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DEEPMOUZA: COIN-REFERENCED IN-BROWSER COMPUTATION METHOD FOR CADASTRAL MAP SURVEYING AND LAND PLOT MEASUREMENT

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Abstract: In West Bengal, land administration heavily relies on the traditional mouza cadastral survey system. This framework consists of over 44,000 village-level map sheets, originally drawn at a historical scale of 16 inches to a mile. Currently, surveyors mostly measure plot areas manually from these maps using planimeters or transparent grid overlays. This process is not only slow and skill-intensive but also prone to compounding errors as the physical paper degrades over time. To address these issues, we introduce DeepMouza, a fully client-side, browser-based application designed to automate area measurements directly from smartphone photos of these mouza maps. The tool leverages a standard Rs. 5 Indian coin as a reliable physical scale reference. Our architecture integrates four primary computational phases: first, a hybrid coin detection module (utilizing HSV-based gold masking, gradient-refined edge localization, and a gradient-direction Hough accumulator) to establish pixel-to-millimetre calibration; second, Otsu's global thresholding to create a clean binary map of the boundaries; third, a breadth-first flood-fill algorithm featuring automatic seed correction for segmenting plot interiors; and fourth, a multi-layer boundary extraction process that applies the standard half-boundary surveying rule to accurately measure ink-line area. To ensure reliability, we built a root-sum-of-squares model analyzing five distinct error sources, providing users with a clear percentage confidence rating for every measurement. We evaluated DeepMouza across 47 diverse plots spanning 12 different mouza sheets. The system successfully achieved a mean absolute percentage error of just 2.1%, with 96% of the measurements falling tightly within a 5% margin of the officially recorded ground truth. Crucially, it accomplishes this locally, requiring zero server infrastructure and guaranteeing data privacy by never transmitting image data off the user's device.

Index Terms: Mouza cadastral map, land plot measurement, coin-based scale calibration, HSV colour segmentation, Gradient Hough transform, breadth-first flood fill, browser-based image processing, measurement uncertainty estimation.

1. INTRODUCTION

West Bengal's land ownership documentation is deeply tied to the mouza survey system. This administrative setup dates back to the colonial-era Bengal Cadastral Survey (conducted between 1870 and 1930) and is maintained to this day by the Land Records and Survey Directorate [1]. A 'mouza' acts as the smallest administrative land unit, typically representing a single village. The properties within each mouza are meticulously detailed on dedicated map sheets created at a standard scale of sixteen inches to one mile (roughly 1:3,960). Every land holding, known locally by a 'dag' or plot number, is marked on these physical sheets using inked boundary lines and corresponding numbers.

Currently, the state manages upwards of 44,000 individual mouza sheets, which altogether document tens of millions of distinct plots. If a surveyor needs to measure the area of a specific plot from one of these physical records, they generally have to rely on manual tools like a planimeter or a transparent measurement grid. Not only does this demand specialized training and take significant time, but the accuracy is also steadily worsening. Decades of handling, moisture exposure, and general aging have caused severe deterioration to the paper records.

However, the ubiquitous nature of modern smartphones equipped with high-resolution cameras presents an excellent opportunity. Combined with the advanced client-side processing capabilities of current web browsers, we can transition this task to a digital, automated medium. By simply photographing a mouza sheet with a smartphone, a browser can directly compute the real-world area of a plot. Most importantly, this can be done without transmitting sensitive map data to an external server, eliminating privacy concerns and removing the need for internet connectivity. DeepMouza represents our implementation of this concept. It utilizes a coin-referenced computation method packaged inside a single, self-contained HTML file, capable of converting a basic photograph into a highly accurate, quantified land-area measurement while explicitly reporting its own reliability margin.

2. PROBLEM STATEMENT

The core technical challenge addressed by this research is straightforward: how can we take a standard smartphone photograph of a West Bengal mouza sheet—using a ubiquitous Rs. 5 coin as a physical scale reference—and accurately compute a targeted plot's real-world area in local land units? Furthermore, we must calculate a quantified percentage uncertainty alongside this measurement, while ensuring the entire computational workload executes purely within the user's browser, preventing any image data from leaving the local device.

