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Novel Types of Upside-Down Logic in Plithogenic Fuzzy Sets

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Abstract

In the real world, numerous reversal phenomena occur, such as cases where a statement once considered false is later acknowledged as true. *Upside-Down Logic* is a framework designed to formalize such reversals within a logical system. It inverts the truth and falsity of propositions through contextual transformations, thereby capturing ambiguity and context-dependent reversals in reasoning. A *Plithogenic Set* models elements using attribute-based membership and contradiction functions, extending the classical frameworks of fuzzy, intuitionistic, and neutrosophic sets. The essential distinction between Plithogenic Sets and traditional Fuzzy Sets lies in their ability to incorporate contradiction parameters, which naturally emerge when uncertainty transitions into certainty. Since research on Upside-Down Logic is still in its early stages, only a few extended logical systems have been defined so far. Therefore, this paper introduces five new concepts: *Partial (Parameterized) Upside-Down Logic*, *Multi-Anchor / Attribute-Aware Upside-Down Logic*, *Temporal / Event-Triggered Upside-Down Logic*, *Probabilistic (Stochastic) Upside-Down Logic*, and *Counterfactual Upside-Down Logic*.

Keywords: Upside-down-logic, Plithogenic Set, De-Plithogenication, Plithogenic Fuzzy Set

1 | Preliminaries

In this section we gather the basic notions and notation used throughout the paper. Unless explicitly stated otherwise, all sets and structures are finite. All graphs under consideration are simple and undirected.

1.1 | Formal Definition of Upside-Down Logic

We now formalize *Upside-Down Logic*, a framework designed to model reversal phenomena—situations in which contextual changes transform statements previously considered false into true ones, and vice versa [1, 2, 3, 4, 5, 6, 7]. Although not always framed explicitly as a logical system, the notion of “upside-down” reasoning and related ideas have been applied across a variety of fields, demonstrating the importance of formalizing this logic (cf. [8, 9]). The terminology required for this development is introduced below.

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Notation 1 (Contextual truth valuation). Let $\mathcal{P}$ be a set of propositions and $\mathcal{C}$ a set of contexts. A *truth valuation* is a map

$$v : \mathcal{P} \times \mathcal{C} \longrightarrow \{\text{True}, \text{False}, \text{Indeterminate}\}, \quad (A, C) \mapsto v(A, C).$$

For a fixed context $C \in \mathcal{C}$, we also write the induced (curried) valuation

$$v_C : \mathcal{P} \rightarrow \{\text{True}, \text{False}, \text{Indeterminate}\}, \quad v_C(A) := v(A, C).$$

Notation 2 (Logical system with contexts). Let $\mathcal{L}$ be a formal language and let $\mathcal{V}$ be a set of truth values. A (context-sensitive) logical system is a triple

$$\mathcal{M} = (\mathcal{P}, \mathcal{C}, \mathcal{V}, v),$$

where $\mathcal{P}$ is the set of propositions of $\mathcal{L}$, $\mathcal{C}$ is the set of contexts, and $v : \mathcal{P} \times \mathcal{C} \rightarrow \mathcal{V}$ is a valuation. In this paper we mainly take $\mathcal{V} = \{\text{True}, \text{False}, \text{Indeterminate}\}$.

Definition 3 (Upside-Down Logic). [2, 3] Let $\mathcal{M} = (\mathcal{P}, \mathcal{C}, \mathcal{V}, v)$ be as above with $\mathcal{V} = \{\text{True}, \text{False}, \text{Indeterminate}\}$. An *Upside-Down Logic* is a logical system $\mathcal{M}'$ obtained from $\mathcal{M}$ by introducing a transformation

$$U : \mathcal{P} \times \mathcal{C} \longrightarrow \mathcal{P} \times \mathcal{C}, \quad U(A, C) = (U_{\mathcal{P}}(A), U_{\mathcal{C}}(C)),$$

acting on propositions and/or contexts, such that the following switching rules hold for every $A \in \mathcal{P}$ and $C \in \mathcal{C}$:

- (1) *True→False switch*: if $v(A, C) = \text{True}$, then

$$v(U_{\mathcal{P}}(A), U_{\mathcal{C}}(C)) = \text{False}.$$

- (2) *False→True switch*: if $v(A, C) = \text{False}$, then

$$v(U_{\mathcal{P}}(A), U_{\mathcal{C}}(C)) = \text{True}.$$

- (3) The operator U is well-defined on $\mathcal{P} \times \mathcal{C}$ and the induced system $\mathcal{M}'$ is consistent (in particular, valuations are unambiguous and respect the grammar of $\mathcal{L}$).

Intuitively, U formalizes how a systematic change in ambient conditions can invert truth values, capturing context-driven reversals in reasoning.

Example 4 (Three concise real-life instances of Upside-Down Logic). We list three concise real-life instances.

- (1) **Weather emergency and office status.** Let A : “The office is open today.” In the normal context C_{clear} (no alerts), $v(A, C_{\text{clear}}) = \text{True}$. In the emergency context $U_{\mathcal{C}}(C_{\text{clear}}) = C_{\text{storm}}$ (city closure order), $v(A, C_{\text{storm}}) = \text{False}$. Thus, the context change flips the truth of A (open $\rightarrow$ closed).
- (2) **Epidemiological risk and mask mandate.** Let A : “Masks are required indoors.” In the low-transmission context C_{low} (no mandate), $v(A, C_{\text{low}}) = \text{False}$. In the high-transmission context $U_{\mathcal{C}}(C_{\text{low}}) = C_{\text{high}}$ (public-health order), $v(A, C_{\text{high}}) = \text{True}$. Hence, the policy truth flips with the risk context (not required $\rightarrow$ required).
- (3) **Interest-rate regime and mortgage advice.** Let A : “An ARM is cheaper than a fixed-rate mortgage this year.” In a stable low-rate context C_{low} , $v(A, C_{\text{low}}) = \text{True}$. In a rising-rate context $U_{\mathcal{C}}(C_{\text{low}}) = C_{\text{hike}}$ (sharp increases), $v(A, C_{\text{hike}}) = \text{False}$. Therefore, the economic context can invert the proposition’s truth value.

