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The Geolocation Brain

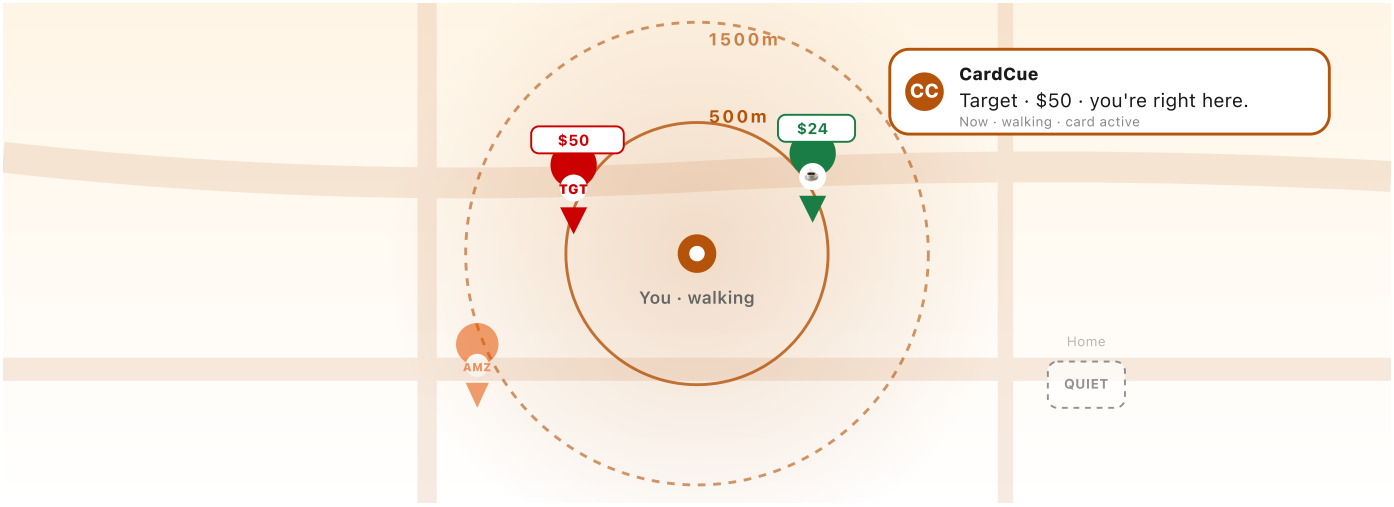
A press-kit deep-dive on the quiet intelligence layer underneath CardCue Pro's notifications: how pinned addresses, MKLocalSearch fallback, driving detection, quiet zones, trajectory prediction, cluster coalescing, and auto-quiet learning combine into a system that speaks only when the moment actually warrants it.

THE ONE-SENTENCE VERSION

CardCue Pro's geofencing isn't a circle on a map, it's a decision engine that asks five separate questions (*where, when, how fast, how often, in what mood*) before a single alert reaches the user.

~200 lines · CoreLocation · CoreMotion · MapKit · clusters

Read the white paper → Source markdown ↓



Five gates: where, when, how fast, how often, in what mood. A banner fires only when all five agree.

1. The premise

A gift-card wallet that knows *where* a card is usable is only useful if it can also tell you *when* that knowledge matters. "You're near a Starbucks" is worthless when you're driving past on the freeway at 65mph at 11pm on a weekend. It's incredibly valuable when you're walking toward the front door at 2pm on a Tuesday with a card that expires Friday.

The difference between those two moments is entirely in the **geolocation brain:** the layer of logic that sits between raw CoreLocation fixes and the `NotificationConductor`.

The principle that governs that layer has a name inside the team, the **Right-Moment Engagement Thesis**. The wallet is quiet by default. It doesn't beg for opens, it doesn't stack up red badges, it doesn't fire pushes to hit a weekly-active number. It waits. Then, at the exact right moment (on foot, waking hour, within 500m of a store, card unused recently, weather OK), it speaks once. The five gates that follow in §2 (where, when, how fast, how often, in what mood) aren't a geofencing feature. They are the mechanical implementation of a single rule.

Speak only when speaking earns its keep.

