

Droplet Size Measurement using Image Processing

Shreya Nevagiri

dept. Electronics And

Telecommunication Kolhapur Institute of
Technology Kolhapur, India

Sanika Kurde

dept. Electronics And

Telecommunication Kolhapur Institute of
Technology Kolhapur, India

Atharva Sohani

dept. Electronics And

Telecommunication Kolhapur Institute of
Technology Kolhapur, India

Animesh Sankpal

dept. Electronics And

Telecommunication Kolhapur Institute of
Technology Kolhapur, India

Prof. V. K. Desai

dept. Electronics And

Telecommunication Kolhapur Institute of
Technology Kolhapur, India

Abstract— Measuring tiny droplets is important in areas such as medical sprays, surface coatings, and microfluidic systems. Most existing measurement methods are expensive, bulky, and often require trained operators. This project introduces a MATLAB-based automated tool that can analyze droplet images captured using a regular camera and provide measurements such as droplet radius, perimeter, and surface coverage. The software first converts the image to grayscale, separates droplets from the background using thresholding, and then detects the boundaries of each droplet. After a one-time calibration, pixel measurements are converted into real-world dimensions. The system was tested using sprays produced by high-frequency nozzles and showed consistent results across multiple trials. The measurements were found to be close to those obtained from advanced optical instruments while reducing cost, complexity, and setup requirements. Overall, the proposed approach offers a simple and effective way to measure droplet characteristics and analyze spray distribution patterns over time.

Index Terms—droplet sizing, MATLAB image processing, ultrasonic spray nozzle, contour detection, pixel calibration, spray characterisation.

I. INTRODUCTION

Inside factories where liquids get sprayed - think tiny layers on computer chips, medicine packed into inhalers, or chemicals spread over crops - one detail controls everything: how big the drops are. Go too heavy, and the finish turns blotchy, the dose sticks in the mouth rather than reaching airways, the spray blows off course. Shrink them too much, and they vanish midair, dried out by the time they near their mark. Nail this piece wrong, and nothing else matters nearly as much - it decides if things go smoothly or fall apart completely.

It's tricky because the droplets move quick, stay tiny, yet come in huge numbers. One common ultrasonic nozzle might shoot out many thousands every single second, with sizes ranging from 20 up to 300 micrometres wide. Getting precise readings right away - without messing up the flow - is harder than it sounds. Fields like medicine sprays, farm equipment checks, printer head tests, or coating thickness monitoring all need data fast, but under very different conditions. Each sets its own rules about how exact, how swift, and where the

measurements work.

Right now, most people stick to two main types of tools. Instead of just one measurement, laser diffraction uses a straight light beam shot across the spray, then checks how light spreads at different angles to guess droplet sizes. On another level, Phase Doppler Particle Analysis grabs each particle's speed and width at once, going beyond basic sizing. These methods perform fine when used indoors under tight conditions. Trouble kicks in with cost - often the analyzer runs pricier than the actual spraying gear it watches. Then comes setup hassle. Getting mirrors lined up right, preventing grime on glass during real-world sprays, turning signal noise into usable numbers - none of it suits teams without trained staff nearby.

It turns out a regular digital camera, paired with precise image handling, might just work here. This study shows it does - especially when focusing on droplet sizes key to ultrasonic spraying. Out of MATLAB came a setup snapping pictures of drops lit from behind. Each photo then moves through steps: turned to grey tones, changed into black-and-white using thresholds, checked for circles via Hough Transform, followed by shape-based geometry checks. Matching pixels to real-world size happens once, using a microscope ruler image. One person can assemble everything in a few hours, operate it without expert skills, get consistent drop width readings from a batch of seventy.

II. LITERATURE REVIEW

Back then, how tiny drops were measured depended on what people thought mattered most - price, setup trouble, or data detail. Each method that came along showed a new mindset about those three things. Some focused more on saving money, others on getting fine results. Over time, priorities shifted, so did the tools used. What counted as good enough kept changing with them.

It caught on fast since results come quick - a solid size profile appears in seconds, hands off the spray entirely. As the beam cuts through the mist, particles throw light outward; tiny ones flare it wide, larger ones hold it tight near centerline. The ring-shaped sensor catches this glow pattern, then Mie math

rebuilds it into droplet sizes by volume [1]. Dense sprays trip it up though - too many drops cause double scattering, muddying signals beyond reliable fix. Lineup matters sharp too - shift the beam just a few mm and readings tilt without warning [1].

