Designing Nigiwai with Clauses: Embodiment via Tangible Communication on Three-Dimensional Cognitive Structures

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Abstract

Designing Nigiwai places is essential to our everyday lives and business activities. The Japanese concept "Nigiwai" does not simply mean crowdedness, but refers to environments that enable diversity of visitors, comfort, and opportunities for discovery and exchange. We frame Nigiwai as a cognitive systems problem in which designed situations support diverse individual contexts and goals. To represent this, we model scenarios as disjunctions of clauses linking goals, situations, and contexts, supporting relaxed abductive inference from observed actions to plausible contexts. As an effective means of working with such clauses, we propose a physical-digital hybrid three-dimensional (PD3D) method that combines BaleeGraph visualization with tangible hierarchical flags and color-coded links. In a workshop with sixteen participants, twenty-one clause-grounded flags were created, making visible the diversity of situations and goals across system, interaction, and ethics levels. Subsequent discussions externalized hidden contexts behind these goals, demonstrating how the method supports shared understanding. Together, the clause representation and PD3D establish a practical foundation for constructing and analyzing Nigiwai structures, providing a basis for future studies with broader participation.

1. Introduction

Currently, the global population is aging, and the effects of this trend are already evident. According to the United Nations' "World Population Prospects: The 2019 Revision," the proportion of the population aged 65 and over is projected to rise from 5.1% in 1950 to 17.8% by 2060. In addition, the total fertility rate is projected to decline from 4.97 in 1950–1955 to 2.11 in 2060–2065. This trend is particularly pronounced in developed countries and is gradually spreading to developing regions. Urban structural transformation is a crucial strategy for addressing the challenges of an aging and declining population. This approach includes reimagining urban areas to create compact

cities that promote urban concentration (Burton, 2000), alongside Transit-Oriented Development (Papa & Bertolini, 2015), which emphasizes efficient public transportation. These initiatives not only enhance physical infrastructure but also incorporate strategic zoning regulations (Pendall, 2000) and targeted deregulation to encourage specific land uses (Sorensen, Okata & Fujii, 2010). In Japan, where declining birthrates and an aging population are significant concerns, local governments are developing plans to revitalize city centers. By implementing both soft and hard measures, often supported by national government subsidies (Morikawa, 2020), they aim to invigorate communities.

The concept of "Nigiwai" is consistently emphasized as key to fostering community vibrancy and sustainability. Nigiwai is the noun form of the Japanese verb "nigiwau," which means "to gather and be lively" or "to prosper." The question then arises: what kind of state would allow people to feel Nigiwai in the short to medium term while responding to an aging society? And could this lead to "prosperity" in the future? Here, we propose a new premise: Nigiwai refers to an environment where people can engage in diverse interests. In addition to the hard aspects of the city, soft aspects such as events in public squares and building uses also play an important role. It is clear that the Nigiwai sought in urban structural reforms that respond to demographic changes does not simply mean efforts such as increasing population density or the proportion of young people. In technical terms, there has been no consensus on the rigorous definition of Nigiwai as mentioned in the literature (Abdelwahab 2021), where the word has been used to simply mean a bustle of people, measurable as amalgamation of places or pedestrians in the area, and the physical interaction of people, and that an individual contributes to the Nigiwai if she/he has a purpose for being in the place and participates in a certain activity.

Additionally, there are other usages of Nigiwai: a place of Nigiwai may have just a few people, and the purpose of an individual to visit the place may be vague or diverse. According to Ohsawa et al. (2024), a strong correlation was observed between the spread of COVID-19 and the diversity of people's movement directions. Specifically, even in areas with relatively low population density, it was demonstrated that infection rates increased when moving direction entropy (MDE) was high (i.e., people were moving in diverse directions within a certain area). These areas generally align with cities that people find attractive and wish to live in. Furthermore, a study by Kondo et al. (2024) confirmed that MDE significantly improved in urban redevelopment projects aimed at creating "vibrancy."

Because Nigiwai has such a complex significance, the systematic construction of Nigiwai structures based on cognitive models has not been fully elucidated, despite its potential usefulness for managing Nigiwai. Therefore, we aim to propose a cognitive model that explains how individuals create Nigiwai within society, given its importance in the management of wealth and risks in places of human life. Technically, we introduce a disjunction of clauses that represent the diverse scenarios comprising contexts, situations, and goals of individuals who visit places. With this representation, we capture the cognition of Nigiwai, where the diverse goals and contexts are accommodated within designed situations. As a result, this approach enables explanation and management of economic and social opportunities in local regions (Kondo et al., 2024) as well as

risks such as infection spread and crimes (Ohsawa et al 2024) through situation design. Given such clauses, one can predict observable actions from hypothesized contexts under relaxed inconsistency, edit situations to increase the expected satisfaction of multiple goals across diverse contexts, and compare Nigiwai structures across levels. These elements provide a basis for computational studies.

In addition, as an effective means of working with these clauses, we also propose a systematic method for constructing cognitive structures that capture its complexity, which is a design communication method called physical-digital hybrid three-dimensional (PD3D) workshop that addresses this gap by providing a systematic approach based on cognitive models. The PD3D method combines a visualization to understand co-creation states as a carpet of the large-scale BaleeGraph (Sekiguchi et al., 2023) with physical flag markers representing hierarchical levels (system, interaction, and ethics) based on hierarchical representation of artifacts (Sekiguchi & Hori, 2020) and colored strings to create tangible network connections.