1.2 | Plithogenic Set

A Plithogenic Set [10, 11, 12] models elements with attribute-based membership and contradiction functions, extending fuzzy[13], intuitionistic[14, 15], and neutrosophic sets[16, 17, 18]. A Plithogenic Fuzzy Set models elements using attribute-based membership and contradiction functions, extending fuzzy sets by explicitly handling inherent contradictions in uncertainty [19, 20, 21].

Definition 5 (Plithogenic Set). [22, 10] Let S be a universal set and $P \subseteq S$ a nonempty subset. A *Plithogenic Set* is a quintuple

$$PS = (P, v, Pv, pdf, pCF),$$

where

- v is an attribute,
- Pv is the set of possible values of the attribute v ,
- $pdf : P \times Pv \rightarrow [0, 1]^s$ is the *Degree of Appurtenance Function (DAF)*,¹
- $pCF : Pv \times Pv \rightarrow [0, 1]^t$ is the *Degree of Contradiction Function (DCF)*.

The DCF satisfies, for all $a, b \in Pv$,

$$\text{Reflexivity: } pCF(a, a) = 0, \quad \text{Symmetry: } pCF(a, b) = pCF(b, a).$$

Here $s \in \mathbb{N}$ is the appurtenance dimension and $t \in \mathbb{N}$ the contradiction dimension.

Definition 6 (Plithogenic Fuzzy Set ($s = 1, t = 1$)). [10] A *Plithogenic Fuzzy Set* is a Plithogenic Set $PS = (P, v, Pv, pdf, pCF)$ with

$$pdf : P \times Pv \rightarrow [0, 1], \quad pCF : Pv \times Pv \rightarrow [0, 1].$$

For $x \in P$ and attribute value $a \in Pv$, write

$$\mu_P(x \mid a) := pdf(x, a) \in [0, 1],$$

the (single) fuzzy membership degree of x w.r.t. a . The contradiction between two attribute values is the scalar $c(a, b) := pCF(a, b) \in [0, 1]$ with $c(a, a) = 0$ and $c(a, b) = c(b, a)$.

Example 7 (Consumer electronics: selecting a smartphone under conflicting feature priorities). Let the items be smartphones $P = \{X, Y, Z\}$. Choose the attribute $v = \text{“feature priority,”}$ with values $Pv = \{\text{Perf, Cam, Batt}\}$ (Performance / Camera / Battery). The fuzzy membership $\mu_P(x \mid a) := pdf(x, a) \in [0, 1]$ encodes how well phone x fits priority a .

Fuzzy memberships.

	$\mu(\cdot \mid \text{Perf})$	$\mu(\cdot \mid \text{Cam})$	$\mu(\cdot \mid \text{Batt})$
X	0.90	0.60	0.30
Y	0.70	0.80	0.55
Z	0.45	0.50	0.92

Contradiction among priorities. Let $c(a, b) := pCF(a, b) \in [0, 1]$ be symmetric with zeros on the diagonal. A typical trade-off structure is

$c(\cdot, \cdot)$	Perf	Cam	Batt
Perf	0	0.40	0.85
Cam	0.40	0	0.60
Batt	0.85	0.60	0

Interpretation: battery-first (Batt) often conflicts with raw performance (Perf), hence $c(\text{Perf}, \text{Batt}) = 0.85$. Camera sits between them with moderate contradictions. Given any downstream aggregation rule (e.g., a plithogenic flip-blend relative to a chosen anchor), Z will tend to rank best under a battery-centric anchor, while X will tend to rank best under a performance-centric anchor, with Y balancing camera and overall trade-offs.

Example 8 (Urban mobility: choosing a commute mode across weather conditions). Let the items be commute modes $P = \{\text{Bike, Car, Sub}\}$ (bicycle / car / subway). Take $v = \text{“weather,”}$ with $Pv = \{\text{Sun, Rain, Snow}\}$. Here $\mu_P(x \mid a)$ is the degree that mode x is suitable when weather a dominates.

¹In the literature, DAF is defined in slightly different ways: some variants use powerset-valued constructions, others the simple cube $[0, 1]^s$. We adopt the latter (classical) form here; cf. [23].

Fuzzy memberships.

	$\mu(\cdot \mid \text{Sun})$	$\mu(\cdot \mid \text{Rain})$	$\mu(\cdot \mid \text{Snow})$
Bike	0.95	0.30	0.10
Car	0.70	0.80	0.85
Sub	0.80	0.90	0.95

Contradiction among weather regimes. Weather states may pull recommendations in opposite directions; model this by

$c(\cdot, \cdot)$	Sun	Rain	Snow
Sun	0	0.70	0.90
Rain	0.70	0	0.40
Snow	0.90	0.40	0

Interpretation: sunny vs. snowy priorities are highly contradictory (0.90), while rainy vs. snowy are closer (0.40). Under a snowy anchor, the plithogenic calculus penalizes memberships that align with contradictory (sunny) priorities, pushing Sub and Car ahead of Bike. Under a sunny anchor, Bike dominates, while the high contradiction with snow dampens the influence of winter-biased preferences.

1.3 | Upside-Down Logic in Plithogenic Fuzzy Set with contradiction reset

Upside-Down Logic in a Plithogenic Fuzzy Set with contradiction reset flips memberships when contradiction exceeds a threshold, while resetting contradictions to maintain consistency.

Definition 9 (Upside-Down Logic in Plithogenic Fuzzy Set with contradiction reset). [24] Let $PS = (P, v, Pv, pdf, pCF)$ be a Plithogenic Fuzzy Set with

$$\mu_P(x \mid a) := pdf(x, a) \in [0, 1], \quad c(a, b) := pCF(a, b) \in [0, 1],$$

and $c(a, a) = 0$, $c(a, b) = c(b, a)$. Fix a reference (anchor) attribute $b \in Pv$ and a threshold $\tau \in [0, 1]$. Define the *activation set*

$$A_\tau(b) := \{a \in Pv : c(a, b) \geq \tau\}.$$

The *Upside-Down transform with contradiction reset* produces a new Plithogenic Fuzzy Set

$$PS^{U_{b,\tau}} = (P, v, Pv, pdf^{U_{b,\tau}}, pCF^{U_{b,\tau}})$$

by

$$pdf^{U_{b,\tau}}(x, a) := \begin{cases} 1 - \mu_P(x \mid a), & a \in A_\tau(b), \\ \mu_P(x \mid a), & a \notin A_\tau(b), \end{cases}$$

and the updated contradiction map $pCF^{U_{b,\tau}}$ defined for all $u, v \in Pv$ by

$$pCF^{U_{b,\tau}}(u, v) := \begin{cases} 0, & \{u, v\} = \{a, b\} \text{ for some } a \in A_\tau(b), \\ pCF(u, v), & \text{otherwise.} \end{cases}$$

That is, whenever the flip is triggered for the pair (a, b) (i.e. $a \in A_\tau(b)$), the post-transform contradiction between a and b is *reset to zero*.