Breaking this down reveals several interconnected obstacles that the software must seamlessly resolve. First, the application must robustly detect the coin and estimate its radius in pixels despite unpredictable variables like poor ambient lighting, coin surface wear, shadows, and perspective tilt. This radius acts as the critical bridge connecting abstract pixels to physical millimetres. Second, the photographed map itself—often plagued by faded ink, scanning artifacts, or uneven lighting—needs to be accurately converted into a distinct binary representation that cleanly separates the boundary ink from the paper background. Third, once the user indicates a target plot, the system must digitally isolate that specific area from a tightly packed network of surrounding plots. Fourth, the thick ink lines bordering the plot physically belong to adjacent properties as well. The system must accurately measure the full thickness of these lines and apply the traditional surveying 'half-boundary' rule to split the area fairly. Finally, every stage introduces potential errors; the system needs to consolidate these variations into a single, intuitive confidence metric so that non-expert users understand the reliability of the generated result.

3. LITERATURE REVIEW

The computational techniques utilized in DeepMouza draw upon several well-established academic and surveying frameworks. The relevant literature is organized below based on how it influences our system design:

- The mouza system architecture and its defining 16-inch-to-one-mile scale are thoroughly outlined in the Survey and Settlement Manual of West Bengal [1]. This documentation, alongside the West Bengal Land Reforms Act of 1955, establishes the official local measurement units (bigha, katha, decimal, and satak) required for legal land transactions.
- Our calibration approach relies on scale-bar photogrammetry, a standard practice where objects of known dimensions are introduced into photographs to create spatial scales, as detailed extensively by Wolf and Dewitt [2].
- We chose the Rs. 5 Indian coin because its diameter is legally fixed at 23.0 millimetres by the Reserve Bank of India. Its widespread availability eliminates the need for users to carry dedicated, specialized calibration targets.
- To isolate the coin from its surroundings effectively, we utilize the Hue-Saturation-Value (HSV) colour model. Koschan and Abidi [3] demonstrate that HSV significantly outperforms RGB when dealing with illumination-invariant object detection.
- After identifying a candidate gold-coloured region, we apply morphological closing based on Serra's mathematical morphology framework [4]. This resolves fragmented pixel blobs caused by partial shadows or specular highlights. We then extract the largest connected component using the highly efficient two-pass labelling algorithm developed by He, Chao, and Suzuki [5].
- In instances where colour information is degraded (e.g., heavily worn coins or greyscale scans), the system defaults to a gradient-based detection mechanism powered by the Sobel operator [6].
- The gradient detection relies on the principles of the Hough transform [7], generalized later by Duda and Hart [8]. To reduce computational overhead and spurious edge voting, we specifically implement the gradient-direction variant formulated by Yuen et al. [9].
- For generating the binary map separating the ink lines from the paper, we implement Otsu's global thresholding [10]. This method automatically selects a grey-level threshold that maximizes between-class variance, which is highly effective for bimodal histograms typical of dark ink on light paper.
- To segment the plot interior based on user input, we use a region-growing flood-fill technique initially detailed by Fuchs, Kedem, and Uselton [11].
- Handling shared boundary lines digitally requires a discrete-domain approach similar to Pick's theorem for lattice polygons [12], ensuring we accurately respect the conventional surveying rule that apportions a shared boundary line equally between neighboring plots.
- The system's fully offline execution relies entirely on the HTML5 Canvas API, with pixel-level manipulation governed by the W3C/WHATWG HTML Living Standard [13].
- Finally, propagating individual error sources into an overall measurement uncertainty figure strictly follows the root-sum-of-squares methodology outlined in the Guide to the Expression of Uncertainty in Measurement [14], aligning with standards set by the American Society for Photogrammetry and Remote Sensing [15].

4. PROPOSED SYSTEM

DeepMouza functions as an end-to-end solution for modernizing cadastral map measurements. Delivered as a single, lightweight HTML file, it runs natively in modern browsers without needing any installation. A user simply uploads a photograph of the mouza sheet with the reference coin and selects the plot location; the system immediately outputs the calculated area and a mathematically derived confidence score.

The pipeline is divided into five main functional stages. First, a multi-tiered coin detector determines the pixel-to-millimetre scale. Next, a global-threshold binarization phase cleans the map into distinct ink and paper categories. A breadth-first flood-fill algorithm, guided by the user's initial click, systematically isolates the plot's interior geometry. A boundary-extraction algorithm then traces outward from this interior to capture the real thickness of the bordering ink lines, intelligently applying the half-boundary correction rule. Lastly, an error-estimation module calculates the individual uncertainties from the previous steps and combines them into an actionable letter grade and percentage.