To validate the effectiveness of our PD3D workshop for constructing cognitive structures in Nigiwai management, we conducted a JURC (Japan US Research Collaboration week) Post-workshop titled “Chance Favors Nigiwai” at Stanford University: (see JURC 2025). This empirical validation serves as a test of whether our two-fold method can successfully generate meaningful insights described below for design of Nigiwai places with collaborative understanding across diverse disciplinary perspectives:

- **Novel cognitive model for Nigiwai management**: We propose the disjunction of clauses to represent the diverse scenarios of the cognition and activities to achieve goals in Nigiwai, and establish a three-dimensional structural framework that adds the dimension of low (*situation*: technical implementations of systems), middle (*function*: interactions in user experiences), and high (*goal*: ethics corresponding to social values) levels to the two-dimensional map of BaleeGraph. This combination provides a reusable cognitive model for analyzing, explaining, and designing Nigiwai places that balance opportunity with risk
- **Novel physical-digital hybrid three-dimensional (PD3D) methodology:** We realize the above 3D model as a tangible interaction approach that combines BaleeGraph with the third dimension by the flag-based hierarchical representation and colored string networks. This aims at the engagement with cognitive structures through spatial manipulation and collaborative construction with considering hidden relationships and social values.

In the remainder, we introduce our idea of clause-based representation of activity scenarios in Nigiwai places, referring to related work (Section 2), the three-dimensional methodology for design communication (Section 3), the results of its implementation (Section 4), discussion of implications and limitations (Section 5), and conclusions and future work (Section 6).

2. Nigiwai Clauses for Modelling Cognitions in Nigiwai, and the Literature

2.1 Nigiwai in Urban Planning and Nigiwai Clause

Nigiwai has scarcely been defined so far in scientific contexts, but used in various situations where some individuals co-exist enjoying the air of the place as exemplified below:

(a) The shopping street had Nigiwai since the morning.
(b) The market's Nigiwai is a symbol of the town's vitality.
(c) Winter illuminations bring Nigiwai to the city.
(d) The square in front of the station had Nigiwai with tourists.
(e) A few families sit on the grass, creating a quiet Nigiwai.
(f) On the cafe terrace, a few people chat as a gentle Nigiwai spreads.
(g) A few people on benches in the park give a sense of afternoon Nigiwai.
(h) A small group enjoyed a Nigiwai in the garden Mozart's Posthorn Serenade was played.

Although multiple individuals coexist in all these cases, the number differs by cases: From (a) through (d), the number of co-existing individuals is large: The shopping street and the market are desired to be crowded from the viewpoint of the salesclerks, as well as the square of a station in a sightseeing region. On the other hand, from cases (e) through (h), the number may be as small as less than ten for the impression of a reader. Families, couples on park benches, or those in a cafe prefer to enjoy a comfortable rest rather than the bustle of many others. They cannot enjoy the music of Mozart in a bustling garden. Another finding from just listing the use cases is that a Nigiwai is a place where the feelings that co-existing individuals are respected, not excluded for the reason of differences in the purposes or contexts from others. Therefore, everyone can enjoy the place.

Let us here express such a scenario by clause. G_i denotes the goal of the i-th individual. S denotes a situation designed or prepared in a place, which is observable. C_i denotes the context of the i-th individual, which is typically unobservable and includes motives, preferences, or constraints. The function place(S, C_i) denotes the role of the place that relates a given situation and an individual context to the realization of a goal. A clause is written as:

$$G_i \leftarrow \text{place}(S, C_i), S, C_i \quad (1)$$

Here, the i-th individual, visiting the place to fulfill G_i, that is one's own purpose to visit the place, which may differ from others in the place. The place works as a function that relates the individual's context to his or her goal, if a specific situation is set which means the design of Nigiwai. For example, if Mozart's music played until a moment is finished in case (h), those who enjoyed it may leave if their purpose was to listen to the music. On the other hand, if a piece of artwork such as Henry Moore's sculptures is exhibited in the same garden, those who like Moore would be seated there and would stay after the music. This scenario can be represented by the following set of clauses, where G_1 and G_2 represent listening to music and viewing artwork respectively, in clauses (2) and (3), and S_a and S_b the playing of Mozart and the exhibition of Moore.

$$G_1 \leftarrow \text{place}(S_a, C_1), S_a, C_1 \quad (2)$$

$$G_2 \leftarrow \text{place}(S_b, C_2), S_b, C_2 \quad (3)$$

A point here is that we added contextual terms, i.e., C_1 and C_2, which may respectively mean that individual 1 had a mental stress due to talking to too many customers in businesses on

weekdays, and individual 2 wanted to see abstract items which allow the viewer's free and unique interpretation. These represent the preparatory situation in the background of each individual. That is, the "context" here is specifically introduced in order to distinguish the observable situation of the place (S in (1)) from the internal situations of individuals (C_i in (1)). A place with Nigiwai can thus be redesigned by changing the situation, which may be playing music, exhibiting artwork, or serving coffee. Here, an essential point of Nigiwai can emerge if a new individual with a new goal appears in the place as in clause (4).

$$G_3 \leftarrow \text{place}(S_b, C_3), S_b, C_3 \quad (4)$$

Here, for this new person (No. 3), G_3 is to find a place to have a seat to attend an online meeting due to her context as a busy urban designer. Because she thinks of setting a commercial S_c below (although she is in the same S_b as above) in this park by organizing a flea market, that is C_3, she attaches posters of the flea market to the boards in the park. This behavior, different from all others, is respected and accepted, which may foster the gathering of people in the place. That is, this newcomer seeks the G_4, i.e., to organize a flea market in the park as in clause (5). Nigiwai, thus, is a place and its situation where a diversity of goals and contexts is accepted, which may foster the gathering and the evolution of the values of the place.