Example 10 (University admissions policy shift: need-based priority with legacy flip). Let applicants be $P = \{A, B, C\}$. Take the attribute $v = \text{“admissions stance”}$ with values $Pv = \{\text{Merit(M)}, \text{Need(N)}, \text{Legacy(L)}\}$. For $x \in P$ and $a \in Pv$, denote the fuzzy membership by $\mu(x \mid a) := pdf(x, a) \in [0, 1]$, and the (symmetric) contradiction by $c(a, b) := pCF(a, b) \in [0, 1]$ with $c(a, a) = 0$.

Initial memberships.

	$\mu(\cdot \mid \text{M})$	$\mu(\cdot \mid \text{N})$	$\mu(\cdot \mid \text{L})$
A	0.85	0.20	0.10
B	0.70	0.80	0.00
C	0.60	0.30	0.90

Contradictions (symmetric; zeros on diagonal).

$c(\cdot, \cdot)$	M	N	L
M	0	0.65	0.50
N	0.65	0	0.95
L	0.50	0.95	0

Upside-Down with contradiction reset. Choose the anchor $b = N$ (need-based priority) and threshold $\tau = 0.80$. The activation set is

$$A_\tau(N) = \{a \in Pv : c(a, N) \geq 0.80\} = \{L\}.$$

Hence only the L-column flips:

$$\mu^U(x | L) = 1 - \mu(x | L), \quad \mu^U(x | a) = \mu(x | a) \quad (a \in \{M, N\}).$$

Explicitly,

	$\mu^U(\cdot M)$	$\mu^U(\cdot N)$	$\mu^U(\cdot L)$
A	0.85	0.20	$1 - 0.10 = 0.90$
B	0.70	0.80	$1 - 0.00 = 1.00$
C	0.60	0.30	$1 - 0.90 = 0.10$

The contradiction on the activated pair is reset to zero:

$$pCF^U(L, N) = pCF^U(N, L) = 0, \quad \text{all other entries unchanged.}$$

Interpretation. Under a need-priority policy, the stance most contradictory to N (legacy) is numerically inverted, and the sharp policy conflict between L and N is declared resolved by setting their contradiction to 0.

Example 11 (Energy portfolio reorientation: sustainability anchor flips short-term ROI). Let projects be $P = \{SF, GU, BS\}$ for Solar Farm (SF), Gas-plant Upgrade (GU), and Battery Storage (BS). Take $v =$ “planning criterion” with $Pv = \{S, L, R\}$ for Short-term ROI (S), Long-term sustainability (L), and Reliability (R). Memberships $\mu(x | a) \in [0, 1]$ encode how well each project satisfies criterion a .

Initial memberships.

	$\mu(\cdot S)$	$\mu(\cdot L)$	$\mu(\cdot R)$
SF	0.40	0.95	0.70
GU	0.90	0.20	0.85
BS	0.50	0.80	0.90

Contradictions (symmetric; zeros on diagonal).

$c(\cdot, \cdot)$	S	L	R
S	0	0.90	0.40
L	0.90	0	0.35
R	0.40	0.35	0

Upside-Down with contradiction reset. Choose the anchor $b = L$ (sustainability-first) and $\tau = 0.80$. The activation set is

$$A_\tau(L) = \{a : c(a, L) \geq 0.80\} = \{S\}.$$

Thus only the S-column flips:

$$\mu^U(x | S) = 1 - \mu(x | S), \quad \mu^U(x | a) = \mu(x | a) \quad (a \in \{L, R\}).$$

Explicitly,

	$\mu^U(\cdot S)$	$\mu^U(\cdot L)$	$\mu^U(\cdot R)$
SF	$1 - 0.40 = 0.60$	0.95	0.70
GU	$1 - 0.90 = 0.10$	0.20	0.85
BS	$1 - 0.50 = 0.50$	0.80	0.90

Contradiction reset on the activated pair:

$$pCF^U(S, L) = pCF^U(L, S) = 0, \quad \text{others unchanged.}$$

Interpretation. When the planning anchor is sustainability, the criterion that most contradicts it (short-term ROI) is flipped so that high short-term ROI no longer dominates selection; simultaneously, the strong S-L disagreement is neutralized for subsequent aggregation and comparison.

2 | Main Results

As the principal contribution of this paper, we propose five new forms of Upside-Down Logic.

2.1 | Partial (Parameterized) Upside-Down Logic

Partial (Parameterized) Upside-Down Logic blends original truth values with complements using parameter, allowing gradual, controllable flips between True and False.

Notation 12. Throughout, let the (possibly fuzzy) valuation be

$$\mu : \mathcal{P} \times \mathcal{C} \rightarrow [0, 1], \quad \mu(A | \mathcal{C}) \in [0, 1],$$

with the classical Boolean case recovered when $\mu \in \{0, 1\}$.

Definition 13 (Partial (Parameterized) Upside-Down Logic). For a control parameter $\lambda \in [0, 1]$, the partial Upside-Down transform

$$U_\lambda : (\mu, \mathcal{C}) \mapsto (\mu'_\lambda, U(\mathcal{C}))$$

updates degrees by a convex blend of μ and its complement:

$$\mu'_\lambda(A | U(\mathcal{C})) := (1 - \lambda)\mu(A | \mathcal{C}) + \lambda(1 - \mu(A | \mathcal{C})).$$

Here $\lambda = 1$ yields a full True $\leftrightarrow$ False flip, while $\lambda = 0$ leaves μ unchanged.

