Gender as a Spherical Topological Space with Fuzzy Memberships [DRAFT 10/23/25]

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Abstract

We model gender as a system of socially realized categories that are defined by aggregating observers' individual perceptions of a subject's gender. In our *Axis Model*, we introduce the concept that gender lies on a woman–man line. Infinitely many gender categories can be created by midpoint-splitting when existing categories are descriptively insufficient. The *Sphere Model* generalizes this concept to a spherical space, where midpoints begin as universes and collapse to points. In the sphere model, categories drift and adopt new specifications. The framework shows that under minimal assumptions and through natural social forces, gender categories proliferate and reconfigure over time. The theory was developed by examining gender, but applies to any consensus-driven system that discretizes continuous variation.

1 Introduction

Queer theory employs varied, contradictory language to describe gender categories. As a result, debates often stall on definitions, and disagreement is as much about terminology as about substance. Without a structural framework, conversations about gender risk becoming circular, fragmented, and confused. Rather than providing a prescriptive model of what gender should or could be, we focus on a descriptive approach that aggregates perceptions, ingesting individuals' perceptions of gender without making judgments about the validity of those perceptions.

To facilitate rigor and exactness, we model gender as a topological space with fuzzy memberships. We describe how these categories emerge and drift over time. The approach captures both the proliferation of new genders and the shifting of existing ones.

Contributions.

1. **Axis Model:** A scalar model on $[0, 1]$ that formalizes midpoint splitting, showing that infinitely many gender categories can arise.
2. **Sphere Model:** A spherical model on S^2 that generalizes the axis, introducing universes of midpoints, collapse to single points, and collective drift (spherical codes).
3. **Extensions:** The framework generalizes to orientations and relationship structures, and beyond gender to other social categories.

1.1 Assumptions and Design Choices

We use a model of gender that renders gender categories maximally descriptively useful. Genders are socially defined categories used to facilitate clarity when communicating about certain collections of behaviors and expectations. Each assumption reflects observed properties of gender classification.

- **A1 (Externalism):** Gender is socially realized, defined by aggregated observer judgments. This captures gender's relational nature and places minimal important on self-identification. We make no claims about the validity of gender self-identification, instead orienting our evaluation to gender as it exists in society. Is it possible for an observer to heavily weigh a person's self-identified gender in their evaluation, but no such commitments are privileged in the model.
- **A2 (Gender cue continuity):** Observers examine gender cues, which are continuous scores that influence their perception of a person's gender. The universe of gender cues is infinite, including physical indicators, social behaviors, associations, etc.
- **A3 (Observer heterogeneity):** Each observer has a distinct scoring function based on their own system for categorizing people into genders.
- **A4 (Equal influence baseline):** Consensus for gender categorization is the average of all observers. Individual observers are not formally privileged by the model, but influential observers have the ability to create new gender cues for others or influence others' scoring functions.

- **A5 (Descriptive usefulness):** Gender categories are assumed to tend toward maximizing distinctiveness between categories. This is based on the assumption that social categories are meant to be maximally useful.
- **A6 (Emergence):** When existing categories are not sufficient to usefully describe significant subsets of people, a new category emerges.

2 Axis Model

We model gender as a socially realized quantity, externally defined through observers. This framework consists of observable traits, observer-specific scoring functions, consensus values, fuzzy classification, and a midpoint-splitting process. The Axis Model situates gender on a woman–man line segment.

2.1 Cue space: observable traits

Let d denote the number of cues relevant to gender perception. Each person is represented by a *cue vector*

$$c = (c_1, c_2, \ldots, c_d) \in C = [0,1]^d,$$

where $c_j = 0$ is maximally woman-coded, $c_j = 1$ maximally man-coded, and intermediate values represent gradations.

2.2 Observers and scoring functions

Let $\mathcal{O}$ be the set of observers. Each observer $o \in \mathcal{O}$ maps cues c to a *gender score*

$$s_o : [0,1]^d \to [0,1].$$

Here $s_o(c) = 0$ corresponds to "woman," $s_o(c) = 1$ to "man," and intermediate values to ambiguous readings.

Linear baseline.

$$s_o(c) = \frac{\sum_{j=1}^{d} w_{oj}\, c_j}{\sum_{j=1}^{d} w_{oj}}, \qquad w_{oj} \geq 0.$$

The coefficient w_{oj} is the *weight* observer o assigns to cue j: it measures how strongly that trait influences their gender perception. For example, if an observer tends to classify people primarily by hair length, then the hair-related coordinate will have a high weight, while less relevant traits (such as clothing style for that observer) will have smaller weights. The normalization by $\sum_{j=1}^{d} w_{oj}$ ensures that scores remain between 0 and 1 and that weights capture relative rather than absolute importance.