$$G_4 \leftarrow \text{place}(S_c, C_3), S_c, C_3 \quad (5)$$

The action of each individual may appear in an exceptional event. For example, the Left-hand side (LHS) of clauses (6) through (8) appear as actions of different people in the park on the same day, whereas on a later day, the flea market is realized as in (9).

$$\text{drink beer} \leftarrow S_a, C_1\text{: mental stress} \quad (6)$$

$$\text{have a tea-time} \leftarrow S_b, C_2\text{: like to see artwork} \quad (7)$$

$$\text{attach posters} \leftarrow S_b, C_3\text{: interested in commerce} \quad (8)$$

$$\text{sell foods} \leftarrow S_c, C_3\text{: interested in commerce} \quad (9)$$

Although all the behaviors and events in the LHSs and terms of S_x in clauses (6) through (9) are observable, C_x and G_x in clauses (2) through (5) may be hidden. However, the co-existence of all in these clauses is allowed i.e., not excluded due to difference or inconsistency. Thus, the analysis of Nigiwai place can be considered as a relaxed abductive reasoning where problem solving is regarded as the process of searching for a solution, given by a set of hypotheses. States can be here generated by applying the operators of inference, until the goal state is reached (Langley et al. 1987). The approach to infer the contexts and situations of individuals in Nigiwai, who are not excluded due to their inconsistency from others, based on their observed behaviors is regarded as abduction without inconsistency constraints among hypotheses. This idea is not new, but within the wide scope of abductive cognition (Magnani et al 2024). Thus, a Nigiwai analysis can start from a disjunctive set of statements by the Horn clauses above. For example:

G_1: relaxation ← Mozart's music, C_1: mental stress, or (10)

G_2: enjoy abstract artworks ← Moore's artwork, C_2: like to see artwork, or (11)

G_3: make a flea market ← be seated ← C_3: interested in commerce (12)

Thus, the clause (1) can be used as a template to represent the scenario of activity, including the cognition of the situation of a Nigiwai place and one's own purpose in a certain context. The values of attributes i.e., the goal, situation, and context, can be collected by questionnaires. The support of (the probability of the co-occurrence of all the events in) each clause can be learned by a classical machine learning method such as Appriori (Agrawal 1994) as its support value from the data obtain in a questionnaire asking visitors the contexts and goals in each situation in a place. Comparing the diversity of the clauses obtained here with the measured quantity of the diversity of mobility e.g. moving direction entropy (MDE in Ohsawa et al 2023, 2024, Kondo et al 2024, etc.), we expect to enable to check the lack in collected samples in the questionnaire by studying the correlation of MDE and the diversity of elements of clauses. Once the clauses are thus validated as a tool to capture the cognition of Nigiwai, it is expected that we can explain the composition of Nigiwai, design Nigiwai, and satisfy the goals of individuals. Furthermore, by deepening the interview to an individual with a novel goal, his/her context can be verbalized, which works as useful information for designing the situation of a Nigiwai place to satisfy the individual.

The clauses in Equations (1) to (12) can be interpreted within production rule architectures. The state is defined by a situation and an agent specific context. The operator edits the situation by adding or removing design features. The goal evaluates outcomes through clause support across multiple individuals. This view clarifies how an agent could search over situations while respecting diversity. It also grounds relaxed abductive inference in which cross person inconsistencies are tolerated.

In established production rule architectures such as Soar, which emphasizes general problem solving and rule learning, and Icarus, which focuses on hierarchical concepts and skills, the clause template aligns with standard ideas about goals, situations, contexts, and rule-based action selection. Our framework develops this line of work in a different direction: first, by incorporating observations of how different situations are realized across multiple individuals, as illustrated in clauses (6)–(9); and second, by applying relaxed abduction, which allows multiple alternative context hypotheses to be maintained simultaneously without enforcing immediate consistency. These elements provide a complementary approach that reuses existing mechanisms while extending their applicability to Nigiwai settings.

2.2 Network Visualization

Regarding teamwork in design processes, network-based structuring of communication histories revealed communication signatures and behavioral patterns (Uflacker et al. 2009). BaleeGraph, developed for representing co-creation networks for social good, provides a foundation for mapping interconnections between diverse elements, which may be technologies, concepts, and stakeholders (Sekiguchi et al., 2023). This network visualization approach becomes

useful for interdisciplinary phenomena such as Nigiwai, where latent connections between situations and contexts, as mentioned in 2.1, are difficult to describe explicitly. It has at least two implications for the preparatory phase of the analysis and the synthesis of Nigiwai.

First, the diverse scenarios of individuals in the place, where various contexts lead to the achievement of goals using the functions of the place, may be studied by interdisciplinary collaboration of various scientists or business-people represented by the nodes on the graph. This approach has been published so far as KeyGraph-based innovators marketplaces as in Ohsawa and Nishihara (2012) and still used for topic discovery for innovation on AI ethics as in Li and Yu (2025), which can be regarded as recently extended into the Balee Carpet Karuta (Sekiguchi & Ohsawa, 2025), by including phrases generated from the learned text such as the Web outside the given input text using Large Language Model (LLM)-based generative AI.

Second, by extending a two-dimensional networked visualization by adding a new dimension of hierarchy as in 2.3, which connects elements to the values obtained (or goals achieved, which may be declared in advance or emerge on the way of intended actions), we can consider the disjunction of scenarios within a Nigiwai considering the effect of contexts and situations on the achievement of goals.

Finally, one of the strengths of such network visualizations, like BaleeGraph, can be understood as not providing a single "correct" representation, but rather presenting the network of relations among key elements to explore the design space from new perspectives and to uncover insights that might otherwise remain implicit.