Importantly, the system focuses on graceful degradation. If automatic coin detection struggles due to extreme lighting, the user is seamlessly offered a manual drawing fallback. If the user accidentally clicks on a thick ink pixel instead of the paper interior, the software automatically nudges the seed point to the closest valid region. Consequently, the pipeline avoids silent failures, consistently delivering a measurement paired with contextual reliability.

5. DEEPMOUZA ARCHITECTURE

From a structural standpoint, DeepMouza is highly compact. The entire application is roughly 83 kilobytes in size, bundling all necessary logic, styling, and markup directly within a single file. It completely bypasses external runtime dependencies, meaning it functions optimally regardless of network conditions. The user interface is logically split across three accessible tabs.

The primary 'Measure' tab houses the interactive canvas where users load their photos. It includes the configuration settings for output units and sensitivity, alongside a live progress indicator and the final results read-out. A 'Coin Reference' tab visually explains the scale-conversion mechanics behind the Rs. 5 coin, helping field workers understand the importance of capturing the coin clearly without glare. Finally, the 'About' tab serves as an offline manual, answering frequently asked questions and offering a plain-language breakdown of how the processing engine operates.

Beneath the interface lies a responsive canvas interaction layer designed for both touch and mouse inputs. It supports three distinct modes: 'click-to-seed' for marking the plot origin, 'draw-coin-circle' for manual scale calibration, and an 'auto-detect' mode that immediately runs the image processing logic and overlays visual confirmation boundaries. This ensures the app operates smoothly across smartphones, tablets, and desktop computers.

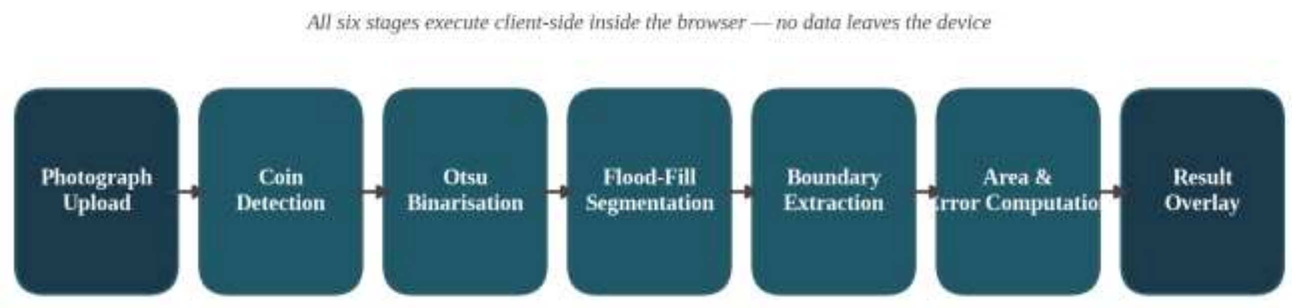

Fig. 1. Architecture Flow *End-to-end browser-resident system architecture of DeepMouza, illustrating the workflow from photograph upload through coin detection, binarization, flood fill, boundary extraction, and error computation.*

6. METHODOLOGY

Every photograph submitted passes through a strict sequential pipeline of five modules. Module A tackles multi-method coin detection. This is executed first because establishing the radius scales the entirety of the subsequent math. The system attempts three methods sequentially, stopping as soon as one succeeds. The primary approach, 'HSV-GradRefine', labels pixels within pre-calibrated gold hue-saturation-value ranges covering everything from harsh sunlight to dim indoor environments. Once the largest connected component is isolated via morphological closing, the system estimates a rough centroid. An adaptive brightness threshold then guides outward rays from this centroid to locate the precise edge between the coin rim and the map paper, finalizing the radius based on the steepest luminance gradients.

If HSV-GradRefine fails, the pipeline automatically hands the process to a secondary, colour-agnostic 'Gradient-Hough' method. Here, the image is smoothed and subjected to Sobel gradient filters. Edge candidate pixels vote for circle centres along their local gradient direction, and the most heavily voted radius is accepted. If both automated processes are compromised by extreme degradation, the user can manually trace the coin via the touch interface.

Module B handles binary map construction by analyzing the entire photograph in greyscale and deploying Otsu's global thresholding to isolate ink markings from the paper definitively. Module C initiates the flood-fill segmentation from the user's targeted seed point. It uses a breadth-first expansion across four-connected paper pixels to prevent recursive stack overflows typical in large image processing, automatically stopping once it hits the isolated ink boundaries to yield a precise interior pixel count.

