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An Integrated Workforce Categorization and Geospatial Matching Framework for On-Demand Services

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ABSTRACT

This paper presents an application-oriented architecture for location-aware workforce discovery in an on-demand services environment. The proposed system combines a four-level workforce categorization model with geographic proximity and multi-attribute filtering so that employers can identify workers who are not only suitable by skill but also appropriate in engagement duration, availability, service charge, and practical logistics. The four categories are Quick Workers, Temporary Work, Short-Term Work, and Long-Term Work. Worker positions are represented as GeoJSON Point objects using longitude-latitude coordinates and queried through MongoDB 2dsphere indexing. A nearby-search workflow applies a configurable radius and can be combined with category, specialization, price, food, accommodation, and keyword constraints. A three-tier pincode-resolution strategy is incorporated to provide local lookup, regional approximation, and wider geocoding fallback when direct coordinates are unavailable. Beyond the documented implementation, this paper proposes a relevance-ranking layer, privacy-aware location handling, dynamic availability, and a reproducible evaluation framework as extensions for a stronger production and research system. Existing project observations report sub-15 ms nearby-search responses on dense datasets and an approximately 75% reduction in server API load after 300 ms input debouncing; these values are treated as implementation observations rather than independently reproduced benchmarks. The proposed architecture therefore provides a practical foundation for workforce discovery while identifying measurable directions for scalability, privacy, ranking quality, and real-world validation.

Keywords: Workforce Categorization; Location-Based Search; Geospatial Search; MongoDB; 2dsphere; On-Demand Services

1. INTRODUCTION

Digital service marketplaces increasingly require search mechanisms that combine several constraints rather than depending on a single keyword. An employer may need a particular skill, an appropriate engagement duration, an available worker, an acceptable service charge, and a worker within a practical travel radius. The Integrated Workforce Services Platform (IWSP) documentation defines four engagement categories: Quick Workers, Temporary Work, Short-Term Work, and Long-Term Work. 1

The central problem is therefore a compound discovery problem. A worker may possess the required skill but still be unsuitable because the worker is too far away, unavailable, outside the requested price range, or classified for a different type of engagement. The proposed architecture addresses this issue by treating workforce category and geographic proximity as complementary dimensions of the same search workflow.

MongoDB provides geospatial capabilities through 2dsphere indexes and proximity operators. A GeoJSON Point uses the coordinate order [longitude, latitude], while the $near operator can return matching documents from nearest to farthest and can apply minimum and maximum distances.

Recent research in spatial task matching also emphasizes the combination of worker characteristics and geographic position, while privacy-preserving approaches demonstrate that location should not be treated as an unrestricted attribute. 34

Problem Statement. Conventional keyword-based workforce search does not inherently guarantee geographic suitability or alignment with engagement duration, availability, and price. A unified search mechanism is required to combine these constraints

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without making proximity a separate post-processing stage.

Objectives. The objectives are to: (i) define a four-level workforce categorization model; (ii) represent worker locations in a geospatially queryable format; (iii) retrieve nearby workers efficiently using spatial indexing; (iv) combine location with categorical and numerical filters;
(v) resolve pincode-based location input when direct coordinates are absent; and (vi) propose a ranking and privacy-aware extension suitable for future evaluation.

Contribution. The principal contribution is an integrated category-and-location discovery workflow. A secondary contribution is a practical extension layer that adds relevance scoring, privacy-aware search, dynamic availability, and a reproducible evaluation protocol without claiming that these extensions have already been experimentally validated.

2. LITERATURE REVIEW

Spatial task matching has developed around the need to assign or recruit workers using both task requirements and geographic position. Recent work on privacy-preserving weighted bidirectional heterogeneous spatial task matching considers worker/requester characteristics together with location while addressing privacy risks in outsourced spatial data processing. [3]

Geo-indistinguishability provides another important direction. Zhang et al. proposed an area-coverage worker recruitment method that protects participant locations while attempting to preserve recruitment utility. Their work demonstrates that worker recruitment can be formulated jointly with location privacy rather than treating privacy as an afterthought. [4]

More recent privacy-preserving spatial-crowdsourcing research has explored combinations of differential privacy, private set intersection, and blockchain-based coordination. These approaches show that location leakage can become a security concern when worker locations are processed by centralized or outsourced services. [5]

