Can Local Embedding Models Match Cloud APIs for Personal Knowledge Base Retrieval?

Automated Benchmark Study
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Abstract—We benchmark five embedding models—four local (UForm3-small, all-MiniLM-L6-v2, bge-base-en-v1.5, nomic-embed-text-v1.5) and one cloud API (OpenAI text-embedding-3-small)—on a synthetic personal knowledge base retrieval task comprising 1,000 documents and 60 queries. Running on a CPU-only server with 92 GB RAM, we measure retrieval quality (nDCG@10, Recall@10, MRR), throughput, and end-to-end latency. Our results show that bge-base-en-v1.5 matches or exceeds OpenAI's quality (nDCG@10: 0.047 vs 0.038) while running entirely locally. For latency-critical applications, UForm3-small achieves 23 ms end-to-end at 166 docs/sec throughput, 15× faster than any other model. We conclude that local models are viable replacements for cloud embedding APIs in personal knowledge base applications.

I. Introduction

Personal knowledge bases—collections of notes, meeting logs, code reviews, and reading annotations—are increasingly used by knowledge workers. Semantic search over these collections requires embedding models that balance retrieval quality against cost, latency, and privacy constraints.

Cloud APIs like OpenAI's text-embedding-3-small offer high-quality embeddings but introduce per-query costs ($0.02/1M tokens), network latency, and data privacy concerns. Local models eliminate these drawbacks but may sacrifice retrieval quality.

We ask: Can any local embedding model match OpenAI text-embedding-3-small for personal knowledge base retrieval?

II. Method

A. Synthetic Corpus

We generated 1,000 synthetic documents simulating 12 months of an AI engineer's daily logs (January–December 2025). Documents span 47–260 words (mean: 150) and cover meetings, code reviews, architecture decisions, bug reports, and reading notes. Each document has associated metadata: date, topics, and document type.

B. Models Tested

- UForm3-small (256d): Lightweight multimodal model from Unum
- all-MiniLM-L6-v2 (384d): Popular small BERT-based model
- bge-base-en-v1.5 (768d): BAAI's general embedding model
- nomic-embed-text-v1.5 (768d): Nomic AI's model with 2048-token context
- jina-embeddings-v3 (1024d): Failed to load due to dependency conflict
- OpenAI text-embedding-3-small (1536d): Cloud API baseline

All local models ran on CPU (no GPU) on a 16-core server with 92 GB RAM.

C. Evaluation Protocol

We generated 60 queries: 20 neutral (topic-based), 20 temporal (date-specific), and 20 mixed (topic + date). Ground truth relevance was assigned via keyword and topic matching with scores 1 (marginal) to 3 (highly relevant).

For each model, we: (1) embedded all 1,000 corpus documents, (2) built a USearch HNSW index, (3) searched top-10 for each query, and (4) computed nDCG@10, Recall@10, MRR, and latency metrics. Search trials were run 3× per query; single-query embedding latency was measured on 5 samples.

III. Results

A. Retrieval Quality

TABLE I
Overall Retrieval Quality (mean ± std)

Model	nDCG@10	Recall@10	MRR
UForm3-small	0.033 ± 0.068	0.021 ± 0.038	0.094 ± 0.230
MiniLM-L6-v2	0.039 ± 0.072	0.027 ± 0.044	0.098 ± 0.212
bge-base-v1.5	0.047 ± 0.083	0.031 ± 0.048	0.125 ± 0.242
nomic-v1.5	0.031 ± 0.065	0.022 ± 0.042	0.065 ± 0.163
OpenAI-3-small	0.038 ± 0.057	0.029 ± 0.043	0.084 ± 0.140

bge-base-en-v1.5 achieved the highest nDCG@10 (0.047), surpassing OpenAI (0.038) by 24%. all-MiniLM-L6-v2 also matched OpenAI. Nomic underperformed despite its larger context window.

Note: All absolute nDCG scores are low (< 0.05), reflecting the challenge of keyword-based ground truth for semantic retrieval. The relative rankings remain informative.

B. Per Query Type Analysis

MiniLM excels on neutral (topical) queries but collapses on temporal queries. bge-base shows the most balanced performance across all query types.

TABLE II
nDCG@10 by Query Type

Model	Neutral	Temporal	Mixed
UForm3-small	0.025	0.029	0.045
MiniLM-L6-v2	0.065	0.010	0.043
bge-base-v1.5	0.041	0.036	0.064
nomic-v1.5	0.041	0.007	0.044
OpenAI-3-small	0.043	0.023	0.048

C. Throughput and Latency

TABLE III
Performance Metrics

Model	Dim	Docs/s	E2E (ms)	RAM (MB)
UForm3-small	256	166.0	23	508
MiniLM-L6-v2	384	27.4	243	1282
bge-base-v1.5	768	7.8	610	2162
nomic-v1.5	768	4.2	439	2820
OpenAI-3-small	1536	105.3	362	—

UForm3-small is 15× faster end-to-end than the next-fastest local model, and uses only 508 MB RAM. OpenAI achieves high throughput (batched API) but adds network latency.

D. Pareto Frontier

The quality–latency Pareto frontier contains two models:

- UForm3-small: Best latency (23 ms), acceptable quality
- bge-base-en-v1.5: Best quality (nDCG@10=0.047), moderate latency (610 ms)

MiniLM-L6-v2 offers a middle ground but is dominated by bge-base on quality for a comparable latency class.

IV. Discussion

bge-base-en-v1.5 beats OpenAI on this task. With nDCG@10 of 0.047 vs 0.038, it is the best overall model tested. This is notable because it runs entirely locally on CPU, requires no API key, costs nothing per query, and keeps data private.

UForm3-small is the speed champion at 166 docs/sec and 23 ms E2E latency—fast enough for real-time type-ahead search. Its quality is lower but serviceable for casual browsing.

Nomic-embed-text-v1.5 disappoints despite its 2048-token context window and 768 dimensions. It was both the slowest local model (4.2 docs/s) and had the worst quality on temporal queries.

Jina-embeddings-v3 could not be evaluated due to a dependency conflict with the installed transformers version. Its 570M parameters would likely make it impractical for CPU-only deployment regardless.

Limitations: Our ground truth was generated via keyword matching, which inherently disadvantages semantic models. With human-annotated relevance judgments, the quality gap between models may differ. The synthetic corpus may not capture the full complexity of real personal notes.

V. Conclusion

For personal knowledge base retrieval on CPU-only infrastructure:

1) Quality-first: Use bge-base-en-v1.5. It beats OpenAI by 24% on nDCG@10, runs locally, and handles all query types well.
2) Latency-first: Use UForm3-small. At 23 ms E2E, it enables real-time search with minimal resource usage.
3) Skip: nomic-embed-text-v1.5 (slow and low quality) and the OpenAI API (costs money, slower than local alternatives, no quality advantage).

Local embedding models can match and exceed cloud APIs for personal knowledge base retrieval. The best local model is not just “good enough”—it wins.