Example 14 (Numerical illustration). Let $\mu(A | \mathcal{C}) = 0.70$. Then

$$\mu'_\lambda(A | U(\mathcal{C})) = 0.70 - 0.40\lambda.$$

For $\lambda = 0.60$, $\mu'_{0.60} = 0.70 - 0.24 = 0.46$; for $\lambda = 1$, $\mu'_1 = 0.30$; for $\lambda = 0$, $\mu'_0 = 0.70$.

Definition 15 (Partial Upside-Down with Contradiction Reset). Let $PS = (P, v, Pv, pdf, pCF)$ be a Plithogenic Fuzzy Set with

$$\mu(x | a) := pdf(x, a) \in [0, 1], \quad c(a, b) := pCF(a, b) \in [0, 1],$$

and $c(a, a) = 0$, $c(a, b) = c(b, a)$ for all $a, b \in Pv$. Fix an anchor (reference) value $b \in Pv$, a threshold $\tau \in [0, 1]$, and a *flip intensity* $\lambda \in [0, 1]$. Define the activation indicator and set

$$\text{Act}(a | b, \tau) := \mathbf{1}[c(a, b) \geq \tau], \quad A_\tau(b) := \{a \in Pv : \text{Act}(a | b, \tau) = 1\}.$$

The *partial Upside-Down transform with contradiction reset* produces $PS^{U_{b, \tau, \lambda}} = (P, v, Pv, pdf^U, pCF^U)$ by

$$\begin{aligned} pdf^U(x, a) &:= (1 - \lambda \text{Act}(a | b, \tau))\mu(x | a) + \lambda \text{Act}(a | b, \tau)(1 - \mu(x | a)), \\ pCF^U(u, v) &:= \begin{cases} 0, & \text{if } \{u, v\} = \{a, b\} \text{ for some } a \in A_\tau(b), \\ pCF(u, v), & \text{otherwise.} \end{cases} \end{aligned}$$

Hence non-activated values are unchanged; activated values undergo a convex blend between μ and its complement, with strength λ . Special cases: $\lambda = 0$ yields the identity, and $\lambda = 1$ recovers the full flip with reset.

Remark 16 (Basic properties). *The operator $U_{b, \tau, \lambda}$ maps memberships into $[0, 1]$ and is idempotent: after one application, all activated pairs $\{a, b\}$ are reset to zero contradiction, so $\text{Act}(a | b, \tau) = 0$ thereafter and a second application makes no further changes.*

Example 17 (Cafeteria menu policy: partial shift toward “Healthy”). Consider items $P = \{\text{Fr, Sa, Gc}\}$ (Fries, Salad, Grilled Chicken). Let the attribute be $v = \text{“diet style”}$ with values $Pv = \{\text{H, B, I}\}$ (Healthy, Balanced, Indulgent). Take anchor $b = \text{H}$ (the cafeteria pivots toward healthy options), threshold $\tau = 0.8$, and partial flip intensity $\lambda = 0.6$.

Memberships (before).

	$\mu(\cdot H)$	$\mu(\cdot B)$	$\mu(\cdot I)$
Fr	0.05	0.40	0.95
Sa	0.95	0.60	0.10
Gc	0.80	0.70	0.20

Contradictions to the anchor. Assume $c(I, H) = 0.90$, $c(B, H) = 0.35$, $c(H, H) = 0$ (symmetric, zero diagonal). Then

$$A_\tau(H) = \{I\} \quad (\text{since } 0.90 \geq 0.8, \quad 0.35 < 0.8).$$

Partial flip (only on $a = I$). For any item x ,

$$\mu^U(x | I) = (1 - \lambda) \mu(x | I) + \lambda (1 - \mu(x | I)) = \mu(x | I) + \lambda(1 - 2\mu(x | I)).$$

Thus

$$\begin{aligned} \mu^U(\text{Fr} | I) &= 0.95 + 0.6(1 - 1.90) = 0.41, \\ \mu^U(\text{Sa} | I) &= 0.10 + 0.6(1 - 0.20) = 0.58, \quad \mu^U(\cdot | H) = \mu(\cdot | H), \quad \mu^U(\cdot | B) = \mu(\cdot | B). \\ \mu^U(\text{Gc} | I) &= 0.20 + 0.6(1 - 0.40) = 0.56, \end{aligned}$$

Contradiction reset. Since $I \in A_\tau(H)$, the post-transform contradiction satisfies

$$pCF^U(I, H) = pCF^U(H, I) = 0, \quad \text{while all other entries remain as in } pCF.$$

Interpretation. The cafeteria does not fully reverse its stance: indulgent alignment is *partially* flipped (e.g., fries lose indulgent “fit” from 0.95 to 0.41), while healthy and balanced evaluations remain intact. The key conflict (Indulgent vs Healthy) is institutionally resolved by resetting their contradiction to zero, preventing repeated flips on subsequent policy iterations.

2.2 | Multi-Anchor / Attribute-Aware Upside-Down Logic

Multi-Anchor / Attribute-Aware Upside-Down Logic uses multiple anchors and contradiction scores to adjust flipping intensity, reflecting diverse perspectives and attribute-based contextual contradictions.

Definition 18 (Multi-Anchor / Attribute-Aware Upside-Down Logic). Let $B = \{b_1, \dots, b_m\}$ be reference anchors and $c : \mathcal{P} \times B \rightarrow [0, 1]$ a contradiction score. For weights $\omega = (\omega_1, \dots, \omega_m)$ with $\sum_i \omega_i = 1$, define the activation strength

$$\alpha(A | \mathcal{C}, B) := \min\left\{1, \sum_{i=1}^m \omega_i c(A, b_i)\right\}.$$

The context-coupled partial flip is

$$\mu'(A | U_B(\mathcal{C})) := (1 - \alpha) \mu(A | \mathcal{C}) + \alpha (1 - \mu(A | \mathcal{C})).$$

For $m = 1$, this reduces to a data-driven intensity for the standard Upside-Down flip.