Nonlinear extensions. Observers may use interaction terms:

$$s_o(c) = f_o(c_1, \ldots, c_d),$$

with f_o continuous and possibly nonlinear. This allows observers to make complex judgements about the interactions between different cues.

2.3 Socially realized gender value

The consensus score is the average of all observer scores

$$\phi(c) = \frac{1}{|\mathcal{O}|} \sum_{o \in \mathcal{O}} s_o(c).$$

Thus $\phi(c) \in [0, 1]$ is the socially realized gender score: external, not self-ascribed.

2.4 Gender categories as labels

At time t, recognized categories are

$$K_t \subseteq [0, 1].$$

Initially $K_0 = \{0, 1\}$, where 0 and 1 represent the categories *woman* and *man*. Midpoint accumulation yields new categories, e.g. $K_1 = \{0, \frac{1}{2}, 1\}$, where $\frac{1}{2}$ represents the category *nonbinary*.

2.5 Fuzzy classification

Each $r \in K_t$ serves as the center of a fuzzy set, represented by a membership function. We define this using a kernel κ that decreases as the distance from r grows:

$$\mu_r(x) = \kappa(|x - r|), \qquad x \in [0, 1].$$

In words, $\mu_r(x)$ gives the degree to which the score x belongs to category r: if x is exactly at r the membership is maximal, and as x moves away from r the membership value decays smoothly rather than dropping abruptly. This reflects the intuition that people near the boundary between two categories can reasonably be considered to belong partly to both.

For practical purposes, however, categories are often treated as crisp. In this case, we assign each individual to the category whose label r is closest to their consensus score $\phi(c)$:

$$A_t(c) = \arg\min_{r \in K_t} |\phi(c) - r|.$$

That is, fuzzy sets describe overlapping regions of membership, but crisp assignment picks the nearest available label as the final social classification.

2.6 Midpoint-splitting rule

If $a < b$ are adjacent labels in K_t and individuals satisfy

$$d(x; a, b) = \min\{x - a,\ b - x\} > \tau,$$

then a new label appears at $m = \frac{a+b}{2}$, updating $K_{t+1} = K_t \cup \{m\}$.

2.7 Implications

- Heterogeneous observers result in different local classifications. While the model results in a single gender category value, that category depends on the conclusions of each observer. Different sets of observers can yield different category conclusions.
- Consensus $\phi(c)$ smooths judgments into one external score.
- Fuzzy memberships capture graded belonging.
- Midpoint-splitting predicts proliferating categories.
- K_t grows without bound, potentially dense in $[0, 1]$.

2.8 Limitations

The Axis Model assumes category meanings are fixed (what it means to be "woman-coded," "man-coded," etc.). In practice, these shift. The model is thus a base case.

3 Sphere Model

The Axis Model is a special case of the Sphere Model, restricted to a single great circle. All Axis results are recovered by projection, but the sphere avoids privileging endpoints and permits category reconfiguration.

We represent gender as points on the unit sphere $S^2 \subset \mathbb{R}^3$. A sphere is chosen to represent the gender space due primarily to three qualities:

1. *Boundarylessness:* No edges, unlike $[0, 1]$.
2. *Rotational invariance:* SO(3) acts transitively.
3. *Geodesics:* The woman–man binary is a geodesic arc; $\theta(x, y) = \arccos(x \cdot y)$ defines distance.

Midpoints as universes. For antipodes u, v, the midpoint set is the equator

$$E = \{x \in S^2 : u \cdot x = v \cdot x = 0\}.$$

Collapse to a point. Use of a midpoint category selects $m \in E$, collapsing the equator to one label.

Collective drift. Labels $L_t = \{\ell_1, \ldots, \ell_k\} \subset S^2$ drift to maximize minimal pairwise distance:

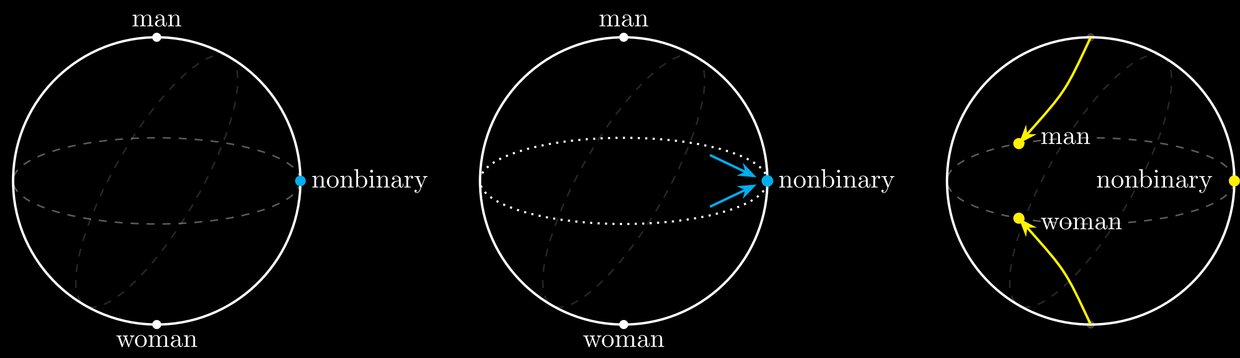
$$\ell_1, \ldots, \ell_k \approx \arg \max_{x_1,\ldots,x_k \in S^2} \min_{i \neq j} \theta(x_i, x_j).$$

