Paper 3

Closed-loop spatial identification by topological fusion of multi-source public spatial data and on-site walking verification feedback (the Block Puzzle formula)

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Abstract

By combining the footprint and regulatory data from the outside (GSI, PLATEAU 3D, nationwide building DB, JMA, Building Standards Act and others) with smartphone walking tracks from the inside—covering only the common areas (entrance hall, corridors end to end, stairs, elevator hall, shared toilets)—through the Block Puzzle formula over private-area, common-area and machine/equipment blocks (XYZ dimensions)—area-conservation normalization + weighted Voronoi partitioning + carry-in/out clearance check by 3D Minkowski difference—we obtain in one pass: ① a floor plan with an area residual of 0.00 m², ② the boundaries between rooms and corridors, ③ equipment pin coordinates, and ④ whether machines can be carried in and out along a route in factories and similar facilities. Private (tenant) spaces are never entered; their layout is back-calculated from the common-area skeleton, the footprint and the contracted m². Floor plans always start with the Block Puzzle; when a more detailed floor plan is wanted, as-built drawing data is overlaid on top.

1. Blocks

Let $B = B_{priv} \cup B_{comm} \cup B_{mach}$. A private block j has a name and target area a_j; common blocks (corridor, stairs, elevator, entrance hall, toilets, etc.) have reference legal/JIS dimensions; a machine/equipment block m has X · Y · Z (width · depth · height) dimensions (X_m, Y_m, Z_m).

2. Area-conservation normalization

The entered private areas are distributed proportionally over the slab area minus the common areas from the 1st Paper, making the area residual 0.00 m².

$$\hat{a}_j = a_j \cdot (A_{slab} - \Sigma_k A_k) / \Sigma_j a_j, \quad \Sigma_j \hat{a}_j + \Sigma_k A_k = A_{slab} \qquad (1)$$

3. Weighted Voronoi partitioning

The door positions of the private areas, confirmed from the corridor while walking the common areas, are the sites s_j; the footprint P minus the common areas is partitioned while iterating weights w_j until

each cell's area equals the normalized area $\hat{a}_j$. Private spaces are never entered.

$$V_j = \{\, x \in P :\ \| x - s_j \|^2 - w_j \le \| x - s_i \|^2 - w_i \quad \forall i \,\}, \quad |V_j| = \hat{a}_j \qquad (2)$$

Corridors are the common-area walking track T dilated by half the corridor width, which fixes the room/corridor boundaries.

$$C = T \oplus D(W/2) \qquad (3)$$

4. Carry-in/out clearance check by 3D Minkowski difference

From the free space F of corridors (plan shape × effective height h_{eff}) and a machine block M_θ at orientation θ, we compute the set of feasible positions. Carry-in/out is possible if a path connected over θ in 5° steps exists from the entrance to the target; turning at a corner is possible if there is a position where θ can rotate continuously.

$$M_\theta = R_\theta(\, [0, X_m] \times [0, Y_m] \,) \times [0, Z_m] \qquad (4)$$

$$C_{free}(\theta) = F \ominus M_\theta = \{\, x : x + M_\theta \subseteq F \,\} \qquad (5)$$

$$\text{feasible} \Leftrightarrow \exists\ \text{path}\ \gamma : [0,1] \to \cup_\theta\, C_{free}(\theta), \quad \gamma(0) = \text{entrance}, \quad \gamma(1) = \text{target}, \quad Z_m \le h_{eff} \qquad (6)$$

5. Closed loop (on-site walking verification feedback)

Each press of "Matches / Fix" on site updates sites, weights and dimensions, and drawing completeness κ approaches 1 with operation. Equipment pins are kept in normalized coordinates $(\xi, \eta) \in [0,1]^2$ relative to the footprint, so positions persist when the footprint is updated.

$$\kappa^{(t+1)} = \kappa^{(t)} + \eta\,(\,1 - \kappa^{(t)}\,) \cdot v^{(t)}, \quad v^{(t)} \in \{0, 1\} \qquad (7)$$

6. Results

① A floor plan with an area residual of 0.00 m², ② room/corridor boundaries, ③ equipment pin coordinates, ④ whether machines can be carried in/out along a route in factories and similar facilities. Upcoming inspection dates are managed as reference guidelines linked to equipment pins on the floor plan.

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