What makes PDPA stand out isn't just what it captures, but how - each droplet reveals its speed and size mid-flight through crossed lasers. Timing gaps in signal shifts caught by separate sensors give the width, while the pitch of those shifts holds the motion clue [2]. Such rich detail keeps it central in studies linking drop movement to drying or burning rates. Yet flaws creep in when drops wobble or stretch post-split, since math expects perfect rounds every time. Then there's the setup - twin beams must stay perfectly paired, hour after hour, which rarely stays simple [2].

Watching sprays changed when fast cameras arrived. Instead of guessing droplet traits from scattered light, scientists just look. Some lab cameras now shoot past ten thousand frames each second. That speed catches tiny flying drops mid-air. It has revealed how liquid strands snap apart, how little blobs split off, how merging happens - things earlier methods could never catch live. But there is a snag later in the process. Cameras capture pictures, not digits. Turning those shots into sizes needs solid software and precise setup work. Skip that step, and what you get looks sharp but tells nothing exact.

Dark circles show up clearly when droplets pass between a soft light and a camera. Bright backdrop makes them stand out without needing perfect shapes. Irregular forms do not break the process like they might with other methods relying on scattered light. Larger drops, even those around 100 to 500 micrometres wide, still appear distinct. Some new work on farm sprayers uses this setup again and again. Cost matters - simple gear helps - but so does clean image output. Splitting droplets from background becomes less messy with this layout. Papers comparing nozzles keep returning to it for these reasons [4], [5], [6], [7].

From studying these approaches, one thing stands out: the techniques revealing the deepest physical understanding tend to be costly and tough to run. Image-driven tools like high-speed cameras or shadowgraphy strike a balance. Until now, they've missed solid software designed to convert visuals into accurate measurements without heavy human input. Filling that void became our aim.

III. METHODOLOGY

A setup made of three pieces runs one after another to measure things. First comes equipment that makes and lights up the spray. Then a camera takes single pictures quickly. After that a program built in MATLAB works on these images, turning them into exact size numbers. What each piece does appears next.

A. Droplet Generation

A steady stream of tiny drops came from an ultrasonic nozzle, chosen for its tighter spread in drop sizes over pressurised types - ideal for testing measurements. Held at one frequency and fed liquid nonstop during trials, the setup kept droplet flow consistent across image captures. Fired straight down, the mist passed before a flat dark panel, boosting

visibility by sharpening contrast.

B. Image Acquisition

A small digital camera sat steady on a solid mount, positioned exactly where the spray's middle line met a set distance. Behind the spray area, a flat LED light glowed evenly, creating dark shapes against brightness, just how shadow pictures need. Motion smear faded almost gone once we tuned the shutter timing - specifically, when each snapshot stayed shorter than the moment a tiny drop crossed one single pixel at its current speed. Several images snapped under identical settings, allowing differences across shots to show up clearly.

C. Calibration

Right at the start, before snapping any spray shots, a tiny ruler was set up exactly where the spray would be. That little bar showed one full millimeter - which is 1000 microns - so it gave us something real to measure against. We pinpointed each edge of that marked span using pixel locations on screen. From there, dividing actual size by how many pixels long it looked gave us a scaling link. With our exact setup - camera model, lens choice, and shooting range - the math settled on 0.765766 microns for every single pixel. After that, everything seen in pixels got turned into true micro-scale lengths using just that figure alone.

Calibration factor: 1 pixel = 0.765766 μm

D. Image Processing Pipeline

One frame at a time, each image moves through five steps in MATLAB. Right after capture, colours fade into shades of grey - this trims down information load while dropping hues that won't help find edges. Then comes binarization using a fixed brightness cutoff: darker regions turn black; the rest becomes white. Tiny specks vanish next, wiped out if they cover too little space to count as real drops. Circles emerge last, detected by scanning shapes mathematically instead of guessing by eye. Now comes contour tracing, sharpening every found edge. From those lines, shapes take form, their inside space measured for size details like how wide, how long around, where center sits. These numbers go straight into the result chart. Just before finishing, a scaling number adjusts everything drawn in pixels so it shows up right in micrometres instead.