From the database perspective, MongoDB 2dsphere indexes are designed for queries that interpret geometry on an earth-like sphere. The database supports proximity, containment, and intersection operations, while $geoNear can return ordered results with calculated distances and additional query conditions. [2]

The gap addressed by the present study is application-oriented. Existing research provides strong foundations for spatial matching and privacy, while the IWSP design combines four operational workforce categories with spatial proximity, service attributes, and frontend availability controls in a single worker-discovery workflow. The novelty claimed here is therefore the focused integration and proposed extension of these functions, rather than a claim that geospatial worker matching itself is new.

Table 1. COMPARISON OF RELATED APPROACHES

APPROACH	PRIMARY FOCUS	RELEVANT GAP
Traditional keyword search	Textual worker discovery	Does not inherently account for geographic proximity or engagement duration.
Spatial task matching	Worker/requester matching using location and attributes	Often emphasizes optimization or task assignment rather than an operational workforce-category interface.
Privacy-preserving recruitment	Location matching with privacy protection	Strong privacy focus; not centered on four engagement categories and marketplace filters.
IWSP focused approach	Category + location + multi-attribute search	Application-oriented integration; requires broader controlled validation.

3. MATERIALS AND METHODS / PROPOSED SYSTEM

The system design is derived from the IWSP project documentation supplied for this study. The implementation-oriented description includes worker categorization, GeoJSON location storage, MongoDB 2dsphere indexing, nearby search, pincode resolution, compound filtering, frontend synchronization, and booking eligibility controls. [1]

3.1 Workforce Categorization

The proposed workforce model divides workers according to the expected duration and operational nature of the engagement. This categorization gives the search interface an operational meaning: an emergency service request should prioritize immediate availability and distance, while permanent recruitment should prioritize employment-oriented attributes.[1]

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CATEGORY	TYPICAL DURATION	EXAMPLE ROLES	SEARCH EMPHASIS
Quick Workers	< 30 minutes	Electrician; Plumber; Carpenter; Cleaner	Emergency dispatch, availability, nearby radius
Temporary Work	Days to weeks	Construction Helper; Event Staff; Delivery Worker	Daily wage, food, accommodation
Short-Term Work	1–6 months	Accountant; Software Developer; Graphic Designer	Milestones, price range, portfolio, skills
Long-Term Work	Permanent	Teacher; Engineer; HR Executive; Manager	Verification and monthly salary

3.2 Geospatial Representation

Worker posts store location as a GeoJSON Point. The coordinate order is longitude followed by latitude, and the location field is indexed with a 2dsphere index. MongoDB documentation specifies that 2dsphere indexes support spherical geospatial queries and proximity operations. [2] For conceptual distance estimation, the system can use the great-circle/Haversine relationship:

$$d = 2R \arcsin\left(\sqrt{\sin^2(\Delta lat/2) + \cos(lat1)\cos(lat2)\sin^2(\Delta lng/2)}\right)$$

where R is the mean Earth radius and angular differences are expressed in radians. The database itself can perform spherical proximity processing through the geospatial index, so application-level distance calculation should be used carefully to avoid redundant processing.[2]

3.3 Nearby Worker Search

The nearby-search function accepts latitude, longitude, workforce category, search distance, availability, and optional service-charge bounds. The application constructs a GeoJSON Point and uses MongoDB proximity querying with a maximum distance expressed in metres. The
$near operator returns documents ordered by distance, eliminating the need for an additional in-memory distance sort in the normal query path. [2]

The important architectural property is that proximity is evaluated together with workforce suitability. The worker must satisfy the relevant category and availability requirements while remaining within the requested geographic range. This reduces results that are technically skill-compatible but operationally impractical.

3.4 Three-Tier Pincode Resolution

The supplied IWSP design specifies three fallback levels. Tier 1 uses an in-memory mapping for known Karnataka pincodes. Tier 2 uses a deterministic regional approximation based on pincode prefixes and a geographic offset. Tier 3 uses Google Maps geocoding when the first two mechanisms cannot provide a usable position. [1]

This hierarchy is useful because it separates fast local resolution from broader network-dependent resolution. However, the approximate tier should be clearly labeled as approximate and should not be presented as an exact worker location. This distinction becomes particularly important when the requested radius is small.

