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What Do We Mean When We Talk About Spatial Intelligence?

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Abstract Spatial intelligence is often invoked in sharply different ways. In psychology, it may refer to an individual's ability to rotate forms, navigate routes, or reason with diagrams. In artificial intelligence, it may refer to 3D perception, mapping, localization, or embodied control. In geography, architecture, urban studies, and spatial computing, it may describe still other relationships among place, representation, design, and action. This editorial introduces the Journal of Spatial Intelligence by arguing that these usages should not be collapsed into a single discipline, nor left as unrelated metaphors. We define spatial intelligence as the capacity of humans, machines, environments, and hybrid systems to perceive, represent, reason about, learn from, generate, interact with, and act within spatial environments across multiple scales. The article clarifies how this broader definition relates to spatial cognition, spatial ability, GeoAI, embodied intelligence, architectural intelligence, urban intelligence, and spatial computing. It proposes that space is not a passive container for intelligence, but a medium in which intelligence is formed, tested, constrained, and made consequential.

Keywords spatial intelligence; spatial cognition; embodied intelligence; GeoAI; spatial computing; architectural intelligence; urban intelligence

1. Introduction

The launch of the Journal of Spatial Intelligence begins from a simple difficulty: many fields study intelligence in space, yet they rarely share a common account of what spatial intelligence means. Psychologists investigate how people imagine, remember, rotate, and navigate spatial configurations. Computer scientists build systems that detect objects, reconstruct scenes, localize robots, and infer relations among entities. Geographers model spatial dependence, scale, place, and territory. Architects and urban researchers examine how built form organizes perception, movement, social encounter, comfort, and environmental performance. Designers of spatial computing systems create interfaces in which digital information is anchored to physical surroundings. Each tradition offers indispensable knowledge. None is sufficient on its own.

This journal is founded on the view that spatial intelligence should name a broader field of inquiry rather than a narrow technical label. The term has a recognizable history in the study of human intelligence. Gardner (1983) treated spatial intelligence as one of several relatively distinct human capacities, associated with the ability to perceive the visual-spatial world and transform those perceptions. That contribution remains important because it resisted a single, language-and-number-centered image of intelligence. Yet the present moment requires a more expansive definition. Spatial

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problems now involve people, machines, buildings, cities, regions, remote environments, and their interactions. They include not only mental rotation or route memory, but also spatial data infrastructures, embodied agents, adaptive environments, generative design systems, and ethically consequential actions in real places.

In this editorial, spatial intelligence is defined as the capacity of humans, machines, environments, and hybrid systems to perceive, represent, reason about, learn from, generate, interact with, and act within spatial environments across multiple scales. The definition deliberately includes multiple subjects of intelligence and multiple operations of intelligence. It also emphasizes environments, not merely internal models. A spatially intelligent system is not one that only stores coordinates or labels scenes. It must engage with arrangement, distance, enclosure, adjacency, accessibility, affordance, visibility, movement, atmosphere, risk, and consequence. It must also recognize that spatial action changes the conditions for later perception and judgment.

2. Conceptual Inheritances and Limits

The first inheritance comes from cognitive science and education. Work on spatial thinking has shown that maps, diagrams, models, gestures, and visualizations are not secondary aids to thought; they are forms through which thought is organized. The National Research Council (2006) argued that spatial thinking combines concepts of space, tools of representation, and processes of reasoning. That triad remains useful for a field that must connect human understanding with computational and design systems. It also warns against reducing spatial intelligence to visual talent. Spatial thinking involves relations, transformations, scales, and situated interpretation.

The second inheritance comes from geographic information science. Goodchild (1992) helped establish GIScience as a research field concerned not only with software, but with the fundamental problems of geographic representation, spatial analysis, uncertainty, and scale. This tradition is essential because much of spatial intelligence operates across landscapes, infrastructures, territories, and planetary systems. It also reminds us that spatial information is never only data about locations. It carries assumptions about classification, measurement, projection, resolution, and the social purposes for which places are made legible.