Example 19 (Two anchors with weighted contradiction). Let $\mu(A | \mathcal{C}) = 0.30$, $B = \{b_1, b_2\}$ with $c(A, b_1) = 0.90$, $c(A, b_2) = 0.50$, and $\omega = (0.6, 0.4)$. Then

$$\alpha = \min\{1, 0.6 \cdot 0.90 + 0.4 \cdot 0.50\} = \min\{1, 0.54 + 0.20\} = 0.74.$$

Hence

$$\mu'(A | U_B(\mathcal{C})) = (1 - 0.74) \cdot 0.30 + 0.74 \cdot (1 - 0.30) = 0.26 \cdot 0.30 + 0.74 \cdot 0.70 = 0.078 + 0.518 = 0.596.$$

Definition 20 (Multi-Anchor / Attribute-Aware Upside-Down (with reset)). Let $PS = (P, v, Pv, pdf, pCF)$ be a Plithogenic Fuzzy Set with

$$\mu(x | a) := pdf(x, a) \in [0, 1], \quad c(a, b) := pCF(a, b) \in [0, 1],$$

and $c(a, a) = 0$, $c(a, b) = c(b, a)$ for all $a, b \in Pv$. Fix a nonempty set of *anchors* $B = \{b_1, \dots, b_m\} \subseteq Pv$, a weight vector $\omega = (\omega_1, \dots, \omega_m)$ with $\omega_i \geq 0$, $\sum_i \omega_i = 1$, and a threshold $\tau \in [0, 1]$.

Aggregated contradiction to the anchor set. For each $a \in Pv$ define

$$C_\omega(a | B) := \min \left\{ 1, \sum_{i=1}^m \omega_i c(a, b_i) \right\} \in [0, 1].$$

Activation. An attribute value a *activates* (w.r.t. (B, ω, τ)) if

$$\text{Act}(a | B, \omega, \tau) := \mathbf{1}[C_\omega(a | B) \geq \tau] = 1.$$

Let $A_\tau(B) := \{a \in Pv : \text{Act}(a | B, \omega, \tau) = 1\}$.

Multi-anchor Upside-Down with reset. Define the transformed set $PS^{U_{B, \omega, \tau}} = (P, v, Pv, pdf^U, pCF^U)$ by

$$pdf^U(x, a) := \begin{cases} 1 - \mu(x | a), & a \in A_\tau(B), \\ \mu(x | a), & a \notin A_\tau(B), \end{cases} \quad (x \in P, a \in Pv),$$

$$pCF^U(u, v) := \begin{cases} 0, & \exists a \in A_\tau(B), \exists b_i \in B \text{ s.t. } \{u, v\} = \{a, b_i\}, \\ pCF(u, v), & \text{otherwise.} \end{cases}$$

Thus every activated value a is fully flipped, and *all* contradictions between a and each anchor b_i are reset to zero; other contradictions remain unchanged. The operator is idempotent on the stabilized state.

Example 21 (Packaging choice with two policy anchors). A company evaluates three package designs $P = \{A, B, C\}$: A=Virgin Plastic (VP) pouch, B=BioPlastic (BP) pouch, C=Refillable Glass (RG) jar. Let the attribute be $v = \text{"sourcing mode"}$ with $Pv = \{VP, BP, RP, RG\}$ (VirginPlastic/BioPlastic/RecycledPaper/RefillableGlass).

Memberships (fit to each value).

	$\mu(\cdot VP)$	$\mu(\cdot BP)$	$\mu(\cdot RP)$	$\mu(\cdot RG)$
A	0.90	0.20	0.10	0.05
B	0.20	0.80	0.40	0.30
C	0.05	0.30	0.60	0.95

Contradictions between values (symmetric, zero diagonal).

$c(\cdot, \cdot)$	VP	BP	RP	RG
VP	0	0.40	0.85	0.95
BP	0.40	0	0.40	0.60
RP	0.85	0.40	0	0.50
RG	0.95	0.60	0.50	0

Anchors and weights. The policy endorses two anchors $B = \{RG, RP\}$ with weights $\omega = (0.7, 0.3)$ (stronger emphasis on RG). Choose threshold $\tau = 0.80$.

Aggregated contradictions to B .

$$C_\omega(VP | B) = 0.7 \cdot c(VP, RG) + 0.3 \cdot c(VP, RP) = 0.7 \cdot 0.95 + 0.3 \cdot 0.85 = 0.92,$$

$$C_\omega(BP | B) = 0.7 \cdot 0.60 + 0.3 \cdot 0.40 = 0.54,$$

$$C_\omega(RP | B) = 0.7 \cdot c(RP, RG) + 0.3 \cdot c(RP, RP) = 0.7 \cdot 0.50 + 0 = 0.35,$$

$$C_\omega(RG | B) = 0.7 \cdot c(RG, RG) + 0.3 \cdot c(RG, RP) = 0 + 0.3 \cdot 0.50 = 0.15.$$

Hence the activation set is $A_\tau(B) = \{\text{VP}\}$.

Membership flip and contradiction reset. Only the VP-column flips, others remain unchanged:

	$\mu^U(\cdot \mid \text{VP})$	$\mu^U(\cdot \mid \text{BP})$	$\mu^U(\cdot \mid \text{RP})$	$\mu^U(\cdot \mid \text{RG})$
A	$1 - 0.90 = 0.10$	0.20	0.10	0.05
B	$1 - 0.20 = 0.80$	0.80	0.40	0.30
C	$1 - 0.05 = 0.95$	0.30	0.60	0.95

Contradictions are reset exactly on pairs involving the activated value and any anchor:

$$pCF^U(\text{VP}, \text{RG}) = pCF^U(\text{RG}, \text{VP}) = 0, \quad pCF^U(\text{VP}, \text{RP}) = pCF^U(\text{RP}, \text{VP}) = 0,$$

and all other entries of pCF remain unchanged.

Interpretation. Under a dual-anchor policy (Refillable Glass, Recycled Paper) with stronger weight on RG, Virgin Plastic is judged highly contradictory and is *flipped*; its conflicts with both anchors are then declared resolved (reset to zero). BioPlastic and both anchors themselves are not activated and remain as they were. The operator will not flip again on a subsequent application (idempotence on the stabilized state).

2.3 | Temporal / Event-Triggered Upside-Down Logic

Temporal / Event-Triggered Upside-Down Logic applies flips only when time-indexed contexts cross thresholds, capturing dynamic reversals triggered by critical real-world events or contextual changes.

