GIOS: Goal-Integrated Operating System for Reasoning and Execution

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***Abstract*—The paper presents the finalized GIOS specification with all previously omitted aspects integrated and formalized: context scoping, role assignment, composition, glossary and catalogue completeness, linkage budgets, growth control, naming and authoring rules, source and regression safety, lexical hygiene, dependency constraints, notational independence, bias control, DRR no-loss tracing, optimization of glossary readability vs. ambiguity, acceptance criteria, and quality metrics. Additions include a unified acceptance gate, extended optimization constraints, fuzzy quality aggregation, explicit metric thresholds, bridge schema, link-cost units, roles/permissions, assurance thresholds, and conformance artifacts.**

I. Overview

Let $\mathcal{C}$ be the set of rooms (contexts). Each artefact a is mapped to rooms via $c(a) \subseteq \mathcal{C}$. A policy $\pi \in \Pi$ issues a decision $\pi(x, c)$ on input x in room $c \in \mathcal{C}$. Utility is $J(\pi(x, c))$ with expectation $\mathbb{E}[J]$. Reading cost is $\mathsf{Read}(a)$ with penalty $\lambda_{\text{read}} > 0$. The adequacy indicator is $\mathsf{Adeq} \in [0, 1]$.

A. Roles and permissions

Let Agents be the set of agents and let $R \in 0, 1^{|\mathsf{Agents}| \times |\mathcal{C}|}$ be the room-permission matrix:

$$\begin{aligned} &\mathrm{Perm}(u, c) = 1 \iff R_{u,c} = 1, \\ &\pi \text{ valid in } c \Rightarrow \mathrm{Perm}(\mathrm{owner}(\pi), c) = 1. \end{aligned} \tag{1}$$

For an artefact owner $\mathrm{own}(a)$ the edit predicate is

$$\mathrm{MayEdit}(a, c) = 1 \iff \mathrm{Perm}(\mathrm{own}(a), c) = 1 \wedge c \in c(a). \tag{2}$$

B. Runtime loop

At step t: observe o_t, pick $y_t \sim \pi(\cdot\,|o_t, c)$, apply y_t, log (o_t, y_t, c). Terminate if $U_t < U_{\min}$ or enter safe mode.

a) Safe-mode automaton:

$$\begin{aligned} s_{t+1} &= \texttt{SAFE} && \text{if G1,} \\ &= \texttt{RECOVER} && \text{if G2,} \\ &= \texttt{RUN} && \text{otherwise.} \end{aligned} \tag{3}$$

b) Recover hold-time: On entry to SAFE, record t_{SAFE}; transition to RECOVER only if $(t - t_{\text{SAFE}}) \geq h$ and $\mathrm{ErrRate}_t \leq \epsilon_{\max}$.

Guards:

G1: $U_t < U_{\min} \ \vee \ \mathrm{ErrRate}_t > \epsilon_{\max}$,

G2: $s_t = \texttt{SAFE} \ \wedge \ \mathrm{ErrRate}_t \leq \epsilon_{\max} \ \wedge \ (t - t_{\text{SAFE}}) \geq h$.

II. Objective

$$\begin{aligned} \max_{a \in \mathcal{A},\, \pi \in \Pi} \quad & \mathbb{E}[J(\pi(x, c))] - \lambda_{\text{read}}\, \mathsf{Read}(a) \\ \text{s.t.} \quad & \texttt{WF\_PartE} = 1. \end{aligned} \tag{4}$$

A. Unified optimization (extended constraints)

$$\begin{aligned} \max_{a \in \mathcal{A},\, \pi \in \Pi} \quad & \mathbb{E}[J(\pi(x, c))] - \lambda_{\text{read}}\, \mathsf{Read}(a) \\ \text{s.t.} \quad & \texttt{WF\_PartE} = 1,\ \texttt{WF\_PartF} = 1,\ \texttt{WF\_G} = 1. \end{aligned} \tag{5}$$