TIER	MECHANISM	PURPOSE
Tier 1	Local pincode lookup	Fast resolution for known pincodes
Tier 2	Regional approximation	Fallback when a local mapping is unavailable
Tier 3	External geocoding	Broader coverage when local methods fail

3.5 Compound Search and Eligibility

The general worker-search pathway combines exact category and specialization conditions with numerical service-charge ranges, food and accommodation requirements, and keyword matching. The supplied implementation also uses input debouncing, map-bound calculation, marker/card synchronization, and eligibility checks to reduce repeated requests and prevent active workers from being double-booked. [1]

3.6 Proposed Relevance-Ranking Extension

A limitation of a purely filtered search is that many workers may satisfy the same hard constraints. To improve result ordering without changing the eligibility rules, this study proposes a transparent relevance score. The score is intended as a future extension

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rather than a measured result:

$S = w_1(1 - D/Dmax) + w_2A + w_3C + w_4P + w_5F + w_6K$

where D is worker distance, Dmax is the selected search radius, A is availability suitability, C is category match strength, P is price suitability, F represents optional food/accommodation compatibility, K represents keyword or specialization relevance, and $w_1 \ldots w_6$ are configurable weights. Hard constraints such as unavailable status can remain outside the score and act as exclusion rules.

This separation between eligibility and ranking is important. A ranking score should not allow a highly relevant but unavailable worker to appear as an actionable result. It should order workers only after the system has established that they are eligible.

3.7 Proposed Privacy-Aware Location Mode

Location is both a functional input and a sensitive attribute. Research on geo-indistinguishability and privacy-preserving spatial matching shows that useful spatial recruitment can be combined with mechanisms that reduce exposure of precise locations. [34]

For the IWSP context, a practical extension is to provide two location modes: a precise operational mode for tasks that genuinely require exact proximity, and a privacy-aware discovery mode that exposes a coarser area or perturbed position until a worker accepts a request. The exact privacy mechanism, privacy budget, and utility trade-off must be evaluated experimentally before deployment.

4. RESULTS AND DISCUSSION

The supplied project documentation reports implementation-level observations rather than a controlled scientific benchmark. It reports sub-15 ms nearby-search response times across dense datasets and an approximately 75% reduction in server API load after a 300 ms input debounce. [1] These observations are useful for understanding the intended efficiency of the architecture, but they should not be interpreted as independently reproducible benchmark results. A research evaluation should specify dataset size, worker density, geographic distribution, hardware, software versions, query rate, concurrency, cache state, and statistical reporting procedures.

EVALUATION ASPECT	DOCUMENTED / PROPOSED BEHAVIOR	RESEARCH INTERPRETATION
Nearby ordering	$near returns nearest-to-farthest results	Useful for distance-oriented discovery
Geospatial indexing	2dsphere index on location	Supports spherical proximity queries
Search radius	Configurable; project documentation reports 10 km as default nearby radius	Lets employers control geographic scope
Debounced search	300 ms input debounce	Can reduce repeated requests during rapid typing
Multi-attribute filtering	Category, specialization, price, food, accommodation, keyword	Improves relevance beyond distance alone
Pincode resolution	Three-tier fallback	Balances speed and geographic coverage
Ranking extension	Proposed weighted relevance score	Requires controlled evaluation; not yet a measured result
Privacy mode	Proposed coarse/perturbed location workflow	Requires privacy-utility analysis before production use

4.1 Architectural Interpretation

The principal technical result is the integration of spatial proximity with workforce suitability. Instead of retrieving a broad skill-based list and filtering it manually, the system can apply location and workforce constraints within the same discovery workflow. This is particularly valuable for emergency services, where travel distance can be as important as skill matching.

The four-category model also changes the meaning of search. A Quick Worker request is time-sensitive and distance-sensitive, whereas a Long-Term Work request is more strongly associated with employment verification, qualifications, salary, and organizational fit. Consequently, a single universal ranking function may be suboptimal; category-specific ranking weights should be investigated.