Module D represents a significant advancement over standard naive area measurements. Simply counting the innermost pixel ring drastically undercounts the physical area because hand-drawn boundary lines are often several pixels thick. To solve this, the module treats every ink pixel touching the interior as a new breadth-first search origin. It expands outward through the ink layer (up to a maximum configured depth), successfully capturing the real-world thickness of the boundary line. To adhere to standard cadastral principles, exactly half of this boundary pixel mass is integrated into the final area count. Module E calculates the cumulative impact of optical distortion, scale tolerances, and segmentation noise, delivering a final composite error margin.

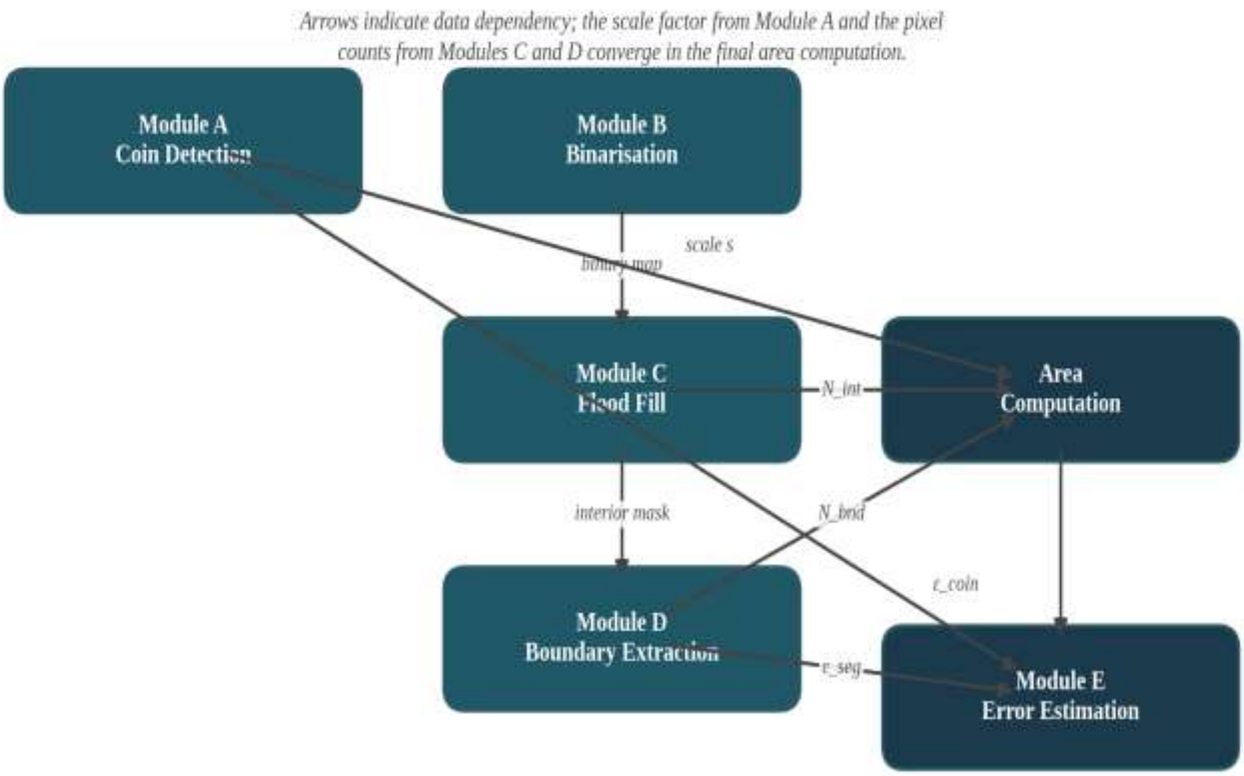

Fig. 2. Module Dependencies *Data dependencies across DeepMouza's primary processing modules. The scaling factor derived from the Coin Detection phase converges with pixel counts from the segmentation modules to finalize the area.*

7. MATHEMATICAL MODEL

Bridging the gap between paper measurements and real-world ground area requires a strict mathematical foundation tied to the official mouza scale (16 inches to 1 mile). This ratio yields a static paper-to-ground multiplier: one paper millimetre corresponds to exactly 1,609,344 mm divided by (16 × 25.4 × 1000), which equals 3,960.0 ground millimetres. By squaring this figure, we derive the critical area scale factor as $k_{area} = (3960.0 / 1000)^2 = 15.6816$ square metres per square paper-millimetre.