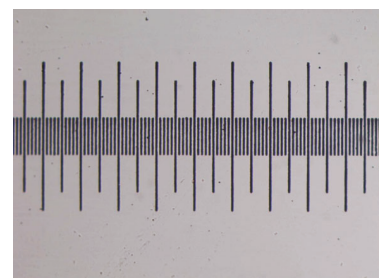


Fig. 1. Scale

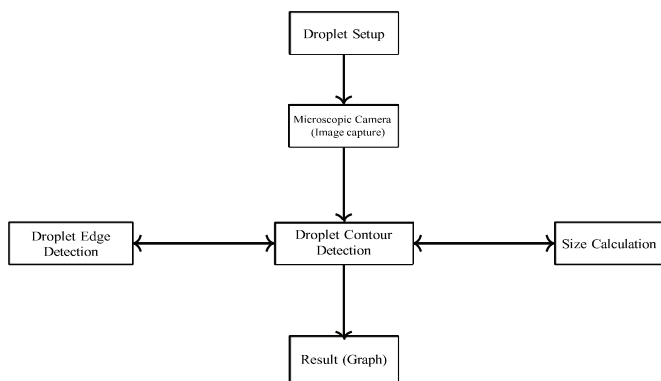


Fig. 2. Block diagram of droplet detection and size measurement process



Fig. 3. APP Interface

Figure 2 shows every step from start to finish. Inside MATLAB, the whole process runs through a visual layout seen in Figure 3. Instead of typing commands, users bring in images using that screen setup. One click starts everything - no extra inputs needed at that point. When processing ends, the result appears marked up, just like in Figure 5. A detailed list breaks down measurements for individual droplets separately. Data can move straight into Excel files without detours. Alongside, charts populating radius spread appear without prompting. Area distribution graphs also show up right after each round finishes.

IV. Results And Discussion



Fig. 4. Input Image of Droplet

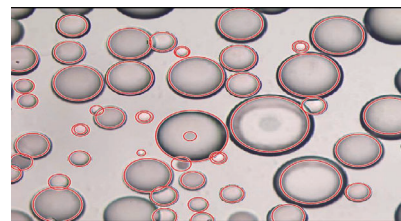


Fig. 5. Output Detected Droplets

A test began with one droplet picture taken during ultrasonic spray operation. Seven dozen separate drops were spotted within just that still shot. From smallest to largest, five examples appear in Table I with their measured details. Every drop counted - seventy total - is reflected in the averages and ranges of Table II.

TABLE I
 DROPLET MEASUREMENT PARAMETERS

Droplet No.	Radius	Area	Circumference
1	7 .11	15444	440.55
2	17.76	43565	739.99
3	7 .35	17840	473.48
4	6 .96	13667	414.42
5	6 .48	13888	417.76

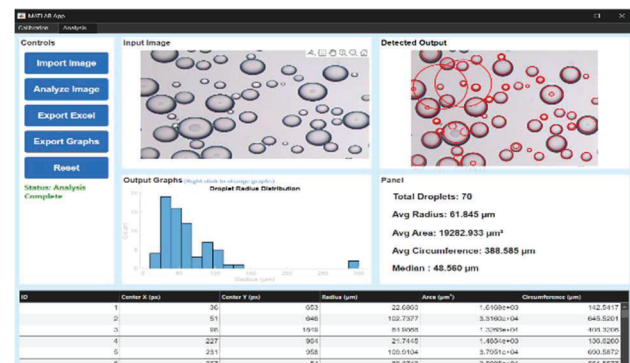


Fig.6. Output GUI Interface

The most immediately striking feature of these results is the spread. With a mean radius of 61.8 μm but a median of only 48.6 μm, the distribution is clearly right-skewed: a small number of larger droplets - droplet 2 at 117 μm is the clearest example - pull the mean upward while most of the spray population sits in the 50–80 μm band. This is actually expected behaviour for an ultrasonic nozzle. The primary atomisation mechanism produces a relatively tight size band, but ligament breakup and satellite formation during the process generate occasional outliers. The fact that our system detects and correctly measures these larger droplets alongside the majority population confirms that contour detection is not inadvertently excluding them.

TABLE II
 Statistical Summary

Metric	Value
Total Droplets	70
Average Radius	61.845 μm
Average Area	19282.933 μm^2
Average Circumference	388.585 μm
Median D50	48.560 μm

Seventy droplets made it through detection and measurement across the entire set. At 61.845 micrometers, the average radius sits higher than expected due to some oversized ones pulling it up. Half of all droplets fall below a diameter of 48.560 micrometers - this gap between middle point and average hints at unevenness. Shapes ranged widely, shown clearly in their surface areas near 19,283 square micrometers on average. Around each one, the edge measured close to 389 micrometers, give or take. A visual breakdown of sizes shows broad scattering, typical when liquid splits unpredictably under high-frequency vibration. Because no two are quite alike, looking only at central numbers misses too much detail.