The third inheritance comes from artificial intelligence and robotics. Brooks (1991) challenged approaches that treated intelligence as detached symbolic representation, arguing instead for situated systems that couple sensing and action. Whether one accepts every implication of that argument or not, it made a lasting point: intelligence in the world cannot be evaluated solely by inspecting an internal description. It must be understood through behavior under environmental constraints. Spatial intelligence therefore includes embodied perception, navigation, manipulation, and interaction, as well as abstract reasoning about spatial relations.

The fourth inheritance comes from mixed reality and spatial computing. Milgram and Kishino (1994) proposed the reality-virtuality continuum to describe how physical and virtual environments may be combined in visual displays. Contemporary spatial computing extends that concern into everyday interaction, using tracking, sensing, mapping, and augmentation to situate digital content in physical space. For spatial intelligence, this matters because the boundary between representation and environment becomes porous. A map can become an interface; a building can become a sensor-rich medium; a virtual model can influence physical action.

These inheritances also have limits. Spatial cognition is often human-centered. Spatial ability is often measured through bounded tasks. GeoAI is often large-scale and data-intensive. Robotics may privilege navigation and control over architectural or urban meaning. Spatial computing may focus on interface experience without fully addressing reasoning, governance, or environmental performance. The field proposed here does not replace those traditions. It offers a place where their partial insights can be compared, connected, and tested against shared spatial problems.

3. Space as a Medium of Intelligence

The central claim of this journal is that space is not a passive container in which intelligence happens. Space shapes what can be perceived, what can be represented, what can be inferred, what can be learned, and what can responsibly be done. A corridor affords movement differently from a plaza. A dense street network supports different forms of access and surveillance than a cul-de-sac. A planetary surface, an operating room, and a housing estate demand different relations among uncertainty, embodiment, autonomy, and care. Intelligence becomes spatial when it depends on such relations and when its success is evaluated in relation to them.

This claim matters for humans. People do not experience environments as neutral geometries. They perceive landmarks, edges, thresholds, sequences, hazards, atmospheres, and opportunities for action. They remember places through routes, stories, emotional associations, and social routines. They use sketches, plans, gestures, and models to coordinate collective spatial understanding. Human spatial intelligence includes bodily orientation, cultural interpretation, technical representation, and practical judgment.

It also matters for machines. Artificial intelligence systems increasingly reconstruct 3D scenes, infer spatial relations from images and language, plan routes, generate floor plans, predict flows, and control mobile agents. Yet a machine that recognizes objects may still misunderstand spatial causality. It may know that a door is visible without knowing whether it is usable, blocked, private, unsafe, or meaningful to a particular community. Spatial intelligence requires moving from detection to relational and situated reasoning: What is connected to what? What can move where? What changes if an intervention is made? What risks are unevenly distributed?

It matters for built and natural environments. Buildings and cities are no longer only backgrounds for intelligent systems. They are increasingly equipped with sensors, actuators, digital twins, adaptive controls, and data platforms. These environments can become more responsive, but responsiveness is not the same as intelligence. A building that optimizes energy without regard for comfort, accessibility, or social use is not spatially intelligent in the full sense. An urban platform that predicts congestion while ignoring equity, privacy, or place-based knowledge is similarly incomplete.

Finally, it matters for hybrid systems. Many consequential spatial decisions are made by assemblages of people, models, devices, institutions, and environments. A planner interpreting mobility data, a designer using a generative tool, a robot collaborating with a worker, and a digital twin supporting emergency response all involve distributed intelligence. The question is not whether the human or the machine is intelligent in isolation, but how perception, representation, reasoning, learning, and action are shared across the system.

4. Relation to Neighboring Concepts

Spatial intelligence overlaps with several established concepts, but it should not be confused with any one of them. Spatial cognition studies how minds understand space. Spatial ability measures variations in individual performance. Geographic intelligence and GeoAI analyze spatial data, places, and territories. Artificial intelligence provides computational methods for perception, inference, learning, and generation. Embodied intelligence emphasizes action in situated environments. Visual intelligence contributes scene understanding and image-based reasoning. Urban and architectural intelligence connect spatial form with collective life, performance, and design. Spatial computing creates interactive systems in which computation is spatially registered.