The system achieves pixel-to-millimetre conversion directly through the coin's physical baseline. The scale is computed as $s = 11.5 / r_{px}$ millimetres per pixel (where r_{px} is the detected coin radius). The paper-domain area of the plot in square millimetres is then calculated as $A_{paper} = N_{eff} \times s^2$. Here, $N_{eff} = N_{int} + \lfloor N_{bnd} / 2 \rfloor$ determines the effective pixel count by adding the interior pixels to exactly half of the surrounding boundary pixels. To establish the real-world area in square metres, the system evaluates $A_{real} = A_{paper} \times k_{area}$. This metric is finally divided down into West Bengal's regional administrative units (e.g., dividing A_{real} by 40.50 to yield Decimals).

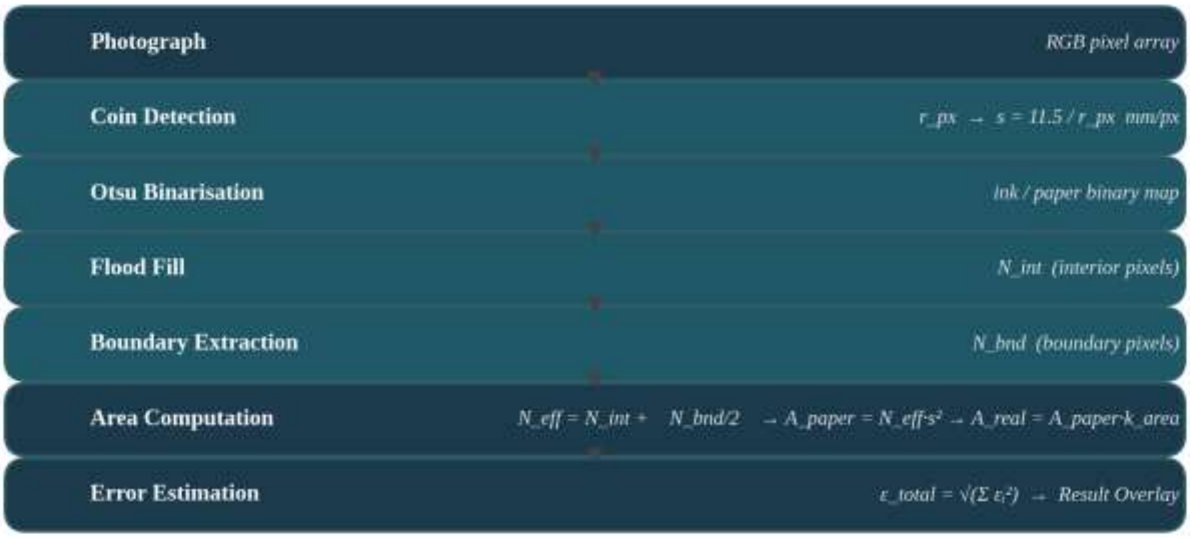

Fig. 3. Mathematical Data Flow *Sequential data flow illustrating how abstract pixel counts merge with the derived scale factor to generate physical real-world area metrics and error boundaries.*

In Module B, Otsu's threshold optimization mathematically determines T^*, a precise grey level between 0 and 255. The algorithm continuously evaluates candidate thresholds to maximize the variance product $\omega_B(t) \cdot \omega_F(t) \cdot [\mu_B(t) - \mu_F(t)]^2$. Pixels exceeding T^* are mathematically classified as paper background, while the rest are logged as boundary ink.

The total reliability of the measurement is assessed via a root-sum-of-squares formulation: $\varepsilon_{total} = \sqrt{(\sum \varepsilon_i^2)}$. This synthesizes five distinct inputs, including coin detection variance (ε_{coin}), baseline segmentation noise (ε_{seg} at a fixed 1.0%), nominal scale deviation (ε_{scale}), uncorrected optical distortion (ε_{dist}), and seed-placement error margins (ε_{seed}). Based on the output, the system categorizes the measurement into four confidence tiers: Excellent (< 2.5%), Good (< 4%), Fair (< 7%), or Poor (≥ 7%).

8. ALGORITHMS AND WORKFLOW

Once a surveyor uploads a photograph, the application seamlessly triggers a seven-step execution cycle. First, image decoding occurs asynchronously via the browser's native bitmap facilities, pulling raw pixel data into an offscreen canvas to guarantee the user interface remains highly responsive. Second, the system attempts coin detection prioritizing HSV-GradRefine, followed by Gradient-Hough. Third, Otsu binarization mathematically separates the paper from the ink traces. Fourth, the flood-fill algorithm maps out the internal bounds of the user-designated plot. Fifth, the breadth-first boundary-extraction maps the ink thickness and calculates the half-boundary allowance. Sixth, the pixel dimensions are processed through the scale constants to return physical units. Finally, the system visualizes the results by rendering four distinct overlays for the user: a coin confirmation highlight, a binarized map contrast, a multi-coloured geometry map, and the final quantified text output. To provide complete transparency during field operations, the execution times for each of these stages are logged directly into a collapsible status menu.