III. Well-Formedness: Part E (Expanded)

A. Aggregate definition

$$\begin{aligned} \texttt{WF\_PartE} = \Big(\bigwedge_{S \in \{\texttt{E.1},\ldots,\texttt{E.14}\}} \texttt{WF\_S} \Big) \\ \wedge \Big(\bigwedge_{j=1}^{4} \mathrm{GR}_j \Big) \wedge \Big(\bigwedge_{i=1}^{11} P_i \Big). \end{aligned} \tag{6}$$

B. Selected elemental rules E.1..E.14 (closed form)

E.1 DevOps lexical firewall:

$$\texttt{WF}_{\texttt{E}}.1(a) = \mathbf{1}!\left[\forall t \in \mathcal{L}\mathrm{ban} : \ \mathrm{freq}a(t) = 0\right]. \tag{7}$$

E.2 Notational independence:

$$\begin{aligned} &\forall a, \ \forall \mathrm{f}_1, \mathrm{f}_2 : \ \mathsf{Render}(a, \mathrm{f}_1) \equiv \mathsf{Render}(a, \mathrm{f}_2) \\ &\Rightarrow \ \mathsf{Sem}(\mathsf{Render}(a, \mathrm{f}_1)) = \mathsf{Sem}(\mathsf{Render}(a, \mathrm{f}_2)). \end{aligned} \tag{8}$$

E.3 Unidirectional dependency:

$$\texttt{WF}_{\texttt{E}}.3 = \mathbf{1}[\text{dependency graph on families is DAG}] = 1. \tag{9}$$

E.4 Cross-domain bias audit:

$$\mathsf{BiasIndex} = \sum_{g \in G} w_g, \left| \Pr(\hat{y} = 1 \mid g) - \Pr(\hat{y} = 1) \right| \ \leq \ \beta_{\max}. \tag{10}$$

E.5 DRR process and no-loss trace:

$$\texttt{trace}_{\rightarrow} : \ \mathcal{A} \to \mathcal{A}, \quad \texttt{trace}_{\leftarrow} : \ \mathcal{A} \to \mathcal{A}. \tag{11}$$

$$\mathbf{1}\big[\texttt{trace}_{\rightarrow} \text{ and } \texttt{trace}_{\leftarrow} \text{ are total}\big] = 1. \tag{12}$$

$$\begin{aligned} \texttt{NoLoss\_Audit} = 1 \ \Leftrightarrow \forall a \ \exists a' : \\ \texttt{trace}_{\rightarrow}(a) = a' \ \wedge \ \texttt{trace}_{\leftarrow}(a') = a. \end{aligned} \tag{13}$$

E.6 Context alias disambiguation:

$$\forall c_1 \neq c_2 : \ \mathsf{Norm}(c_i) = k \Rightarrow c_1, c_2 \text{ reference the same } k. \tag{14}$$

E.7 I/D/S separation:

$$\mathtt{WF_E}.7 = \mathbf{1}[I \cap D = \varnothing \wedge I \cap S = \varnothing \wedge D \cap S = \varnothing] = 1. \tag{15}$$

E.8 Lex-bundle uniformity:

$$\mathtt{WF_E}.8 = \mathbf{1}[\text{dictionary coverage complete and unambiguous}] = 1. \tag{16}$$

E.9 Naming discipline reference:

$$\mathtt{WF_E}.9 = \mathtt{WF_N ame}(n) \text{ as in (46).} \tag{17}$$

E.10 Catalogue coverage trigger:

$$\mathtt{WF_E}.10 = \mathbf{1}[\text{all } u \in \mathcal{U} \text{ catalogued}] = 1. \tag{18}$$

E.11 Adequacy non-degradation:

$$\Delta \mathbb{E}[J] \geq 0 \quad \text{under admissible refactorings.} \tag{19}$$

E.12 Valid identifier rate:

$$\Pr[\text{artefact has valid } \mathtt{DRR\_id}] \ \geq \ 0.995. \tag{20}$$

E.13 Change-log schema compliance:

$$\forall \text{row} : \ \text{row} = \mathsf{CL_r ow} \text{ as in (66).} \tag{21}$$

E.14 Source/regression safety reference:

$$\mathtt{WF_E}.14 = \mathtt{WF_S CR} \wedge \mathtt{WF_R SCR} \text{ as in (48).} \tag{22}$$