The purpose of the term is not to produce a new umbrella that absorbs every neighboring field. Its purpose is to identify problems that require their conjunction. A robot moving through a hospital must interpret geometry, semantics, social norms, human movement, and institutional rules. A generative architectural model must produce not only plausible forms, but usable, lawful, accessible, and environmentally responsible spatial arrangements. A regional climate adaptation platform must connect geospatial data, infrastructure models, local knowledge, and governance. These are spatial intelligence problems because they require knowledge of space as relation, experience, system, and site of action.

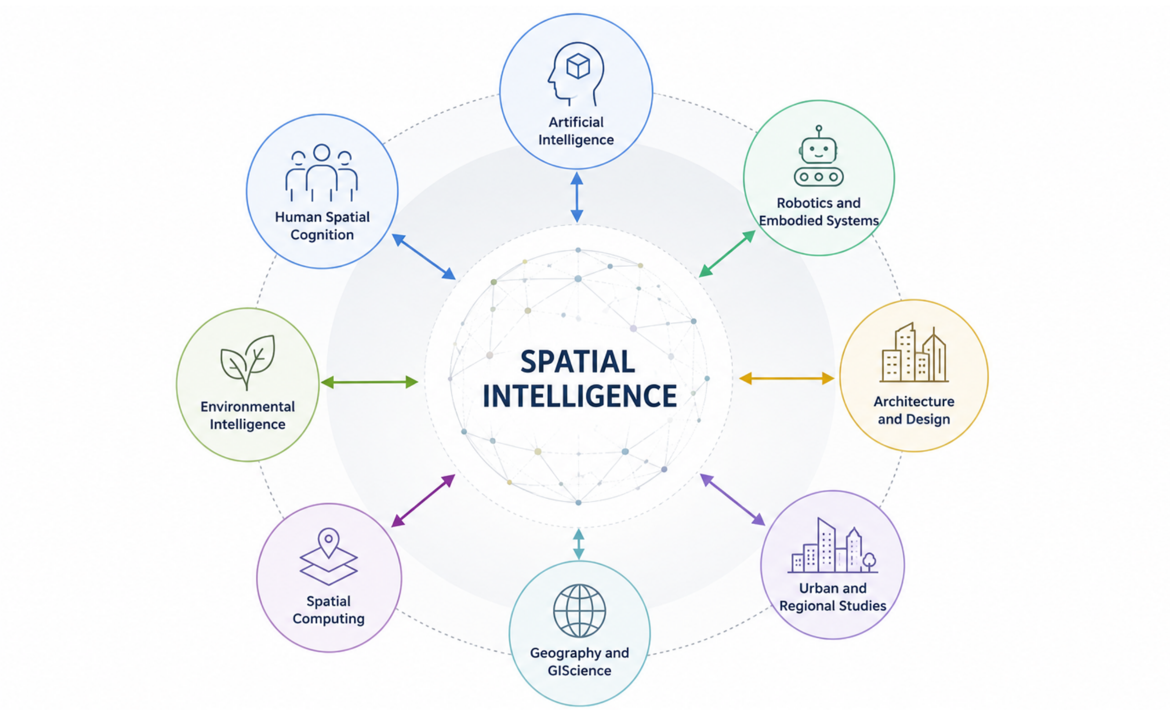

Figure 1. The evolving conceptual territory of spatial intelligence.

Figure 1 visualizes this conceptual territory. The diagram positions spatial intelligence as a cross-disciplinary territory organized around relations among humans, machines, environments, and spatial settings rather than as a subfield of any single tradition. Table 1 summarizes the relationship between spatial intelligence and several adjacent concepts. The table is intentionally comparative rather than hierarchical. It suggests that spatial intelligence should function as a meeting ground: a field in which concepts, methods, and evaluation criteria can be translated across traditions without erasing their differences.

Table 1. Related concepts and their relationship to spatial intelligence.