Definition 22 (Temporal / Event-Triggered Upside-Down Logic). Let contexts be time-indexed $\{\mathcal{C}_t\}_{t \geq 0}$ and let $g : \mathcal{C} \rightarrow \mathbb{R}$ be a trigger functional with threshold θ . Define the stopping time

$$\tau := \inf\{t \geq 0 : g(\mathcal{C}_t) \geq \theta\}.$$

Set $U(\mathcal{C}_t) = \mathcal{C}_t$ for $t < \tau$, and at $t = \tau$ apply a (possibly partial) flip with $\lambda_\tau \in [0, 1]$:

$$\mu'(A \mid \mathcal{C}_\tau) := (1 - \lambda_\tau) \mu(A \mid \mathcal{C}_\tau) + \lambda_\tau (1 - \mu(A \mid \mathcal{C}_\tau)).$$

Example 23 (Threshold crossing). Suppose $g(\mathcal{C}_t)$ records ICU occupancy with $\theta = 0.80$. Let $g(\mathcal{C}_0) = 0.62$, $g(\mathcal{C}_1) = 0.76$, $g(\mathcal{C}_2) = 0.83$. Then $\tau = 2$. If $\mu(A \mid \mathcal{C}_2) = 0.20$ and $\lambda_\tau = 1$, the flip gives

$$\mu'(A \mid \mathcal{C}_2) = (1 - 1) \cdot 0.20 + 1 \cdot (1 - 0.20) = 0.80.$$

For $\lambda_\tau = 0.5$, $\mu'(A \mid \mathcal{C}_2) = 0.5 \cdot 0.20 + 0.5 \cdot 0.80 = 0.50$.

Definition 24 (Temporal / Event-Triggered Upside-Down (with reset)). Let $PS = (P, v, Pv, pdf, pCF)$ be a Plithogenic Fuzzy Set with

$$\mu(x \mid a) := pdf(x, a) \in [0, 1], \quad c(a, b) := pCF(a, b) \in [0, 1],$$

and $c(a, a) = 0$, $c(a, b) = c(b, a)$ for all $a, b \in Pv$. Fix an *anchor* $b \in Pv$ and a *contradiction threshold* $\tau \in [0, 1]$. Define the activation set

$$A_\tau(b) := \{a \in Pv : c(a, b) \geq \tau\}.$$

Let time be discrete $t = 0, 1, 2, \dots$. Let $g : \mathbb{N} \rightarrow \mathbb{R}$ be an observable (trigger) and $\theta \in \mathbb{R}$ a trigger threshold. Define the (first) trigger time

$$\tau^* := \inf\{t \geq 0 : g(t) \geq \theta\} \in \mathbb{N} \cup \{\infty\}.$$

The *temporal/event-triggered Upside-Down transform with contradiction reset* is the time-indexed structure $PS^U(t) = (P, v, Pv, pdf_t^U, pCF_t^U)$ given by

$$pdf_t^U(x, a) := \begin{cases} \mu(x | a), & t < \tau^*, \\ 1 - \mu(x | a), & t \geq \tau^* \text{ and } a \in A_\tau(b), \\ \mu(x | a), & t \geq \tau^* \text{ and } a \notin A_\tau(b), \end{cases}$$

$$pCF_t^U(u, v) := \begin{cases} pCF(u, v), & t < \tau^*, \\ 0, & t \geq \tau^* \text{ and } \exists a \in A_\tau(b) \text{ with } \{u, v\} = \{a, b\}, \\ pCF(u, v), & t \geq \tau^* \text{ and otherwise.} \end{cases}$$

Thus, no change occurs before the event ($t < \tau^*$); once the trigger fires, all activated values $a \in A_\tau(b)$ are *flipped* (membership complemented) and their contradictions with the anchor b are *reset to zero*. The update is idempotent for all $t \geq \tau^*$.

Example 25 (Pandemic-triggered workplace mode reversal). Consider employees $P = \{E1, E2, E3\}$. Let the attribute $v = \text{“work mode”}$ have values $Pv = \{O, H, R\}$ (On-site / Hybrid / Remote). Choose anchor $b = R$ (remote-preferred policy) and $\tau = 0.70$.

Memberships (suitability by mode).

	$\mu(\cdot O)$	$\mu(\cdot H)$	$\mu(\cdot R)$
E1	0.20	0.60	0.90
E2	0.70	0.50	0.40
E3	0.80	0.30	0.20

Contradictions among values (symmetric, zero diagonal).

$c(\cdot, \cdot)$	O	H	R
O	0	0.50	0.90
H	0.50	0	0.40
R	0.90	0.40	0

Hence $A_\tau(R) = \{O\}$ since $c(O, R) = 0.90 \geq 0.70$ while $c(H, R) = 0.40 < 0.70$.

Event trigger. Let $g(t)$ be the ICU occupancy fraction at week t , with sequence $(g(0), g(1), g(2)) = (0.65, 0.72, \mathbf{0.84})$ and $\theta = 0.80$. Then $\tau^* = 2$.

Temporal update. For $t < 2$, no change: $pdf_t^U \equiv pdf$, $pCF_t^U \equiv pCF$. At $t = 2$ and thereafter, only the O-column flips; all contradictions between O and the anchor R reset to zero.

	$\mu_{t \geq 2}^U(\cdot O)$	$\mu_{t \geq 2}^U(\cdot H)$	$\mu_{t \geq 2}^U(\cdot R)$
E1	$1 - 0.20 = 0.80$	0.60	0.90
E2	$1 - 0.70 = 0.30$	0.50	0.40
E3	$1 - 0.80 = 0.20$	0.30	0.20

$$pCF_{t \geq 2}^U(O, R) = pCF_{t \geq 2}^U(R, O) = 0, \quad \text{all other } pCF_{t \geq 2}^U(u, v) = pCF(u, v).$$

While the ICU load remained below threshold, the baseline appraisal stood. Crossing the critical level (θ) triggers an Upside-Down update: on-site suitability values are complemented (reflecting an immediate shift away from on-site work) and the on-site vs remote contradiction is administratively neutralized (reset to 0) to stabilize subsequent decisions. Because the reset makes $c^U(O, R) = 0$, the transformed state is idempotent under further applications for $t \geq \tau^*$.

2.4 | Probabilistic (Stochastic) Upside-Down Logic

Probabilistic (Stochastic) Upside-Down Logic flips truth values randomly with probability p , producing expected outcomes and modeling uncertainty-driven reversals in reasoning processes.