C. Guards and Points (enumeration)

$$\mathrm{GR}_1 = \mathbf{1}[\text{all external interfaces versioned and frozen}], \tag{23}$$

$$\mathrm{GR}_2 = \mathbf{1}[\text{backward-compatible schema diffs only}], \tag{24}$$

$$\mathrm{GR}_3 = \mathbf{1}[\text{no orphan artefacts in } c(a)], \tag{25}$$

$$\mathrm{GR}_4 = \mathbf{1}[\text{unit tests cover all contracts}]. \tag{26}$$

$$P_1 = \mathbf{1}[\text{I/D/S separation holds at row level}], \ \ldots, \ P_{11} = \mathbf{1}[\text{NoLoss trace resolvable within one hop}]. \tag{27}$$

D. Bias cohorts and review cadence

$$G = \{g_1, \ldots, g_m\}, \quad w_g \geq 0, \ \sum_{g \in G} w_g = 1, \tag{28}$$

BiasIndex as in (10), reviewed at each release.

E. Fairness: Equal Opportunity

$$\mathrm{EO\_gap} = \max_{g \in G} \left| \mathrm{TPR}_g - \mathrm{TPR} \right| \ \leq \ \delta_{\mathrm{eo}}. \tag{29}$$

IV. Well-Formedness: Part F (Expanded)

A. Domain coverage and acyclicity

$$\mathbf{1}! \left[\bigcup_{i=1}^{N} \mathtt{scope}_i = \mathtt{TargetDomain} \right] \wedge \mathbf{1}! \left[\mathtt{DAG}(v_i) \right] = 1. \tag{30}$$

B. Cluster cohesion and purity

$$\forall s \ \forall t, t' \in \mathrm{cluster}(s) : \ \mathrm{sim}(t, t') \geq \theta, \tag{31}$$

$$\mathbf{1}! \left[\mathcal{K}_c \text{ does not intersect other clusters} \right] = 1. \tag{32}$$

C. Link budget, growth control, new-type quota

$$\begin{aligned} &\textstyle\sum_{\text{links}} CL \leq \zeta_{\max}, \\ &\mathsf{ExplodeIndex} = \tfrac{\#\,\text{NewRows} + \#\,\text{NewTemplates}}{\#\,\text{ReusedRows}+1} \ \leq \ \xi_{\max}. \end{aligned} \tag{33}$$

$$\#\,\text{NewTypes per release} \ \leq \ K. \tag{34}$$

D. Link-cost units and budget aggregation

$$\begin{aligned} &CL : \text{links} \to \mathbb{R}_{\geq 0}, \\ &CL = \tfrac{\text{reading time}}{\text{page unit}}, \\ &\textstyle\sum CL \text{ is additive under } \Gamma_{\text{work}}. \end{aligned} \tag{35}$$

E. Bridges and cross-room discipline

$$\begin{aligned} &\mathbf{1}[\text{bridges well formed}] = 1, \\ &\mathbf{1}[\text{no implicit cross-room jumps}] = 1. \end{aligned} \tag{36}$$

F. Map cost regularity

$$\begin{aligned} &\text{Let } p = (c, s_c), \ q = (c', s_{c'}); \\ &CL(p \leftrightarrow q) = CL(q \leftrightarrow p). \end{aligned} \tag{37}$$

$$\begin{aligned} &\text{Let } p = (c, s_c), \ q = (c', s_{c'}), \ r = (c'', s_{c''}); \\ &CL(p \leftrightarrow r) \leq CL(p \leftrightarrow q) + CL(q \leftrightarrow r). \end{aligned} \tag{38}$$

G. Bridge schema

$$\begin{aligned} \mathrm{Bridge} = (&c_{\mathrm{src}}, s_{\mathrm{src}}, c_{\mathrm{dst}}, s_{\mathrm{dst}}), \\ &\mathbf{1}[\text{bidirectional}] \\ &\wedge \ \mathbf{1}[\text{cluster-consistent}] \\ &\wedge \ \mathbf{1}[\text{no hidden jumps}]. \end{aligned} \tag{39}$$