2.3 Hierarchical Frameworks

Complex socio-technical systems require structured approaches that can organize phenomena across multiple levels. The hierarchical representation of artifacts, extending from traditional design theory, has been adapted to address social considerations in technology design. Sekiguchi and Hori (2020) proposed a hierarchy for organizing social considerations such as artificial intelligence (AI) ethics. This hierarchy covers system-level implementations (complete systems, services, or mechanisms), interaction-level experiences (user experiences and customer interactions), and ethics-level values (social values including diversity, equity and inclusion). This hierarchical approach has proven effective for organizing interdisciplinary discussions and revealing connections that might otherwise remain invisible.

In this study, the interaction level can also be understood as corresponding to the functional mediation of the place between situation and context, as represented in the Horn clause template. From this perspective, the hierarchical Horn-clause representation (System → Interaction → Ethics) and the clause template with the *place* operator express the same scenario. Note that the individual's context works as an additional variable beyond the three levels, serving as the background condition for each scenario.

2.4 Tangible design communication

Analysis of cognitive characteristics and interaction behaviors in the design process revealed that teams with greater cognitive style diversity discussed more topics and exhibited greater interconnectedness of those topics. This increased number of topics may indicate a more thorough exploration of the design space, suggesting that maximizing cognitive style diversity in design teams argues for idea generation (Jablokow et al., 2019). Creative communication methodologies for design have evolved from traditional discussion formats toward more interactive and embodied approaches. Physical artifacts can serve as boundary objects that help participants from different disciplines communicate and collaborate more effectively (Carlile, 2002). The integration of physical and digital elements in collaborative settings shows promise for enhancing understanding and generating novel insights. Kent et al. (2021) revealed that Mixed Reality technology, which combines physical and virtual environments, enhances both individual cognitive engagement through advanced visualization of design concepts and distributed cognition through collaborative manipulation and shared visualization of physical-virtual prototypes. The Balee Carpet Karuta (BCK), a competitive game-based design communication transformed traditional card games into logic-generation activities for collaborative problem-solving (Sekiguchi & Ohsawa, 2025). Therefore, tangible interaction design principles suggest that physical manipulation of abstract concepts facilitates deeper cognitive engagement and supports the distributed cognition processes essential for complex problem-solving.

Overall, prior work on network visualization, hierarchical frameworks, and tangible interaction is used as a cognitive instrument. The clause representation provides structured knowledge. PD3D provides a shared representational workspace that supports distributed cognition and the formation of common ground. The combination serves computational cognitive modeling and supports diverse implementation choices.

3. A Three-Dimensional Design Communication

3.1 Three Items for the Three-Dimensional Structure

We developed a PD3D design-communication method to construct cognitive structures corresponding to the above-mentioned clauses for visualizing Nigiwai. Here, we employed three core elements below:

- **Carpet**: A 1,800mm × 2,400mm printed BaleeGraph visualization
- **Flags**: Physical markers with attached sticky notes for ideas
- **Strings**: Colored vinyl tape for visualizing connections

The carpet serves as a shared surface for perception and reference. Flags serve as symbolic propositions at the system, interaction, and ethics levels. Strings instantiate relational hypotheses among flags and across levels. These elements work together to create a three-dimensional cognitive structure that spans from technical implementations to social values represented at the

ethics level, which work as the preset situation of Nigiwai. Therefore, PD3D supports cycles of observation, representation, inference, and evaluation within a shared representational workspace and participants made all structural decisions. The resulting structure reflects human reasoning.

3.2 Carpet: BaleeGraph of Nigiwa-Related Research and Practice Themes

The carpet served as a shared canvas displaying relationships between key concepts from existing Nigiwai research and practice, generated using BaleeGraph visualization technology. Placed on a table, this 1,800mm × 2,400mm physical instantiation of digital network visualization accommodated multiple participants simultaneously, enabling them to explore the research and practice landscape from various angles and examine individual nodes and connections in detail. Beneath the carpet, 2-inch thick insulation material enabled flag insertion at any point of interest, creating an interactive experience that engaged spatial cognition.

BaleeGraph is a network-style visualization method. In BaleeGraph, black nodes represent entities such as researchers or practitioners with their own themes. Blue nodes are arranged radially around the black nodes, indicating keywords of the themes. When a certain degree or more of similarity between themes is recognized through calculation, the nodes turn red and are connected by red edges. In this way, clusters of red nodes and edges are formed in areas where there are shared interests. Keywords unique to each theme remain as blue nodes.

Following the original BaleeGraph framework, an LLM (OpenAI API, gpt-4o) is used to extract salient keywords from the input texts provided by participants. These keywords are then represented as vectors using a locally run embedding model (sentence-transformers), and pairwise semantic similarities are calculated to generate candidate links.

The BaleeGraph used in the design communication was created locally by one of the authors using a modified version of the baleegraph.com program, in which the font style was slightly adjusted to improve clarity for printing compared with the web-based environment. The text inputs provided directly by researchers and practitioners or organized using ChatGPT. Additionally, as supplementary materials for the black node information, cards containing these persons' photos and theme summaries were created and placed on the carpet.