Definition 26 (Probabilistic (Stochastic) Upside-Down Logic). Let the flip occur randomly with probability $p = p(A, \mathcal{C}) \in [0, 1]$. Draw $F \sim \text{Bernoulli}(p)$ and set

$$\mu'(A | U(\mathcal{C})) := (1 - F) \mu(A | \mathcal{C}) + F(1 - \mu(A | \mathcal{C})).$$

Then

$$\mathbb{E}[\mu'(A | U(\mathcal{C}))] = (1 - p) \mu(A | \mathcal{C}) + p(1 - \mu(A | \mathcal{C})).$$

Example 27 (Expected flipped degree). Let $\mu(A | \mathcal{C}) = 0.40$ and $p = 0.75$. Then

$$\mathbb{E}[\mu'] = 0.25 \cdot 0.40 + 0.75 \cdot 0.60 = 0.10 + 0.45 = 0.55.$$

A realized flip $F = 1$ produces $\mu' = 0.60$; no flip $F = 0$ leaves $\mu' = 0.40$.

Definition 28 (Stochastic Upside-Down with Contradiction Reset). Let $PS = (P, v, Pv, pdf, pCF)$ be a Plithogenic Fuzzy Set with

$$\mu(x | a) := pdf(x, a) \in [0, 1], \quad c(a, b) := pCF(a, b) \in [0, 1],$$

and $c(a, a) = 0$, $c(a, b) = c(b, a)$ for all $a, b \in Pv$. Fix an anchor $b \in Pv$ and a contradiction threshold $\tau \in [0, 1]$. Define the activation set

$$A_\tau(b) := \{a \in Pv : c(a, b) \geq \tau\}.$$

For each activated value $a \in A_\tau(b)$, let the *flip* occur at random with probability $p(a, b) \in [0, 1]$ (e.g., chosen as a nondecreasing function of $c(a, b)$). Draw independent Bernoulli variables $F_a \sim \text{Bernoulli}(p(a, b))$ for $a \in A_\tau(b)$, and set $F_a := 0$ for $a \notin A_\tau(b)$. The *stochastic Upside-Down transform with contradiction reset* produces a random updated structure

$$PS^U = (P, v, Pv, pdf^U, pCF^U),$$

defined by, for all $x \in P$, $a, u, v \in Pv$,

$$\begin{aligned} pdf^U(x, a) &:= (1 - F_a) \mu(x | a) + F_a (1 - \mu(x | a)), \\ pCF^U(u, v) &:= \begin{cases} 0, & \text{if } \{u, v\} = \{a, b\} \text{ for some } a \in A_\tau(b) \text{ with } F_a = 1, \\ pCF(u, v), & \text{otherwise.} \end{cases} \end{aligned}$$

In expectation, for each $a \in Pv$,

$$\mathbb{E}[pdf^U(x, a)] = (1 - p(a, b)) \mu(x | a) + p(a, b) (1 - \mu(x | a)), \quad \mathbb{E}[pCF^U(a, b)] = (1 - p(a, b)) c(a, b).$$

Thus, flips (membership complements) occur only on activated values and only when the random flip fires; whenever a flip fires for $\{a, b\}$, the contradiction on that pair is reset to 0.

Example 29 (Weather-driven stochastic shift in work modes). Let $P = \{E1, E2, E3\}$ be employees. Attribute $v =$ “work mode” with values $Pv = \{O, H, R\}$ (On-site, Hybrid, Remote). Choose anchor $b = R$ (remote-preferred), threshold $\tau = 0.70$.

Memberships (suitability by mode):

	$\mu(\cdot O)$	$\mu(\cdot H)$	$\mu(\cdot R)$
E1	0.20	0.60	0.90
E2	0.70	0.50	0.40
E3	0.80	0.30	0.20

Contradictions (symmetric, zero diagonal):

$c(\cdot, \cdot)$	O	H	R
O	0	0.50	0.90
H	0.50	0	0.40
R	0.90	0.40	0

Hence the activation set is $A_\tau(R) = \{O\}$ because $c(O, R) = 0.90 \geq 0.70$ while $c(H, R) = 0.40 < 0.70$.

Stochastic flip rule. Suppose severe-weather guidance implies an *on-site* $\rightarrow$ *remote* flip with probability

$$p(O, R) = 0.80, \quad p(H, R) = 0, \quad p(R, R) = 0.$$

Draw $F_O \sim \text{Bernoulli}(0.80)$. If $F_O = 1$, complement the O-column and reset the O–R contradiction to 0.

Expected post-transform memberships (only O-column changes):

$$\mathbb{E}[\mu^U(E1 | O)] = 0.2 \cdot 0.20 + 0.8 \cdot (1 - 0.20) = 0.04 + 0.64 = 0.68,$$

$$\mathbb{E}[\mu^U(E2 | O)] = 0.2 \cdot 0.70 + 0.8 \cdot (1 - 0.70) = 0.14 + 0.24 = 0.38,$$

$$\mathbb{E}[\mu^U(E3 | O)] = 0.2 \cdot 0.80 + 0.8 \cdot (1 - 0.80) = 0.16 + 0.16 = 0.32.$$

Hybrid/Remote columns remain unchanged in expectation.

Expected contradiction after reset (only the activated pair):

$$\mathbb{E}[pCF^U(O, R)] = (1 - 0.80) c(O, R) = 0.20 \times 0.90 = 0.18,$$

while all other pCF entries are unchanged in expectation.

Interpretation. A severe-weather forecast (uncertain ex ante) stochastically triggers an “upside-down” update that downgrades on-site suitability (by complementing that column) and administratively resolves the O–R conflict (reset to 0) whenever the flip occurs. The expected post-transform table already reflects the policy’s probabilistic effect on both suitability scores and contradictions.

2.5 | Counterfactual Upside-Down Logic

Counterfactual Upside-Down Logic transforms valuations by interventions in causal models, allowing propositions false observationally to become true under interventional scenarios with causal semantics.

Definition 30 (Counterfactual Upside-Down Logic (Interventional Semantics)). Given a structural causal model M with variables $(X, Y, \dots)$, let $M_{\text{do}(X=x)}$ denote the interventional model. Define an Upside-Down transform that moves from observation to intervention:

$$U_{\text{do}(X=x)} : (\mu, \mathcal{C}) \mapsto (\mu^{\text{cf}}, U(\mathcal{C})), \quad \mu^{\text{cf}}(A | U(\mathcal{C})) := \Pr_{M_{\text{do}(X=x)}}[A],$$

or, in the crisp case, $\mu^{\text{cf}}(A | U(\mathcal{C})) = \mathbf{1}[M_{\text{do}(X=x)} \models A]$.