V. Glossary and Catalogue

A. Completeness and cardinality

$$\mathtt{Glossary} = \{\mathsf{Entry}(u) \mid u \in \mathcal{U}\}, \qquad |\mathtt{Glossary}| = |\mathcal{U}|. \tag{40}$$

B. Graph maps: bidirectionality and navigation

$$\begin{aligned}\texttt{WF}_{\texttt{G}} = \mathbf{1}\big[&\text{(40) holds}\big]\\ \wedge\ \mathbf{1}\big[&\text{maps are bidirectional and}\\ &\text{transitively navigable}\big].\end{aligned} \tag{41}$$

C. Optimization of readability vs. ambiguity

$$\begin{aligned}\max_{\text{Glossary, Catalogue, } R}\quad & \mathbb{E}\big[\text{Readability}(\text{Glossary})\big]\\ & -\lambda\,\text{Ambiguity}(\text{Glossary}, R)\\ \text{s.t.}\quad & \texttt{WF}_{\texttt{G}} = 1,\\ & |\text{Glossary}| = |\mathcal{U}|.\end{aligned} \tag{42}$$

D. KPIs for readability and ambiguity

$$\begin{aligned}\text{Readability} &= \frac{1}{|\mathcal{U}|}\sum_{u\in\mathcal{U}} r(u),\\ \text{Ambiguity} &= \frac{1}{|\mathcal{U}|}\sum_{u\in\mathcal{U}} a(u,R),\\ &\text{where } r, a \in [0,1].\end{aligned} \tag{43}$$

E. Adaptation and Resilience thresholds

$$\text{AdaptRate} \ \geq\ \rho_{\text{adapt}}, \qquad \text{Resilience} \ \geq\ \rho_{\text{res}}. \tag{44}$$

F. Row stub completeness

$$\texttt{WF}_{\texttt{S}}\texttt{tub}(p) = \mathbf{1}\big[\text{all 10 fields present}\big]. \tag{45}$$

VI. Naming Discipline and Authoring

A. Name quality

$$\texttt{WF}_{\texttt{N}}\texttt{ame}(n) = \mathbf{1}\big[\text{unique}\big] \wedge \mathbf{1}\big[\text{readable}\big] \wedge \mathbf{1}\big[\text{suffix in registry}\big]. \tag{46}$$

B. Authoring structure

$$\texttt{WF}_{\texttt{A}}\texttt{uthoring}(a) = \mathbf{1}\Big[\texttt{Sections} = \{\texttt{Intent},\ \texttt{Contract},\ \texttt{Invariants},\ \texttt{Examples}\}\Big]. \tag{47}$$

VII. Source and Regression Safety

$$\begin{aligned}\texttt{WF\_SCR} &= \mathbf{1}\big[\texttt{No\_Dangling}\big],\\ \texttt{WF\_RSCR} &= \mathbf{1}\big[\texttt{No\_Regression\_Breaks}\big].\end{aligned} \tag{48}$$

VIII. Lexical Hygiene and Dependencies

A. Core leakage prevention

$$\texttt{NoLeak}_{\texttt{C}}\texttt{ore}(a) = \mathbf{1}!\left[\forall t \in \mathcal{L}\text{ban}:\ \text{freq}a(t) = 0\right]. \tag{49}$$

B. Dependency constraints

$$\texttt{WF}_{\texttt{D}}\texttt{eps} = \mathbf{1}\big[\nexists\ (\texttt{Core} \to \cdot)\ \vee\ (\texttt{Tooling} \to \texttt{Pedagogy})\big] = 1. \tag{50}$$

IX. Composition Operators and Levels

A. Method composition

$$\Gamma_{\text{method}}:\ M_2 \circ M_1,\ \ M_1 \parallel M_2,\quad \mathbf{1}\big[\text{boundaries aligned}\big] = 1. \tag{51}$$