3.3 Flags: Three-Level Hierarchical Framework

The workshop methodology (PD3D) applies a hierarchical framework established in previous work on ethical design (Sekiguchi & Hori, 2020) and extends it to more multi-dimensional spaces such as Sekiguchi & Ohsawa (2024). This framework provides a structured approach to organizing ideas across system implementations, interaction experiences, and social values, enabling participants to understand relationships between concrete technical solutions and abstract social goals. The three levels this work applied are as follows:

- **System level**: Complete systems, services, or mechanisms as organic wholes
- **Interaction level**: Experiences for system users and customers
- **Ethics level**: Social values including diversity, equity and inclusion

These levels maintain purpose-means relationships where higher levels represent purposes and lower levels serve as means to achieve them. Technical systems enable specific user interactions, which in turn realize social values. Figure 1 shows an image of flags. As shown here, participants expressed ideas by attaching notes at appropriate heights on flag poles, physically representing the hierarchical nature of their contributions. This tangible representation helped participants immediately understand relationships between situations where technologies are implemented and the resultant values, making theoretical structure actionable in practice.

In Figure 1, the area in the dotted ellipse indicates a flag. On the notes on this flag, 'AI-based tools support ethical design' is written by a participant at the system level; 'Urban planners design "Nigiwai" with clear social values' is written at the interaction level; 'Society provides a platform for attracting diverse people' is written at the ethics level. Participants made their own flags to represent their scenarios of Nigiwai.

3.4 Strings: Three Colors of Networks above BaleeGraph

For the design communication, we used color-coded strings to visualize types of connections:

- **Red strings**: System level connections between technical implementations
- **Yellow strings**: Interaction level connections between user experiences
- **Green strings**: Ethics level connections between values and principles

This color coding served multiple functions. It allowed participants to immediately identify connection types in the emerging network. It enabled analysis of network density and patterns at each hierarchical level. It facilitated discussions about cross-level connections when strings of different colors converged at particular flags. These string images are also shown in Figure 1.

3.5 The Implemented Process of Design Communication

Activities were designed as four main phases to progressively build from individual idea generation to collective structure visualization and reflection:

- **Flag creation phase**: Create flags with poles and sticky notes
- **Flag presentation phase**: Explain their flags to facilitate knowledge sharing
- **Connection phase**: Use colored strings to create network connections
- **Reflection phase**: Share own understanding of the structure and discuss it with others

In flag creation, participants created flags by attaching notes at the three hierarchical levels to poles, which were inserted through cuts in the carpet into insulation material beneath. Each participant could create up to two flags, allowing expression of multiple research and practice interests. Here, each participant explained his/her flag to others. In the connection phase, participants used colored strings to create networks both within and across levels, representing existing relationships or potential future connections. This phase encouraged negotiation and discussion as participants

identified meaningful connections. Then, participants shared their understanding of emerging network patterns. Each participant identified significant patterns, clusters, or surprising connections in the evolving structure. This collective sense-making process synthesized individual observations into shared insights about Nigiwai structure and organization potential.

4. Results

4.1 The Implementation and Participation of Design Communication

The JURC Post-workshop "Chance Favors Nigiwai" was conducted on July 31, 2025, at Stanford University's Li Ka Shing Center for Learning, with sixteen participants from Japan and the United States representing diverse backgrounds, including computer science, urban planning, education, and healthcare spanning both academic and business sectors. The workshop was built upon the JURC Session "Nigiwai: Placemaking Driven by Human Behavior" held on July 29, incorporating its key themes into the tangible, interactive format shown in the methodology section.

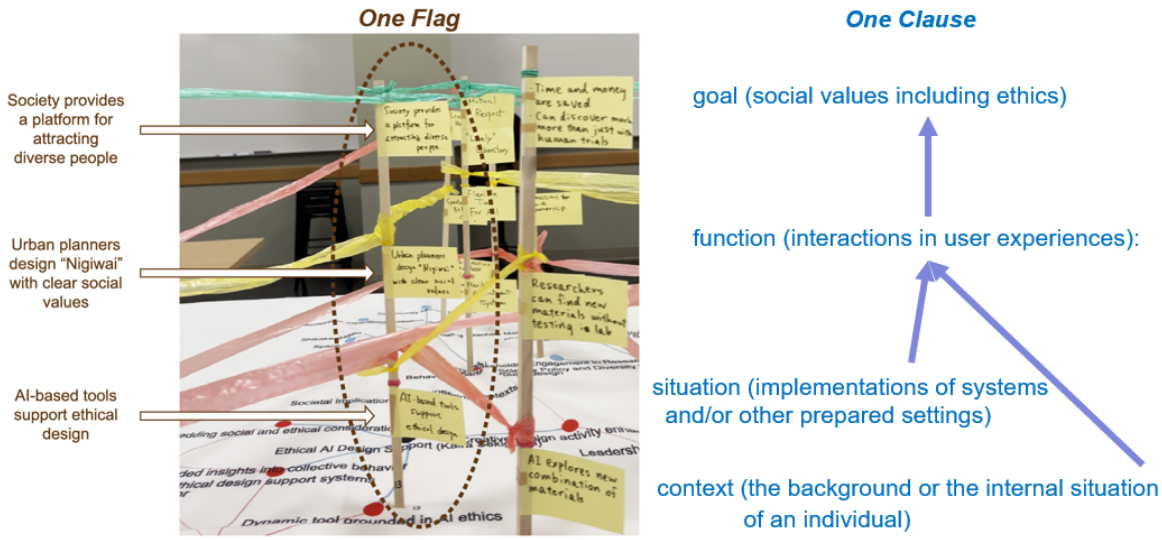

Figure 1. Image of a flags created during the design communication, corresponding to the proposed clause.

4.2 Created Flags

Participants created a total of twenty-one flags positioned across the BaleeGraph carpet as shown in Figure 2. Some participants created two flags each, with one participant creating three. The flags were placed strategically near keywords of interest identified on the carpet or in blank areas where participants added new concepts not previously represented. The physical insertion of flags through cuts in the carpet created a literal three-dimensional structure that manifested the hierarchical

organization of Nigiwai concepts from technical implementations through user experiences to social values.