Example 31 (Observation vs. intervention). Let $Y := X$ (binary) in M , and suppose observationally $\Pr(X = 1) = 0.20$. For $A \equiv (Y = 1)$, we have

$$\mu(A | \mathcal{C}) = \Pr(Y = 1) = \Pr(X = 1) = 0.20.$$

Under intervention $\text{do}(X = 1)$, $\Pr_{M_{\text{do}(1)}}(Y = 1) = 1$, hence

$$\mu^{\text{cf}}(A | U(\mathcal{C})) = 1.$$

Thus A flips from 0.20 (possibly “mostly false”) to 1 (true) by changing semantics from observation to intervention.

Definition 32 (Counterfactual (Interventional) Upside-Down in PFS with Reset). Let $PS = (P, v, Pv, pdf, pCF)$ be a Plithogenic Fuzzy Set with

$$\mu(x | a) := pdf(x, a) \in [0, 1], \quad c(a, b) := pCF(a, b) \in [0, 1],$$

and $c(a, a) = 0$, $c(a, b) = c(b, a)$ for all $a, b \in Pv$. Fix an *anchor* $b \in Pv$ and a *threshold* $\tau \in [0, 1]$. Let M be a structural causal model over the ambient *context* and let $\mathbf{l}$ denote an intervention (do-operator), e.g. $\mathbf{l} = \text{do}(X = x)$. Write

$$pdf^{\text{cf}}(x, a) := \Pr_M^{\mathbf{l}}[“x \text{ exhibits attribute value } a”] \in [0, 1]$$

for the *interventional* degree (counterfactual DAF) predicted under $\mathbf{l}$. Define the activation set

$$A_\tau(b) := \{a \in Pv : c(a, b) \geq \tau\}.$$

The *Counterfactual Upside-Down transform with contradiction reset* produces

$$PS^{U_{\text{cf}}} := (P, v, Pv, pdf^{U_{\text{cf}}}, pCF^{U_{\text{cf}}}),$$

where, for all $x \in P$ and $a, u, v \in Pv$,

$$pdf^{U_{\text{cf}}}(x, a) := \begin{cases} 1 - pdf^{\text{cf}}(x, a), & a \in A_\tau(b), \\ pdf^{\text{cf}}(x, a), & a \notin A_\tau(b), \end{cases}$$

$$pCF^{U_{\text{cf}}}(u, v) := \begin{cases} 0, & \{u, v\} = \{a, b\} \text{ for some } a \in A_\tau(b), \\ pCF(u, v), & \text{otherwise.} \end{cases}$$

Thus, (i) the *degrees* used by Upside-Down are the *interventional* ones, and (ii) any value a that is sufficiently contradictory to the anchor ($a \in A_\tau(b)$) is *flipped* (complemented) and its post-transform contradiction with b is *reset to zero*. If $\mathbf{l}$ is the identity (no intervention), $pdf^{\text{cf}} = pdf$ and we recover the standard Upside-Down-with-reset.

Remark 33 (Aggregation after the counterfactual transform). *If a scalar anchor-relative acceptance is desired, one may apply any standard plithogenic aggregator (e.g. flip-blend averages) to $pdf^{U_{\text{cf}}}$ together with $pCF^{U_{\text{cf}}}$.*

Example 34 (City policy intervention: remote-work facilitation). Consider employees $P = \{E1, E2, E3\}$ and the attribute $v = \text{“work mode”}$ with values $Pv = \{O, H, R\}$ (On-site / Hybrid / Remote). Choose anchor $b = R$ (remote-preferred) and $\tau = 0.80$. The (symmetric) contradiction map is

$c(\cdot, \cdot)$	O	H	R	
O	0	0.50	0.90	$\Rightarrow A_\tau(R) = \{O\}.$
H	0.50	0	0.40	
R	0.90	0.40	0	

A city-level structural intervention $\mathbf{l} = \text{do}(\text{FreeTransit} = 1, \text{ParkingLimit} = 1)$ is expected (by model M) to change work-mode tendencies. The model yields the *interventional* memberships pdf^{cf} as:

	$pdf^{\text{cf}}(\cdot O)$	$pdf^{\text{cf}}(\cdot H)$	$pdf^{\text{cf}}(\cdot R)$
E1	0.10	0.55	0.95
E2	0.50	0.45	0.65
E3	0.60	0.30	0.50

Applying Def. 32, only the O-column flips and the O–R contradiction is reset:

	$pdf^{U_{\text{cf}}}(\cdot O)$	$pdf^{U_{\text{cf}}}(\cdot H)$	$pdf^{U_{\text{cf}}}(\cdot R)$	$c^{U_{\text{cf}}}(\cdot, \cdot)$	O	H	R
E1	$1 - 0.10 = 0.90$	0.55	0.95	O	0	0.50	0
E2	$1 - 0.50 = 0.50$	0.45	0.65	H	0.50	0	0.40
E3	$1 - 0.60 = 0.40$	0.30	0.50	R	0	0.40	0

Policy $\mathbf{l}$ induces counterfactual (interventional) suitability scores (pdf^{cf}). Because On-site is highly contradictory to the Remote anchor ($c(O, R) = 0.90 \geq \tau$), the Upside-Down step complements that column and administratively

resolves the strongest conflict by setting $c^{U_{cf}}(O, R) = 0$. Subsequent anchor-relative aggregation may be performed on $(pdf^{U_{cf}}, pCF^{U_{cf}})$.

3 | Conclusion

This paper introduced five new concepts: *Partial (Parameterized) Upside-Down Logic*, *Multi-Anchor / Attribute-Aware Upside-Down Logic*, *Temporal / Event-Triggered Upside-Down Logic*, *Probabilistic (Stochastic) Upside-Down Logic*, and *Counterfactual Upside-Down Logic*. Future work is expected to explore extensions of these notions using Graphs [25], HyperGraphs[26], and SuperHyperGraphs[27, 28, 29, 30], along with investigations into their mathematical properties.

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