B. Strategic evolution layer

$$\Gamma_{\text{evolve}}:\ \kappa_{t+1} = \mathcal{T}(\kappa_t, \delta_t),\quad \kappa_t \in \mathcal{K},\ \delta_t \in \mathcal{D}_{\text{adm}}. \tag{52}$$

$$\texttt{EvoStable} = 1 \iff \tag{53}$$

$$\begin{aligned}&\texttt{WF\_PartE} = 1\\ &\wedge\ \texttt{WF\_PartF} = 1\\ &\wedge\ \texttt{WF\_G} = 1\\ &\wedge\ \textstyle\sum CL \leq \zeta_{\max}.\end{aligned} \tag{54}$$

C. Strategic evolution objective

$$\min_{\{\delta_t\}_{t=0}^{T-1}} \sum_{t=0}^{T-1} \Big(-\mathbb{E}[J(\kappa_{t+1})] + \lambda_{\text{chg}}\ \text{ChangeCost}(\delta_t)\Big) \tag{55}$$

$$\text{s.t.}\ \ \kappa_{t+1} = \mathcal{T}(\kappa_t, \delta_t),\ \delta_t \in \mathcal{D}_{\text{adm}},\ \text{(44), EVO\_ROB=1} \tag{56}$$

D. Work aggregation

$$\Gamma_{\text{work}}:\ \sum \texttt{consume},\quad \mathbf{1}\big[\text{budgets additive}\big] = 1. \tag{57}$$

E. Strategic evolution

$$\Gamma_{\text{evolve}}:\ \kappa_{t+1} = \mathcal{T}(\kappa_t, \delta_t),\quad \kappa_t \in \mathcal{K},\ \delta_t \in \mathcal{D}_{\text{adm}}. \tag{58}$$

F. Evolutionary composition (strategic layer)

$$\Gamma_{\text{evolve}}:\ \ \kappa_{t+1} = \mathcal{T}(\kappa_t, \delta_t),\quad \kappa_t \in \mathcal{K},\ \delta_t \in \mathcal{D}_{\text{adm}}. \tag{59}$$

An evolution step $\mathcal{T}$ is admissible only if well-formedness and budgets are preserved: $\texttt{WF\_PartE} = 1$, $\texttt{WF\_PartF} = 1$, $\texttt{WF\_G} = 1$, and $\sum CL \leq \zeta_{\max}$.

G. Policy semantics and composition contract

$$\pi:\ \mathcal{X} \times \mathcal{C}\ \to\ \Delta(\mathcal{Y}) \tag{60a}$$

$$\mathbb{E}[J(\pi_2 \circ \pi_1)] \geq \alpha\,\mathbb{E}[J(\pi_1)] + (1-\alpha)\,\mathbb{E}[J(\pi_2)]\,,\quad \alpha \in [0,1]. \tag{60b}$$

Consistent with Γ_{method}.

H. Assurance levels

$$L_0 < L_1 < L_2, \qquad \mathbf{1}\big[\text{thresholds satisfied}\big] = 1. \tag{61}$$

I. Numerical thresholds for assurance

$$\exists\,\{\tau^{(L_i)}, \hat{\tau}^{(L_i)}\}_{i\in\{0,1,2\}}: \quad \mathrm{Acc} \geq \tau^{(L_i)} \ \wedge\ \mathrm{Spec} \geq \hat{\tau}^{(L_i)} \\ \Rightarrow\ L \geq L_i \qquad (\forall\, i \in \{0,1,2\}). \tag{62}$$

X. Aliases and Normalisation

A. Invariants

$$\underline{\texttt{IDEM}}: \ \mathsf{Norm}(k,c) = (k, v_k) \Rightarrow \\ \mathsf{Norm}(k,c) = (k, v_k) \tag{63}$$

$$\underline{\texttt{UNIQ}}: \ (\ell_1 \neq \ell_2) \wedge \mathsf{Norm}(\ell_i, c) = (k, v) \Rightarrow \\ \ell_1, \ell_2 \text{ reference the same } k \tag{64}$$

$$\underline{\texttt{TRACE}}: \ \forall \ell: \ \exists\ \texttt{DRR\_id}(\ell \to k) \wedge \\ \texttt{ChangeLog}(\ell, k, v) \tag{65}$$

XI. DRR Change Log: Schema and Example

A. Row schema

$$\mathsf{CL\_row}^{+} = (\mathsf{CL\_row},\ \mathcal{U}_{\mathrm{fuzzy}},\ \texttt{RB\_Test},\ \texttt{EVO\_ROB},\ \mathsf{BiasIndex}). \tag{66}$$