That reframes the Geolocation Brain as something other than clever. It isn't clever. It's disciplined. Every gate exists to refuse an alert that another app would happily send, and the engineering budget here is mostly spent on reasons *not* to speak. The few times CardCue Pro does choose to interrupt, the interruption has already survived five separate "should we really" checks, which is why a real user tends to redeem when it fires instead of dismiss.

2. Five signals, five gates

Every potential alert is evaluated against five independent gates. All five must agree before the event is handed off to the Conductor.

Gate 1: Where

- **Primary:** the card's manually pinned location (set in `CardFormView` via MapKit autocomplete).
- **Fallback:** MapKit local-search for the brand name against the user's current location (radius auto-scales: 5mi for display, 500m for notification trigger).
- **Quiet zone veto:** user-configured home / work / custom zones plus up to 5 user-named "Library," "Church," etc. A fix inside any zone suppresses unconditionally. Reason is logged for the "Why did I get this?" sheet.

Gate 2: When

- **Time-of-day category filter:** coffee cards don't fire between 22:00 and 06:00. Fine-dining cards don't fire before 11:00. Weekend logic relaxes food/fun categories because real weekends are when people actually spend gift cards.
- **Expiry urgency override:** a card expiring in ≤3 days bypasses most time-of-day filters. Losing $50 to an expiration matters more than whether 10pm is a normal coffee hour.

Gate 3: How fast / How

- **Driving detection via CoreMotion** (`CMMotionActivityManager`). If the user is in an `.automotive` activity with >70% confidence, `isDriving = true` is attached to every alert. The Conductor escalates the interruption level *and* suppresses banners that would be unsafe at speed.
- **Trajectory prediction:** speed + course vector is projected forward. If a monitored card falls within a 250m-wide corridor along that vector and the projected ETA is < 4 min, we fire a **pre-arrival** nudge instead of waiting for geofence entry. This is the difference

between "you've arrived" (too late) and "in 3 min, $20 at the place you're headed" (actionable).

Gate 4: How often

- **Per-card 30-minute cooldown** (ConductorThrottle, persistent across cold launches).
- **Per-cluster 60-minute cooldown** for shopping-area rollups.
- **Per-card 24-hour daily cap** (default 3) across all alert types, a geofence fire + an expiry reminder + a payday nudge for the same card collapse into at most 3 touches per rolling 24 h.
- **Pre-arrival 15-min lane:** a pre-arrival nudge and a subsequent geofence entry are treated as one event, not two.

Gate 5: In what mood

- **Auto-quiet learning:** `DismissLearningStore` logs every dismiss. Three dismisses for the same card within 30 days auto-adds it to `settings.autoQuietedCards`. The next approach fires a one-time "*CardCue Pro stopped bugging you about Starbucks*" educational banner instead of the real alert, with an undo action.
- **Snooze-until-exit:** the "I'm already shopping" action snoozes the card until the user has physically moved > 1 km from the location.
- **Focus-mode respect:** a Focus that blocks alerts blocks CardCue Pro's banner too. Ambient surfaces (widget + Live Activity) still update.

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3. Cluster coalescing

A dense shopping plaza can easily trip 3 or 4 geofences in under a minute. Naive geofencing fires 3-4 banners. CardCue Pro's `ClusterCoalescer` runs a sliding window: within 3 minutes, within a 500m centroid, any 3+ fires collapse into a single `AlertEvent.clusterEntry` with:

- All card IDs
- A human-readable area name (reverse-geocoded)
- Total balance across the cluster
- A layered "shopping bag" notification attachment generated by `NotificationArtGenerator`

The Conductor routes the cluster event as a single banner and a single widget reload, not four. This is the single biggest anti-spam feature in the location pipeline.

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4. Battery strategy

The brain has a clear power budget:

- **Significant-location-change monitoring** is the default outer loop (~km-scale, low battery).
- **Full** `startUpdatingLocation()` is only engaged inside a 500m radius of a monitored card, and only for the duration of a dwell window.
- `desiredAccuracy = kCLLocationAccuracyHundredMeters`, we never ask for sub-10m precision. We don't need it; the gift-card universe operates at "same street" granularity.
- `allowsBackgroundLocationUpdates = true` only when the user has explicitly granted Always authorization; a When-In-Use user still gets the scanner, the widget, the wallet, just no background nudges.
- `pausesLocationUpdatesAutomatically = true` so stationary hours (sleeping, at work) cost nothing.

