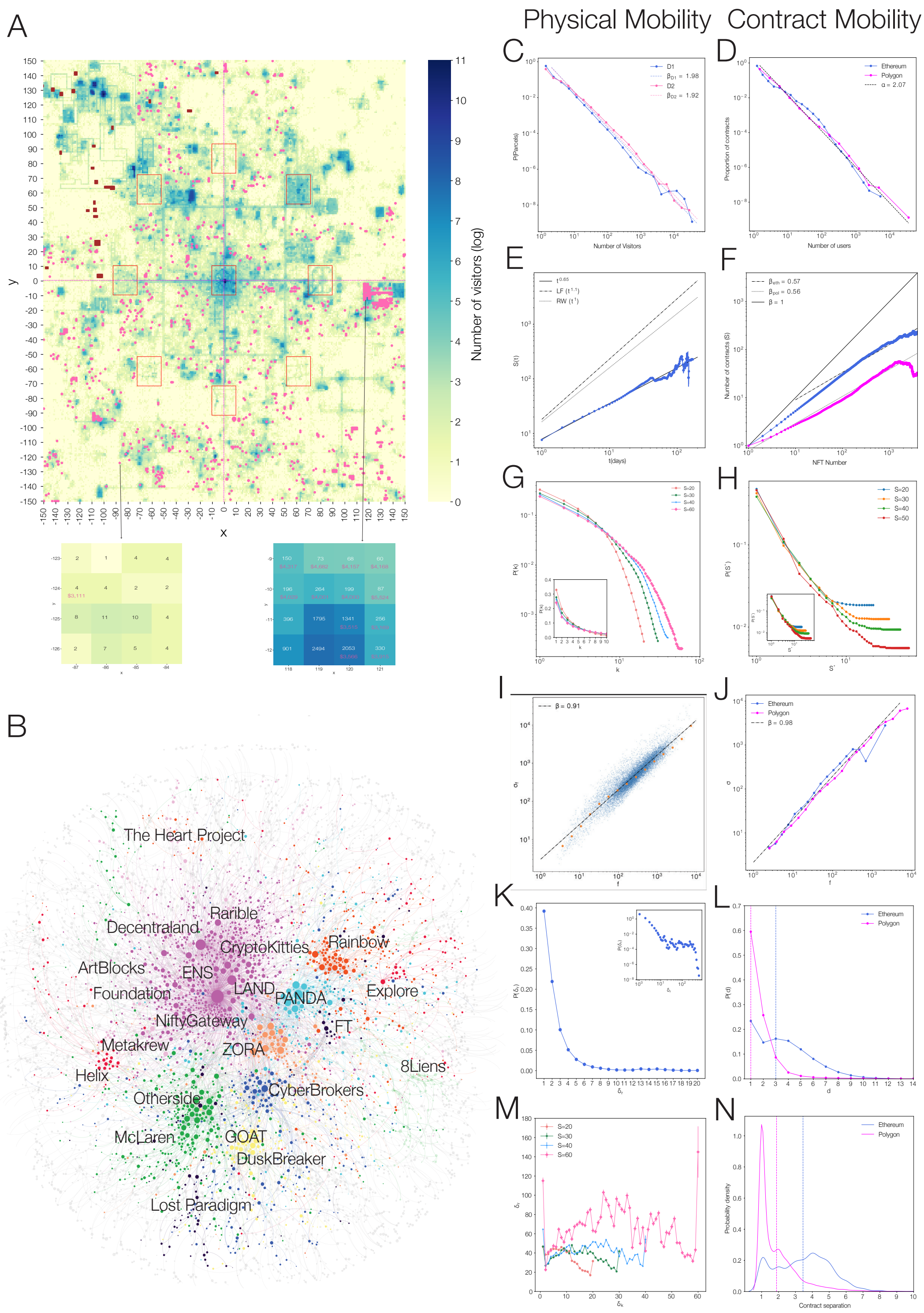

Figure 1: Patterns of individual exploration in physical and contract space in the metaverse.