B. Field formats

$$\texttt{When} \in \text{ISO-8601}, \quad v_{\mathrm{old/new}} \text{ in SemVer}, \quad \Delta \in \texttt{add}, \texttt{mod}, \texttt{del}. \tag{67}$$

C. Rollback predicate

$$\texttt{Rollback} = 1 \iff \exists\,\text{row}: \ \Delta \in \{\texttt{mod}, \texttt{del}\} \\ \wedge\ \text{replay}(\texttt{trace}_{\leftarrow}) \text{ succeeds}. \tag{68}$$

D. Rollback test

$$\texttt{RB\_Test} = \mathbf{1}[\,\neg\exists\,\text{row: } \Delta \in \{\texttt{mod}, \texttt{del}\}\,] \ \vee\ \texttt{Rollback} = 1. \tag{69}$$

E. Example row

DRR_id	Obj	v_{old}	v_{new}	Δ	When	Who
A1234	a	1.2.0	1.3.0	add	2025-01-01	team_B

F. Row coverage constraint

$$\texttt{WF\_G.2} = \mathbf{1}\Big[\{\, p \in \text{Catalogue} \mid p.\text{kind} = \text{row}\,\} \\ \subseteq \text{table rows}\Big] \ \wedge\ \prod_{p} \texttt{WF\_Stub}(p) = 1. \tag{70}$$

XII. Acceptance Conditions

A. E/F/G acceptance

$$\texttt{ACCEPT\_E} = \mathbf{1}\big[\texttt{WF\_PartE} = 1\big] \ \wedge \\ \mathbf{1}\big[\mathbb{E}[J] \text{ non-decreasing}\big]. \tag{71}$$

$$\texttt{ACCEPT\_F} = \mathbf{1}\big[\texttt{WF\_PartF} = 1\big] \ \wedge \\ \mathbf{1}\big[\textstyle\sum CL \leq \zeta_{\max}\big] \ \wedge \\ \mathbf{1}\big[\mathsf{ExplodeIndex} \leq \xi_{\max}\big]. \tag{72}$$

$$\texttt{ACCEPT\_G} = \mathbf{1}\big[\texttt{WF\_G} = 1\big] \ \wedge \\ \mathbf{1}\big[\text{all } u \in \mathcal{U} \text{ catalogued}\big] \ \wedge \\ \mathbf{1}\big[\text{maps bidirectional}\big]. \tag{73}$$

B. Evolutionary robustness

$$\texttt{EVO\_ROB} = \mathbf{1}\begin{bmatrix} \forall\,\delta \in \mathcal{D}_{\mathrm{adm}}: \ \mathbb{E}[J(\kappa_{t+1})] \ \geq\ \mathbb{E}[J(\kappa_t)] - \epsilon_{\mathrm{evo}} \\ \wedge\ \texttt{WF\_PartE} = \texttt{WF\_PartF} = \texttt{WF\_G} = 1 \end{bmatrix} \tag{74}$$

C. Unified acceptance gate (with rollback & evo-robustness)

$$\texttt{ACCEPT\_OS} = 1 \iff \texttt{ACCEPT\_E} = 1 \tag{75}$$

$$\wedge\texttt{ACCEPT\_F} = 1 \tag{76}$$

$$\wedge\texttt{ACCEPT\_G} = 1 \tag{77}$$

$$\wedge\texttt{RB\_Test} = 1 \tag{78}$$

$$\wedge\texttt{EVO\_ROB} = 1 \tag{79}$$

$$\wedge\mathbb{E}[J] \geq U_{\min}. \tag{80}$$

D. Glossary objective bound

$$\texttt{ACCEPT\_G} = \begin{cases} 1, & \mathrm{Obj}^{\star} \geq \rho > 0, \\ 0, & \mathrm{Obj}^{\star} < \rho. \end{cases} \tag{81}$$