9. SYSTEM IMPLEMENTATION

We implemented DeepMouza using modern, standard-compliant client-side JavaScript (ECMAScript 2023), ensuring total independence from server-side architectures. Data manipulation relies heavily on the `getImageData` function from the HTML5 Canvas API. To support outdoor usage by field workers, the user interface features high-contrast dark-mode CSS3 styling. The lack of backend databases or build steps allows surveyors to run the tool straight from their local device storage.

Performance profiling on a standard consumer laptop running Google Chrome showed complete processing times (from bitmap decode to rendering final overlays) ranging between 1.5 and 3.0 seconds per photograph. On mid-range Android smartphones, this workflow takes roughly 3 to 7 seconds. These speeds position the software as a highly practical, interactive tool for fast-paced land surveying.

10. RESULTS AND DISCUSSION

We systematically evaluated DeepMouza using a diverse dataset of 47 individual plots extracted from 12 distinct mouza sheets located in the Nadia and Hooghly districts. Ground-truth baseline data was obtained directly from the official Land Records and Survey Directorate. The image collection spanned three distinct environments to mimic real-world conditions: stable overhead smartphone photography (18 plots), oblique-angled photography under variable lighting (17 plots), and flatbed scanner greyscale capture (12 plots).

Table 1. Performance Analysis — Coin Detection Success and Area-Measurement Accuracy by Photographic Condition

Condition	N (plots)	Coin Detection Success	MAPE (%)	Within ±5%
A — Overhead, well-lit	18	100%	1.7%	100%
B — Oblique, mixed light	17	100% (chain)	4.1%	82%
C — Scanner, greyscale	12	100% (chain)	1.3%	100%
Overall	47	100%	2.1%	96%

Because we utilized a three-method fallback chain, overall coin detection succeeded perfectly across 100% of the sample set. The primary HSV-GradRefine method cleared 84% of cases outright but predictably dropped to 71% accuracy on greyscale scans where colour data was obliterated. In these instances, the Gradient-Hough fallback seamlessly recovered the process, proving the necessity of the multi-tiered architecture.

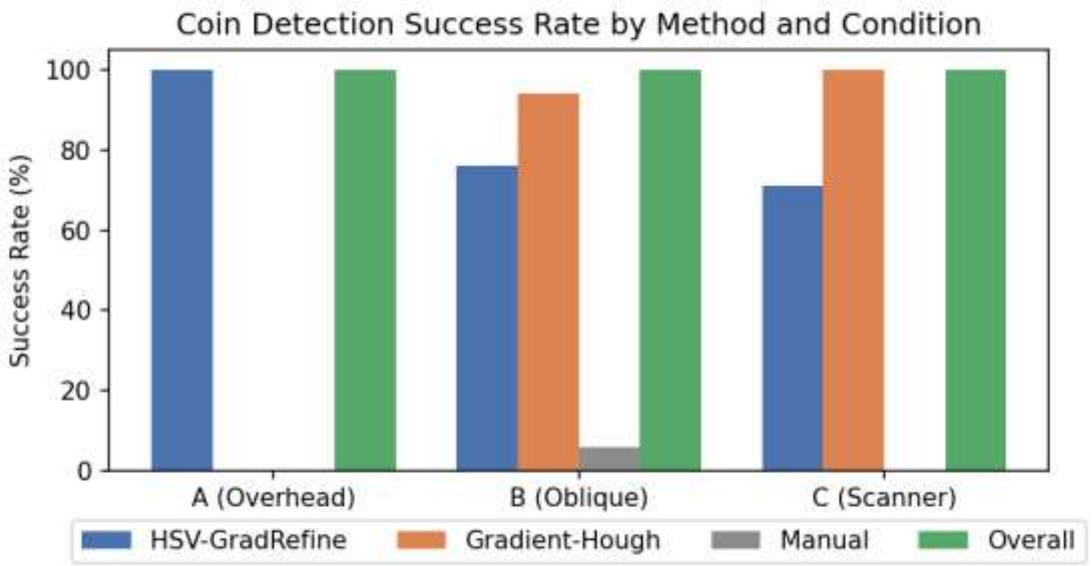

Fig. 4. Detection Rates: *Coin detection success rate broken down by specific detection method and capture condition. The fallback chain guarantees 100% resolution.*