Then, we can categorize the descriptions of each flag. To maintain neutrality in the categorization process, we used *ChatGPT−5 Pro* to generate the categories and perform the classification. In this case, we permitted each flag to be assigned to more than one category. Table 1 shows the categorization of flags and their proportions. The percentages were calculated by dividing the count by the total number of flags (=21). Additionally, Table 2 shows the descriptions of flags and corresponding category labels. The descriptions were extracted and organized by one of the authors after the experiment. Here, we rephrase an *interaction* with a *function* for the humans interacting with the situation created in the place by technology or an artificial system. In addition, we regard the social value as the pursued *goal* corresponding to the clauses in Section 2.1.

Table 1. Categorization of flags and their proportions

Label	Name	Count	Percentage
A	Urban Planning & Public Space	10	47.6%
B	Mobility & Transportation	3	14.3%
C	Health, Medical & Well-being	6	28.6%
D	Data, AI & Smart Systems	6	28.6%
E	Governance, Participation & Policy	4	19.0%
F	Education, Talent & Work	4	19.0%
G	Economy, Inclusion & Startups	2	9.5%
H	Science & Technology R&D	2	9.5%

4.3 Participants Discussion on Flags

Extensive discussions on Diversity, Equity, and Inclusion emerged as a central theme, connecting to concepts of Lively Laboratory (Flag 21), next-generation science approaches (Flag 12), and investment strategies (probably Flag 9, though the record is slightly incomplete). Participants explored contrasts between Japanese and US approaches to diversity, examined characteristics specific to Japanese rural areas, and discussed university hiring practices regarding women. The importance of examining ratios rather than absolute numbers when assessing diversity was emphasized. Another major discussion thread focused on integrating human health monitoring technologies (Flag 16) with human-centered urban design that explicitly includes children's perspectives (Flag 2), to reach approval that technologies for health monitoring could be useful for the creation of Nigiwai places. Additionally, the concept of "Shikake" (Matsumura, Fruchter & Leifer, 2015) (Flag 20) received particular attention, with participants emphasizing the importance of design interventions that non-coercively change behavior in fostering Nigiwai (Flag 4, 5).

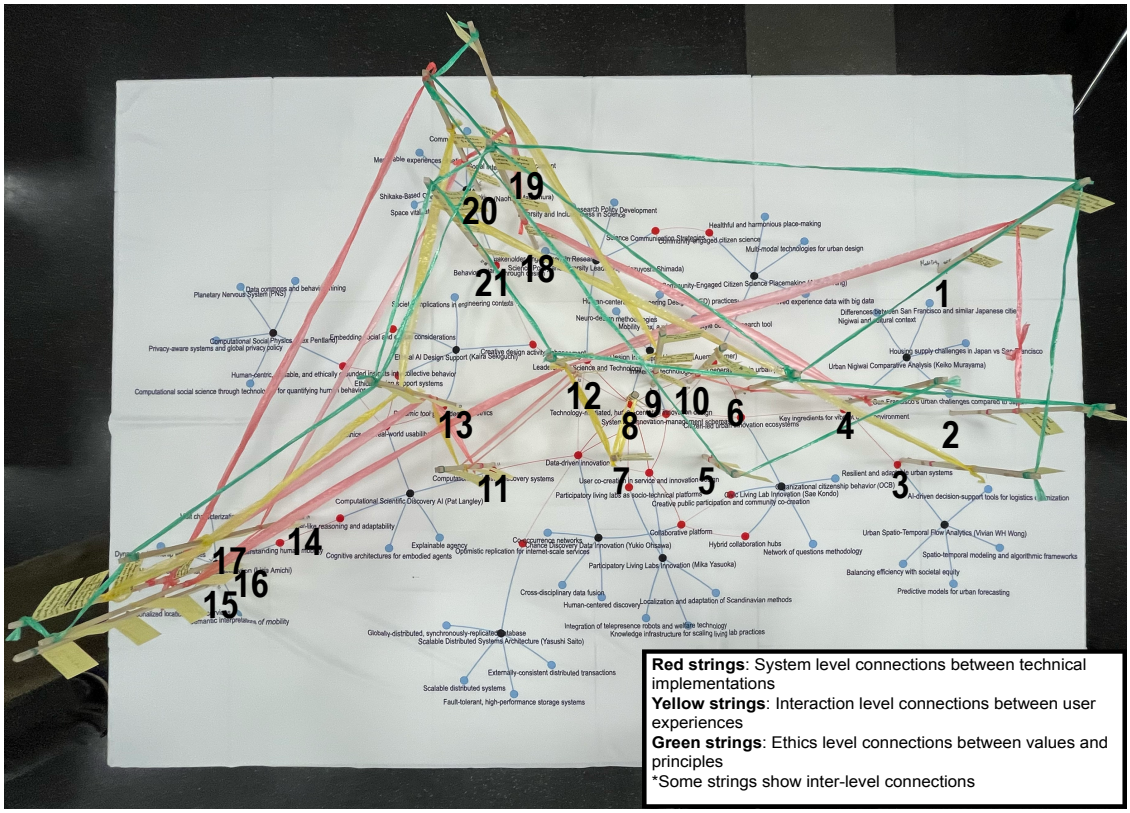

Figure 2. Image of the cognitive structure of Nigiwai themes generated in the design communication and twenty-one flags connected on the map. The numbers indicate the locations where each flag is placed.