Concept	Primary focus	Typical scale	Main research tradition	Relationship to spatial intelligence
Spatial cognition	Perception, memory, orientation, mental imagery, and navigation	Body, room, route, landscape	Cognitive psychology and neuroscience	Provides human-centered accounts of how spatial environments are encoded and used, but does not by itself cover machines or adaptive environments.
Spatial ability	Individual differences in mental rotation, visualization, and spatial problem solving	Object, diagram, map, small-scale task	Psychometrics and education	Offers important measures of human capacity, but spatial intelligence in this journal is broader than individual test performance.
Spatial computing	Digitally mediated interaction with mapped, sensed, augmented, or mixed physical space	Room, building, urban interface, extended reality	Human-computer interaction and mixed reality	Contributes interactive media and real-time spatial interfaces, while spatial intelligence also includes reasoning, learning, action, and governance.
GeoAI	Machine learning and AI methods applied to geospatial data and geographic problems	City, region, territory, planet	GIScience and spatial data science	A crucial large-scale computational tradition within spatial intelligence, especially for place, environment, mobility, and earth systems.
Embodied intelligence	Intelligence grounded in perception-action loops, bodies, sensors, and situated behavior	Body, object, room, route	Robotics and cognitive science	Explains why spatial intelligence must be tested in action, not only in abstract symbolic representations.
Urban intelligence	Sensing, modelling, prediction, and governance of urban systems	Street, neighborhood, city, metropolitan region	Urban analytics and planning	Addresses collective and infrastructural spatial systems, but often needs stronger links to cognition, embodiment, and design.
Architectural intelligence	Reasoning about spatial organization, use, performance, and design in buildings	Room, interior, building, campus	Architecture, building science, and design computation	Connects spatial intelligence to inhabited form, environmental performance, affordance, and human experience.
Spatial intelligence	Capacity to perceive, represent, reason about, learn from, generate, interact with, and act within spatial environments	Object to planetary and extraterrestrial environments	Interdisciplinary field spanning cognition, AI, robotics, design, GIScience, and urban studies	An integrative field concept that links human, machine, environmental, collective, and hybrid systems across scales.

5. The Role of the Journal and Conclusion

The Journal of Spatial Intelligence is established to support this meeting ground. Its scope includes, but is not limited to, human spatial cognition, computational spatial reasoning, spatial artificial intelligence, embodied and robotic intelligence, 3D scene understanding, spatial computing, GIScience and GeoAI, architectural intelligence, intelligent buildings, urban intelligence, digital twins, generative spatial design, human-environment interaction, environmental sensing and adaptation, planetary and extraterrestrial spatial intelligence, and ethics and governance of spatial technologies.

The journal will welcome theoretical, empirical, computational, design, and critical work. It will encourage authors to state clearly which subject of intelligence is being studied: human, machine, environmental, collective, or hybrid. It will ask what scale is involved, what kind of spatial representation is used, what form of reasoning is claimed, and how action or consequence is evaluated. It will value technical advances, but it will also ask whether those advances respect the complexity of lived and governed spaces. It will value design imagination, but it will also ask how spatial claims can be tested, reproduced, and compared.

Editorially, this means that the journal will look for work that crosses boundaries with discipline and care. A paper on a navigation algorithm should explain the spatial assumptions built into its environment. A paper on an intelligent building should clarify what is sensed, inferred, optimized, and experienced. A paper on urban intelligence should say whose movement, comfort, risk, or opportunity is being modeled. Such questions are not barriers to innovation; they are the conditions under which innovation becomes spatially meaningful.

This position implies an open editorial stance. Spatial intelligence should not become a proprietary slogan, a synonym for a single technology, or a loose metaphor for any spatially flavored work. It should become a research field through careful definitions, shared problems, rigorous evidence, and interdisciplinary hospitality. The journal's task is to make that field discussable before it is fully settled.

When we talk about spatial intelligence, we are talking about more than a person's ability to solve spatial tests and more than a machine's ability to map or navigate. We are talking about the ways intelligent capacities emerge through spatial environments, representations, bodies, tools, infrastructures, and actions. We are also talking about responsibility, because spatial intelligence acts in places where people live, move, work, remember, and belong. The Journal of Spatial Intelligence begins with the conviction that this field is necessary precisely because no existing discipline owns it. Its promise lies in sustained exchange among those who study minds, machines, buildings, cities, territories, and worlds beyond Earth.

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