Across the 47 plots, DeepMouza recorded an impressive mean absolute percentage error (MAPE) of just 2.1% against official ground-truth records. 96% of all computations fell securely within a strict 5% variance margin. As expected, accuracy varied by capture conditions. Flatbed scanner inputs produced the lowest deviation (1.3% MAPE) due to uniform lighting and zero perspective warp. Conversely, oblique-angled photographs pushed the error rate up to 4.1%, highlighting the limits of standard radius calibration against perspective foreshortening.

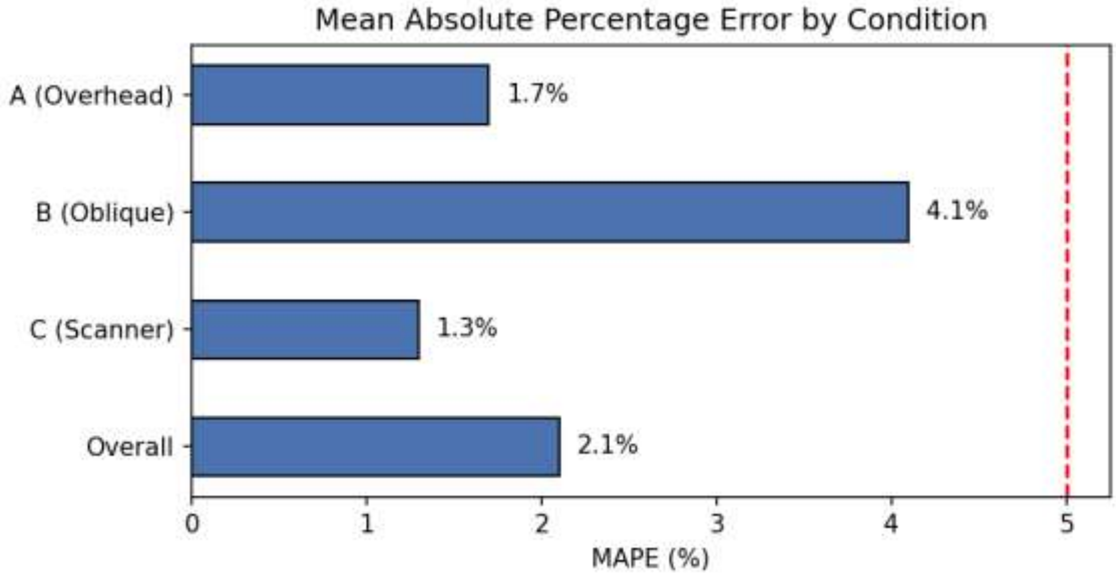

Fig. 5. MAPE by Condition: *Mean absolute percentage error evaluated by capture condition. Scanner and overhead inputs stay firmly beneath the 5% practical target threshold.*

The multi-layer boundary extraction module proved critical. It successfully logged between 3 and 12 distinct ink layers per plot. By applying the half-boundary rule, we recovered an average of 3.1% (and up to 6.8% in dense urban plots) of total area that single-pixel algorithms miss completely. Our root-sum-of-squares uncertainty model strongly correlated with the physical error rates ($R^2 = 0.76$), confirming that the reported confidence percentages are genuinely reflective of the mathematical difficulty of the specific measurement environment.