4.4 Participants Discussion on Connections

The connection phase revealed distinct network structures emerging at each hierarchical level. Cross-level connections also emerged throughout the structure. In this phase, participants are emergently forming networks through their own interpretations while communicating with each other. Then, as in Figure 2, the cognitive structure of Nigiwai was generated. Here, we find the yellow strings are structured similarly to the red string, indicating alignment between technical implementations and user experiences. In contrast, the green strings at the ethics level followed different organizational logic, revealing that value considerations connect through patterns distinct from technical or experiential relationships.

Then, the number of unique edges is twelve for red, eight for yellow, and seventeen for green, as confirmed from the photographs of the completed network. Next, we construct a correspondence table between the flags, assigning 1 if a string is stretched between a pair and 0 if not. Based on this

representation, we calculate the Euclidean distances among the red, yellow, and green networks. The results show that the distance between the red and yellow networks (=4.2) is smaller than that between the yellow and green networks (=4.8), which in turn is smaller than that between the red and green networks (=5.0).

In conclusion, participants articulated several key observations about the three-dimensional structure that emerged. The ethics-level discussions externalized hidden latent values essential for Nigiwai that might not emerge from technical or interaction considerations alone.

5. Discussion

5.1 Three-Dimensional Structure: Revealing Multi-Level Complexity of Nigiwai

The results validate how three-dimensional structuring enables comprehensive understanding of Nigiwai phenomena. The twenty-one interconnected flags across three levels, with distinct network patterns at each level and between levels, reveal relationships that would remain hidden in traditional approaches.

These results indicate several requirements for cognitive systems. Diversity-aware evaluation over clause sets is needed rather than a single goal utility. Operations that edit situations are useful for exploring design alternatives. A shared representational workspace supports coordination among multiple people. Relaxed abductive inference is needed to tolerate inconsistencies across individuals.

5.1.1 Revealing Hidden Values and Contextual Embeddedness

Nigiwai is fundamentally related not only to urban planning and public space but also to various other themes as shown in Table 1. The three-dimensional structure served an important discovery function, particularly in revealing hidden latent social values. The DEI discussions exemplify this phenomenon, where consideration of target values proved fundamentally important for understanding Nigiwai.

Note that the *contexts* in the clauses (6) through (8) in Section 2 were not explicitly written on the flags, but were externalized via the insights in the oral presentation of each participant. The contextual parts of the clauses, which is supposed to connect the written scenarios if similarity of contexts in spoken scenarios are found, are perceived as diversified rather than overlooked in the conversation. For example, the participants' emphasis on Shikake as mentioned above indicates that the design of Shikake for creating a Nigiwai requires not only conceptual discussion but also practical implementation of Nigiwai in the social contexts of Japan and US, which was highlighted in the conversation: The Flag 4 and 5 in Figure 2 and Table 2 were given by a leading figure in the computer technology industry and the Flag 20 was done by a Japanese university professor, which represent different goals through applying Shikake to different situations. The participants' exploration of contrasts between Japanese and US contexts, and between historical (Showa era) and contemporary periods, indicates that Nigiwai structures are deeply embedded in specific social and temporal conditions as well as individual contexts.

Thus, from the conversation, we found that the three-dimensional visualization aided the externalization of these individual high-level contexts by showing how ethics-level considerations (green strings) connected differently from technical implementations (red and yellow strings), revealing that creating Nigiwai places cannot be separated from questions about what society values, how inclusion and diversity are measured, and which cultural values receive priority.

As a side-effect, additional insights here included the identification of disciplinary gaps in current scope of the workshop and the real variety of Nigiwais. Participants noted the absence of sports expertise in these networks and suggested inviting such experts to future sessions.

5.1.2 Distinct Network Structures and Organizational Logic

The observed formation of different network structures at each hierarchical level confirms the multi-dimensional nature of Nigiwai. The structural similarity between system and interaction level networks suggest alignment between technical implementations and user experiences. In contrast, the distinct pattern formed by green strings at the ethics level indicates that social considerations follow different organizational logic from technical or experiential relationships.

This structural differentiation provides practical guidance for organizing Nigiwai initiatives. The participants' observation that ethics-level collaborations correspond to purpose-based approaches while system-level collaborations correspond to means-based approaches suggests that the choice of collaboration level should depend on whether the primary goal is value alignment or technical implementation.

5.2 Methodological Sustainability and Scalability

The structures surfaced by PD3D this time should be understood not as definitive truths but as organized hypotheses that preserve diversity while making Nigiwai analyzable and actionable. To reveal a fuller landscape of Nigiwai structure, future workshops need to involve broader sites and a more diverse range of participants. At that point manual synthesis becomes impractical and computational assistance is required. The clause-based representation introduced in this study provides the logical foundation for such assistance because it encodes situations, contexts and goals as production rule knowledge, supports relaxed abductive inference from observed actions to plausible contexts, and enables comparative evaluation of edits to situations across diverse individuals.

While the design communication successfully demonstrated the value of PD3D approaches for constructing cognitive structures, practical challenges require attention. The procurement and storage of insulation materials present logistical difficulties that limit the method's scalability and sustainability. Future iterations must explore alternative implementation approaches that maintain the benefits of tangible, three-dimensional visualization while reducing material requirements.

Another limitation lies in expressing the branching of scenarios. As questions arose from participants, scenarios can potentially branch in both directions—from technology toward society and from society toward technology. It is difficult to represent this with a flag. It is desirable to allow scenario branching, like a tree with branches and roots.

6. Conclusion and Future Work

This paper presented and validated a novel PD3D method of design communication for constructing three-dimensional cognitive structures including clauses essential to Nigiwai management. The approach successfully generated twenty-one interconnected research themes across three hierarchical levels, revealing distinct network structures and cross-level relationships that provide a foundation for systematic Nigiwai understanding and implementation.