E. Fuzzy quality aggregation

Let $m = (\mathrm{Acc}, \mathrm{Prec}, \mathrm{Rec}, \mathrm{F1}, \mathrm{Spec}, 1-\mathrm{FPR}, 1-\mathrm{FNR})$. Define membership functions $\mu_i : [0,1] \to [0,1]$ and normalized weights $\nu_i \geq 0$ with $\sum_i \nu_i = 1$. The aggregate score is

$$\mathcal{U}\text{fuzzy} = \sum i\nu_i, \mu_i!\,(m_i)\,, \qquad \mathcal{U}_{\mathrm{fuzzy}} \in [0,1]. \tag{82}$$

F. Metric thresholds

$$\mathrm{Acc} \geq 0.985, \tag{83}$$

$$\mathrm{Prec} \geq 0.980, \tag{84}$$

$$\mathrm{Rec} \geq 0.975, \tag{85}$$

$$\mathrm{F1} \geq 0.977, \tag{86}$$

$$\mathrm{Spec} \geq 0.990, \tag{87}$$

$$\mathrm{FPR} \leq 0.010, \tag{88}$$

$$\mathrm{FNR} \leq 0.025. \tag{89}$$

G. Operational SLOs

$$\text{Latency} \le \ell_{\max}, \quad \text{Throughput} \ge \tau_{\min}, \quad \text{ErrRate} \le \epsilon_{\max}. \tag{90}$$

$$\text{RollbackSuccRate} \ \ge r_{\min}, \qquad \text{MTTR} \ \le t_{\max}. \tag{91}$$

$$\text{Latency}_{p99} \ \le \ \ell^{99}_{\max}. \tag{92}$$

H. Emergent indicators

$$\text{AdaptRate} = \frac{\Delta \text{Acc}}{\Delta t}, \qquad \text{Resilience} = \Pr\big[\text{recover within } k \text{ steps}\big]. \tag{93}$$

I. Workflow gate for publish

$$\text{Gate}_{\text{publish}} = 1 \iff \texttt{ACCEPT\_OS} = 1 \ \wedge \ \text{Acc} \ge 0.985 \ \wedge \ \mathcal{U}_{\text{fuzzy}} \ge \eta. \tag{94}$$

for a release policy constant $\eta \in (0, 1)$.

XIII. Quality Metrics

Let $\text{TP}, \text{FP}, \text{FN}, \text{TN} \in \mathbb{N}$, $P = \text{TP} + \text{FN}$, $N = \text{TN} + \text{FP}$, $T = P + N$. Then

$$\text{Acc} = \frac{\text{TP} + \text{TN}}{T}, \tag{95}$$

$$\text{Prec} = \frac{\text{TP}}{\text{TP} + \text{FP}}, \tag{96}$$

$$\text{Rec} = \frac{\text{TP}}{P}, \tag{97}$$

$$\text{F1} = \frac{2\,\text{TP}}{2\,\text{TP} + \text{FP} + \text{FN}}, \tag{98}$$

$$\text{Spec} = \frac{\text{TN}}{N}, \tag{99}$$

$$\text{FPR} = \frac{\text{FP}}{N}, \tag{100}$$

$$\text{FNR} = \frac{\text{FN}}{P}. \tag{101}$$

A. Emergent indicators

$$\text{AdaptRate} = \frac{\Delta \text{Acc}}{\Delta t}, \qquad \text{Resilience} = \Pr\big[T_{\text{rec}} \le k\big]. \tag{102}$$

B. KPI mapping

Principial component	Metric	μ_i in $\mathcal{U}_{\text{fuzzy}}$
Predictivity	Acc, Prec, Rec, F1, Spec	$\mu_{\text{pred}}(m)$
Calibration	ECE (aux.), threshold tuning	$\mu_{\text{cal}}(m)$
Fairness	BiasIndex	$\mu_{\text{fair}}(\cdot)$
Robustness	EVO_ROB	$\mu_{\text{rob}}(\cdot)$
Recoverability	RB_Test, MTTR	$\mu_{\text{rec}}(\cdot)$
Readability	Readability	$\mu_{\text{read}}(\cdot)$
Ambiguity	Ambiguity	$\mu_{\text{amb}}(\cdot)$
Cost/Budget	$\sum CL$, ExplodeIndex	$\mu_{\text{cost}}(\cdot)$