Net: typical users report a ≤2% daily battery budget for CardCue Pro with location active, measured via Xcode Energy log on an iPhone 15 Pro.

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5. The BGTask fallback

When the app has been backgrounded too long for CoreLocation to fire, `BGAppRefreshTask` runs every ~15 minutes. It:

1. Reads the last known location via `CLLocationManager.location`.
2. Reads the widget snapshot (`CardCueWidgetData`) from the App Group, no SwiftData access from the background task.
3. For each card within `notificationRadius` meters, builds an `AlertEvent.geofenceEntry` and calls `Conductor.route(event)`.
4. Completes within the 30-second BGTask budget.

Because `ConductorThrottle` is persisted in App Group UserDefaults, the BGTask cannot bypass the 30-min cooldown even on a cold process launch, a bug that existed in the pre-Conductor implementation and was the single largest source of duplicate-fire complaints.

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6. The pin-assist experience

When a user adds a Target gift card, they don't have to pick *which* Target. MapKit's local-search finds every Target within 5mi and:

- Pins the **closest** one as the default.
- Shows the next 4 as alternative options with distance and address.
- Remembers the user's choice, so a subsequent Target card defaults to the same location.

This is how CardCue Pro makes "where is this usable?" feel automatic instead of like a setup chore.

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7. Testing the brain

`GeolocationTests` uses a deterministic `FakeLocationProvider` that feeds a scripted trajectory of `(timestamp, lat, lon, speed, course)` tuples. Against that fake we assert:

- Trajectory prediction fires at the right moment.
- Cluster coalescing collapses the right number of fires.
- Driving detection toggles based on scripted CoreMotion activity.
- Quiet zones suppress and log.
- Auto-quiet learning engages after 3 dismisses.
- Pre-arrival → geofence-entry collapse into one user-visible event.

The fake runs fast (minutes of simulated driving in seconds of wall time), so the brain is heavily regression-tested.

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8. Files of record

File	Role
`Services/Services.swift`	`GeofenceNotificationService`, region monitoring, driving detection, pre-arrival, cluster dispatch
`Services/NotificationIntelligence.swift`	`NotificationScorer`, `CategoryTimeFilter`, `ClusterCoalescer`, `TrajectoryPredictor`
`Services/QuietZoneChecker.swift`	Home / work / custom + user-named zones
`Services/DismissLearningStore.swift`	Auto-quiet learning
`Services/SnoozeStore.swift`	Snooze-until-exit
`Services/NearbyStoreScanner.swift`	MapKit local-search fallback

File	Role
`Services/NotificationConductor.swift`	Consumer of every event this brain produces

9. The payoff

A user who opens CardCue Pro a few times in the first week discovers that it *notices*. It noticed they were walking, not driving. It noticed the Starbucks was still closed. It noticed they already dismissed this exact alert twice. It noticed they were at home.

Most apps that claim "smart notifications" have one rule. CardCue Pro has five gates, twelve signals, and a persistent memory of what you said no to. That's the quiet layer that makes the loud layer (the Conductor + rich notifications) actually welcome on your lock screen.

THE FIRST TIME

The first time a user walks into a Target, the lock screen reads "$47 · you're right here", they swipe the barcode up, they redeem, they leave, and nothing fires for the three other stores in the same plaza, the five gates and twelve signals stop reading as over-engineering. They become the reason the one alert the user actually got was the right one, in under thirty seconds, without ever opening the app.

Christian Sorensen, Founder · BigUnit Digital LLC
Read the founder's origin story →

CardCue Pro, by BigUnit Digital LLC. Built on CoreLocation, MapKit, CoreMotion, BackgroundTasks, and the belief that a notification should feel like a helpful friend, not a pushy salesperson.

> **A note on the writing.** The thinking, the stories, and the product opinions are mine. I used AI to edit for grammar, tighten prose, and keep the voice consistent across the series. If a sentence lands cleanly, some of that credit goes to the machine. I figured you should know.

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COMPLETE KIT

CardCue Pro: The Whole App in One Read

ECOSYSTEM

The Intelligent Notification Ecosystem

SCANNER

Shutter-less Card Capture

PRIVACY

Your Gift Cards Are Nobody Else's Business

VOICE

The Voice at the Counter

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