The three-dimensional structure also revealed critical gaps in current Nigiwai representation. The participants' suggestion for involving social science and humanities experts indicates recognition that understanding Nigiwai's value dimensions requires expertise beyond technical disciplines. The identified absence of sports perspectives, and the need for AI researchers to articulate "healthy" visions, became visible precisely because the hierarchical structure forced consideration of how different disciplinary contributions map across levels.

These observations suggest that future Nigiwai research requires more diverse disciplinary involvement, including social science and humanities experts who could contribute deeper understanding of value dimensions, to capture the complexity of creating divergent and comfortable places. The three-dimensional framework provides a scaffold for organizing these diverse contributions, showing where each discipline's expertise is needed and how different perspectives can be integrated across levels. The implemented method also revealed that different types of collaboration emerge from different levels in the hierarchy, with ethics-level networks supporting purpose-based collaboration while system-level networks facilitate means-based cooperation.

Other future work is addressed to the preparatory step for the design communication. That is, the LLM used in preparing the BaleeGraph reflect the knowledge and intelligence of existing individuals and communities, rather than its own insight of the context behind human life as pointed out in Terrence J. Sejnowski (2023). A new encounter of a newcomer to a place, who is respected and accepted, may stimulate a new feeling not covered so far by analysis of data on questionnaire or logs of communication is beyond the scope of BaleeGraph. Methods to improve the completeness to capture Nigiwai to catch up with the infinite creativity of Nigiwai place is addressed to our future work too.

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Table 2. Summary of the descriptions in twenty-one flags

No	System level i.e., Situation	Interaction level i.e., Function	Ethics level i.e., Goal	Category labels
1	Multi-Modal Transportation Choice (walk, bike, public trans, last mile transit	Reduce Car Dependency Increase Walkability	Reduce Adverse Environmental Impact Improve Health / Well-being. QOL	A, B, C
2	Child Friendly Urban Design (Early Childhood 0-5 yrs o.	Play-based Sate and Clean Urban Environment	Sate and Vibrant Sense of Community place for ALL (outdoor / street	A
3	Encourage people to provide Data set.	Design Safe & Well-used Building	Long-Life & Sustainable urban Environment	A, D
4	Service Systems as muti-level responsible actors | comparative analysis	Secure Belonging Value Cocreation university& City interaction AI Digital Twin Communication	Shikake design as Noncoercive ethical behavior | Good Challenge & Growth	A, D, E
5	Collective | Service Systems Capabilities ++ benefits ++ harms --	Value Co-creation win-win non-coercive interaction & change AI-Digital Twin	Individual | Shikake Design Non-coercive interaction & Change of service systems at all levels	D, E
6	Evaluation of Environment	Create new policies	People can select Well-being settle down	C, E
7	Improving the work environment in Japan	making 10,000 friends in Bay area	Encouragement of Studying abroad for younger Students	F
8	EDUCATIONAL METHOD ON MEDICAL SCHOOL STUDENTS	CLASS INTERNSHIP	MEDICAL START-UP (INNOVATION FOR HEALTH	C, F
9	SYSTEM: INCLUSIVE CAPITALISM	- VENTURE CARTER FOR INDIVIDUALS IN POVERTY (INCUSION IN CAPITAL FORMATION - PRODUCT DESIGN FOR NEEDS OF PEOPLE IN POVERTY	ETHICS: EQUAL WEALTH DISTRIBUTION	G
10	Data Visualization of infection-spread risks in local regions	Controls of human flow in traffic systems (roads, trains, buses	Safety in Nigiwai	A, B, D
11	Al explores new combination of materials	Researchers can find new materials without testing in lab	・Can discover much more than just with human trials ・Time and money are saved	C, H

12	Developing molecular tools for understanding cell biology	Encouraging next-generation scientists to pursue their interest	Advancement in science technology Positive mentality Inclusive academic environment	H
13	AI-based tools support ethical design	Urban planners design "Nigiwai" with clear social values	Society provides a platform for attracting diverse people	A, D
14	Change people's mindset	Provide choice of transformation	Create human-friendly town	A
15	JURC is R. collaboration for ex. (1 scientists, (2 startup・pre startup, (3 Finance SP, (4 Funding Agency	DEI Education people are able to exchange・interact to make team in only 3 days	Ethics Global Unicorn ・IP ・share rate of Equity	F, G
16	Mikiwame ls diagnose your status of your hearth	ePHR You vs. home Your (Home vs. clinic You (clinic vs Hospital	Ethics Clinical Trial ・How to protect privacy ・By coding it's easy and foster for CT and New Drug	C
17	- Understanding Human Mobility Behavior (Place definition, Data analysis, Ethical Methods Place cultural signature context influence - AI & Knowledge-driven approaches Behavioral Data	An adaptive Human-Place model able to explain and capture Individuals' usage of space	- Create an adaptive and responsive Urban environment with privacy-preservation - Capture what is a normal behavior and usage of space & what can be anomalous	A, B, D
18	Dialog among various stakeholder (politicians, Gov. officers, researchers, residents, etc.	Decisions with ownership	Create a place where everyone wants to go	A, E
19	INFORMATION PLATFORM FOR ELDER (65~ PERSON	SOCIAL EVENTS (FOOD, TRAVEL, SERVICE	JOYFUL LIFE	C
20	SHIKAKE (visual, attractive, tangible trigger	Spontaneous Behavior Change	Create Memorable Place	A
21	Flexible Appointment System	Flexible Time For All	- Mutual Respect - "Lively" Laboratory	F