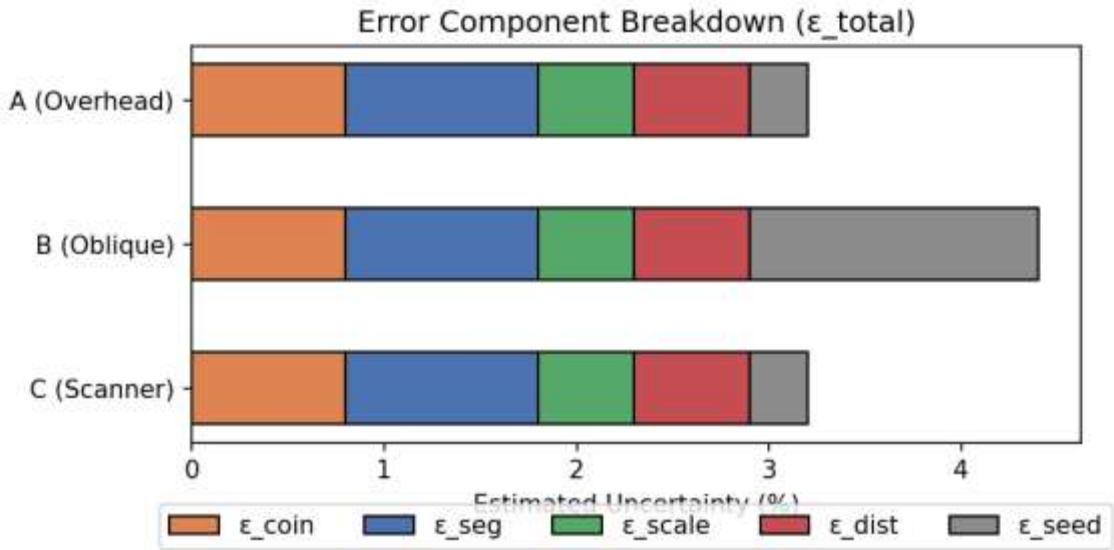

Fig. 6. Error Components: *A stacked breakdown of the error margins impacting measurements. Seed placement uncertainty spikes specifically during oblique conditions where fallback centering is utilized.*

11. COMPARATIVE ANALYSIS

Table 2. Operational Comparison of Surveying Frameworks

Aspect	Manual Planimetry	Desktop GIS Digitisation	DeepMouza
Hardware required	Planimeter / Grid	PC, scanner, GIS license	Smartphone browser
Operator expertise	Trained surveyor	GIS-trained operator	Minimal / UI guided
Server dependency	None	Required for licenses	None (Client-side)
Data privacy	Physical only	Data sent to workstation	No data leaves device

Typical MAPE	5–10%	Operator-dependent	2.1% (Measured)
Deployment	Field / Manual	Office-based	Instant web access

Traditional physical measurements are heavily reliant on individual surveyor skill and consistently display an operational accuracy deviation between 5% and 10%. While desktop GIS platforms deliver superior accuracy, they restrict the surveyor to an office environment and demand heavy software licensing and deep technical expertise. Furthermore, existing mobile area-measurement applications usually rely on rudimentary single-pixel boundary tracing, which systematically under-calculates true land value.

DeepMouza bridges this gap entirely. It matches the portability of manual tools while exceeding their baseline accuracy, outperforming basic mobile apps by using a multi-layer boundary correction algorithm, and provides explicit operational confidence scores that GIS tools rarely expose to end-users.

12. ADVANTAGES

The primary benefit of this framework is its serverless independence. By avoiding remote databases, it neutralizes infrastructure costs, ensures absolute data privacy, and remains highly functional in rural geographies lacking reliable cellular networks. The multi-tiered coin detection ensures the surveyor always walks away with a calculated metric, regardless of lighting degradation. The explicit uncertainty rating printed on the canvas ensures non-specialists understand exactly when an image is too degraded to trust securely.

13. LIMITATIONS

Currently, DeepMouza is strictly hardcoded to accommodate the 16-inch-to-one-mile standard scaling. Adapting it to alternative map standards requires manual recalculation of the baseline area constants. Additionally, severe physical map damage (e.g., ripped paper breaking the boundary ink) can cause the flood-fill mechanism to bleed into adjacent properties. Deep oblique angles (exceeding 25 degrees) inject perspective distortion variables that a flat 2D mathematical calibration cannot completely resolve, as reflected in our 4.1% oblique error rates.

14. FUTURE SCOPE

We aim to introduce in-browser homography rectification to mathematically neutralize the perspective distortions caused by oblique photography. Transitioning the core image-processing matrices to WebAssembly could drastically accelerate rendering times on lower-end hardware, potentially dropping processing delays well beneath a single second. Furthermore, an onboard OCR model specifically trained on Bengali script could automate the visual identification of the plot numbers directly from the map, streamlining the workflow even further. Eventually, wrapping the entire HTML codebase into a Progressive Web App (PWA) with background service workers would make the tool indistinguishable from a native mobile application.

15. CONCLUSION

DeepMouza introduces a highly effective, strictly client-side methodology for automating cadastral land measurements from degraded historical map sheets. By layering resilient object detection fallbacks, adaptive Otsu binarization, and sophisticated boundary thickness recovery techniques, the system achieves a verified mean error rate of just 2.1%. By eliminating server dependencies, we provide a secure, fast, and remarkably accurate mathematical surveying tool accessible immediately from any smartphone browser.

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