XIV. Conformance Checklist

ID	Rule (formula)	Verification artefact	Status
E.2	$\mathsf{Sem}(\mathrm{f}_1) = \mathsf{Sem}(\mathrm{f}_2)$	paired renders + semantic diff	pass/fail
E.3	DAG on families	dependency graph audit	pass/fail
E.4	$\mathsf{BiasIndex} \le \beta_{\max}$	cohort metrics report	pass/fail
E.5	NoLoss trace (11–13)	round-trip traces	pass/fail
F.*	(30–36)	scope, clusters, links	pass/fail
CL	(37–38)	map cost symmetry/triangle	pass/fail
G.Obj	(42, 43, 81)	readability/ambiguity report	value
Name	(46)	registry check	pass/fail
SCR	(48)	CI logs	pass/fail
SLOs	(90)	perf. monitoring report	pass/fail
EvoStable	(59, 53)	evolution audit	pass/fail
Rollback	(68)	rollback test log	pass/fail
Emergent	(93)	KPI report	value
Safe-mode	(3)	runtime traces	pass/fail
EVO_ROB	(55, 75)	adversarial evolution tests	pass/fail
Adapt/Res	(44)	learning curve + recovery stats	pass/fail
Latency p99	(92)	perf. monitoring report	pass/fail
EO_gap	(29)	cohort TPR analysis	pass/fail
Fairness	$\mathsf{BiasIndex} \le \beta_{\max}$ (value shown)	cohort metrics report	pass/fail

XV. Symbols to Semantic Names

Legacy symbol	Semantic name
$\mathcal{C}$	set of rooms (contexts)
$\mathcal{U}$	universe of canonical entries
a	artefact (generic)
x	input instance
c; $c(\cdot)$	room; artefact-to-rooms map
Π, π	set of policies; policy
$\pi(x, c)$	policy decision on (x, c)
J, $\mathbb{E}[J]$	utility; expected utility
λ_{read}, $\mathsf{Read}(a)$	read penalty; reading cost
Adeq	adequacy indicator
$\text{sim}(t, t')$, θ	similarity; similarity threshold
$CL(\cdot)$, $\zeta_{\max}$	link cost; max total link cost
$\mathsf{ExplodeIndex}$, $\xi_{\max}$	explode index; explode limit
K	new-type quota per release
Γ_{method}, Γ_{work}	composition (methods, work)
$\beta_{\max}$	bias index limit
TP, FP, FN, TN	confusion counts
P, N, T	actual positives, negatives, total
$U_{\min}$, η	minimum expected utility; publish gate threshold
$\mu_i(\cdot)$, ν_i	membership functions; normalized weights
$\tau^{(L_i)}$, $\hat{\tau}^{(L_i)}$	assurance thresholds (acc./spec.)
$s_t \in \{\texttt{RUN}, \texttt{SAFE}, \texttt{RECOVER}\}$	runtime mode state
Γ_{evolve}	strategic evolution operator
`Rollback`, `RB_Test`	rollback predicate and acceptance test
AdaptRate	adaptation speed (dAcc/dt)
Resilience	recovery probability within k steps
`SAFE`, `RUN`, `RECOVER`	runtime states
`Rollback`	rollback test predicate
Γ_{evolve}	strategic evolution operator
κ_t, δ_t	architecture config; admissible change
$\mathcal{T}$	architecture transition function
`EvoStable`	evolutionary stability predicate
AdaptRate	adaptation speed KPI
Resilience	recovery probability KPI
t_{SAFE}, h	SAFE entry time; hold time for recovery
`SAFE`, `RUN`, `RECOVER`	runtime states (safe-mode automaton)
`RB_Test`, `EVO_ROB`	rollback test; evolution robustness gate
Γ_{evolve}	strategic evolution operator
AdaptRate, Resilience	adaptation speed; recovery probability

XVI. Conclusion

The formulation delivers a minimal, self–contained operational semantics with three functional gates and measurable acceptance criteria. Explicit naming replaces opaque labels, and structure budgets bound growth. The result is directly auditable and ready for implementation.

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