3.1 Implications.

The sphere model is more easily understood when instantiated. Suppose there is a spherical space where the genders *woman* and *man* exist at the poles and *nonbinary* exists at the equator (see *Figure 1A*). Because *nonbinary* is initially defined in opposition to the categories *man* and *woman*, it exists at all midpoints between the two. The category lacks an ideal, as opposed to *man* and *woman*, which have ideals represented by points.

As the term *nonbinary* is used to describe individuals, it is no longer defined only in opposition to the other genders, but begins to adopt an identity of its own. For example, while watching the television show Steven Universe may not have had strongly defined gender associations with *man* and *woman*, enough *nonbinary* people watched it to make the pattern identifiable to observers. As *nonbinary* became a category, it took on these associations which caused it to develop an ideal and collapse to a point. This phenomenon is represented by *Figure 1B.*

When *nonbinary* takes on a category identity and collapses to a point, it is no longer the case that all the gender categories are as far away from each other as possible. This means they are not maximally descriptively useful. As a result, the points shift to maximize the



(A) Sphere with poles (man, woman) and equator E; nonbinary is a midpoint on E.

(B) The equator E collapses to a single category point: nonbinary.

(C) Collective drift: man, woman, and nonbinary spread to maximize minimal pairwise distance.

Figure 1: *

Emergence and drift on a sphere. (A) Poles (man, woman) with equator E and midpoint nonbinary. (B) The equator collapses to the nonbinary point. (C) All three labels co-move to maximize distinctiveness ($\approx 120^\circ$ apart).

distance between them (represented in *Figure 1C*). If these points didn't shift, there would be an unnecessarily large gap in the gender space with no categories to define it.

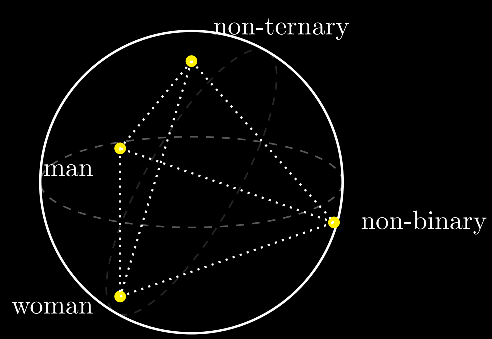


Figure 2: *

Four maximally separated categories on a sphere. Dotted lines indicate the tetrahedral edges, showing that all pairwise distances are equal.

This process of category emergence can, in theory, be repeated endlessly. When individuals cluster in areas not close to the categories *man*, *woman*, and *nonbinary*, a new category, *nonternary*, emerges. It's likely that these categories will take on new, more useful names as they develop. When the *nonternary* gender emerges, the categories must again maximally differentiate as shown in Figure 2.

4 Generalization to Social Categories

The framework applies beyond gender. It is especially suited to category systems where classification is based on collective perception and where the goal is to transform continuous variation into discrete, socially meaningful categories.

This framework is therefore most applicable to domains where consensus-driven perception discretizes an underlying continuum. Examples of such domains include gender, political identity, musical genres, or occupational roles.

5 Conclusion

We have proposed a mathematical framework for modeling gender as a socially realized quantity, defined externally through the aggregation of observers' judgments. Beginning with the Axis Model, we showed how midpoint-splitting yields a potentially infinite proliferation of categories. In the Surface Model, we argued that a spherical topology better captures the dynamics of category formation: midpoint universes collapse into single points and categories drift collectively to maximize distinctiveness.

The benefit of this approach lies in its clarity and extensibility. Familiar queer-theoretical claims about the instability and proliferation of gender categories receive a precise formal treatment. The same structure can be applied to other consensus-driven category systems, such as political identities, musical genres, or occupational roles. In each case, continuous variation is discretized into labels through social consensus, fuzzy membership, midpoint emergence, and drift.

The framework is deliberately minimal and focused on explaining the core dynamics of category definition and emergence. Future work can make the model more concrete and descriptive by defining observer weights or aggregation patterns. The details of these enhancements could be informed by empirical study.

The model advances a simple claim: when categories are socially realized, consensus-based, and grounded in continuous variation, they can proliferate without bound and reconfigure over time. This inevitability is not a weakness of queer theory but its mathematical foundation.