4.2 Proposed Experimental Evaluation

A reproducible evaluation should compare at least four configurations: (A) keyword/category filtering without geospatial indexing; (B) geospatial filtering with 2dsphere indexing; (C) geospatial filtering plus compound attributes; and (D) compound filtering plus the proposed relevance-ranking layer. Each configuration should be tested over multiple dataset sizes and worker-

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density distributions.

Recommended metrics include median and 95th-percentile latency, throughput, query failure rate, candidate-set size, ranking relevance, distance error for approximate pincodes, and API requests per user interaction. For the privacy extension, utility should be evaluated together with a defined privacy budget or location-error measure. These experiments would convert the present architecture from an implementation report into a stronger empirical research contribution.

5. NEW DESIGN DIRECTIONS AND RESEARCH OPPORTUNITIES

5.1 Dynamic Availability

Worker availability can change rapidly in an on-demand marketplace. A future implementation should maintain a time-aware availability state so that the search engine distinguishes between a worker who is generally active and one who is immediately dispatchable. This can be combined with booking state to avoid presenting workers who cannot accept a new assignment.

5.2 Category-Specific Ranking

Ranking should reflect the operational objective of each workforce category. Quick Worker ranking can emphasize distance and immediate availability; Temporary Work can emphasize daily cost, accommodation, and schedule; Short-Term Work can emphasize skills, milestones, and portfolio evidence; and Long-Term Work can emphasize qualifications, verification, salary compatibility, and organizational requirements.

5.3 Privacy-Preserving Discovery

A privacy-aware discovery process can initially expose approximate location information and reveal more precise information only when operationally necessary. This direction is supported by the broader literature on geo-indistinguishability and privacy-preserving spatial task matching. [34]

5.4 Learned Ranking and Explainability

A later stage could learn ranking weights from accepted bookings, response rates, completion rates, distance, price, and employer feedback. However, learned ranking should remain explainable. The interface could show reasons such as “nearby,” “available now,” “matches requested specialization,” and “within budget,” rather than producing an opaque score alone.

5.5 Geographic Expansion and Uncertainty

The pincode strategy should be expanded beyond a region-specific lookup table. At the same time, approximate locations should carry an uncertainty indicator so that the search engine does not treat a coarse pincode estimate as an exact worker coordinate. This is especially important when the requested search radius is smaller than the location uncertainty.

5.6 Scalability

For large deployments, future studies should examine query concurrency, index growth, partitioning strategies, caching, workload skew, and geographic clustering. MongoDB documentation also identifies restrictions around geospatial indexes and sharding, so deployment architecture should be designed and benchmarked rather than assuming that a single index strategy remains optimal at every scale. [2]

6. LIMITATIONS

This paper has several limitations. First, the reported performance figures originate from the supplied project documentation and were not independently reproduced. Second, no large public workforce dataset was supplied for controlled experimentation. Third, the proposed ranking and privacy extensions are architectural proposals rather than experimentally validated components.

Fourth, pincode-based approximation can introduce location uncertainty, and the magnitude of that error has not been measured in the supplied material. Finally, real-world workforce systems involve legal, ethical, privacy, fairness, and verification requirements that cannot be fully evaluated from database search performance alone.

7. CONCLUSION

This study presents a location-aware workforce discovery architecture that integrates four engagement categories with geospatial proximity and multi-attribute filtering. GeoJSON Point representation and MongoDB 2dsphere indexing provide a practical basis for nearby-worker retrieval, while category, specialization, availability, price, food, accommodation, and keyword constraints improve the operational relevance of results. [12]

The main research value lies in treating workforce classification and location as joint search dimensions. The architecture also identifies a clear path for further research: category-specific ranking, dynamic availability, privacy-aware discovery, uncertainty-aware pincode resolution, and reproducible scalability evaluation. The documented sub-15 ms response observation and approximately 75% reduction in API load after debouncing indicate the intended efficiency of the implementation, but controlled experiments are required before these values can be generalized. [1]

Future work should therefore focus on building a representative dataset, defining repeatable workloads, comparing alternative

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spatial-search strategies, measuring ranking quality, and evaluating privacy-utility trade-offs. These steps can strengthen the system from a practical application into a rigorously evaluated workforce-search research platform.

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