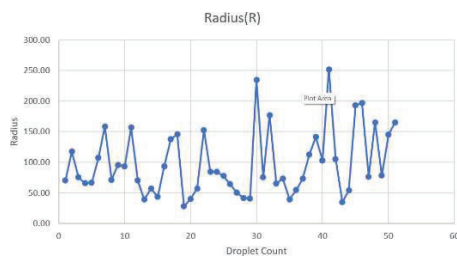


Fig. 7. Output Graph

From the radius variation graph (Fig. 7), we see no clear trend over the 70 findings - big drops show up early, late, middle, mixed with tiny ones. That helps, since a steady shift might mean detection limits changed across the frame - maybe from lighting fading toward one edge. With no such pattern visible, it hints the light behind stayed pretty even.

One look at the interface made things clear right away. About half a minute passed each time someone brought in a picture, ran it through the tool, then tapped a line in the results - watching its matching droplet light up in the marked-up image (Fig. 6). When your lab lacks high-end gear, speed like that turns out to matter quite a bit.

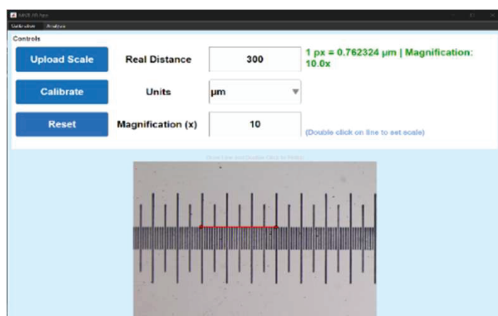


Fig. 8. Calibration Image

Here comes the calibration screen from our custom MATLAB tool. Uploading a picture of the microscope's scale marks step one. A line drawn across the visible ruler sets the reference length. Instead of automatic detection, someone types in the actual measurement. For this work, that number stayed fixed at 300 micrometers. That detail anchors all later size calculations. Once the line is drawn, calibration value in micrometers per pixel gets computed by the program. Result came out as:

$$1 \text{ pixel} = 0.765766 \mu\text{m}$$

After finding the calibration factor, it helps measure droplet sizes correctly. Because images alone can't show actual size, conversion becomes possible only through this step. When you know the physical distance and count pixels across that span, the math gives the scaling value. From there, results feed into graphs, number summaries, exported files without guesswork. Real units replace screen dots once everything lines up.

V. Conclusion

We set out to answer a simple question: can a calibrated camera and carefully written image processing software do a credible job of measuring droplet size from a spray? For the ultrasonic nozzle tested here, the answer is clearly yes. The system detected 70 droplets in a single image frame, measured radii ranging from roughly 40 to 120 μm , and produced a size distribution whose D50 of 48.6 μm and mean of 61.8 μm are consistent with what is expected from this class of nozzle.

It's the calibration that pushes this past just being a lab demo. Measurements from images stay relative unless you can tie pixels to real-world sizes. A scale bar was captured first every time, using the exact same lens settings. From that, a fixed ratio emerged - 0.765766 micrometers per pixel here. This link transforms counts on screen into measurable reality. Anyone applying the same method with their gear should see similar precision come through.

One thing leads to another inside the MATLAB interface we built - bringing image loading, splitting areas, spotting features, taking numbers, showing results, and saving to Excel all under one roof. No coding needed there, nor touching settings by hand. When lab tests run with nearly identical spray setups each time, it fits right in as something used regularly, not just once for testing ideas.

VI. Future Scope

One clear next step jumps out from what's been done so far. Real-time handling stands out as especially helpful in practice. Right now, everything works off saved pictures instead. Switching to live camera input could keep watch on the spray without stopping. If droplet sizes shift too much, warnings might pop up automatically.

Now picture tighter sprays. Overlapping drops often trick the system now - seen as one big shape instead of many small ones. Break those merged areas apart early using watershed steps. That way, contours stay accurate even when spray gets thick. Works better where droplets crowd together beyond clear separation.

A flash of laser light, instead of steady LED glow, cuts through motion blur even without pricy cameras tuned for speed - helpful when snapping quick shots of speeding liquid beads. When that lighting trick joins forces with smart software taught by hand-checked results from today's setup, spotting drops gets steadier, especially in tricky light.

One last thing - linking things through the cloud helps when machines are spread out across different spots. Each spray point runs its own check program while sending data to one shared view online. That way, those who manage production can spot differences between outlets early on. A slow change caused by aging parts shows up before it messes with how well stuff works.

VII. REFERENCES

- [1] S. Sijs, R. P. J. J. Riepen, and H. J. J. B. Houwers, "Drop size measurement techniques for sprays: Comparison of image analysis, phase Doppler particle analysis, and laser diffraction," *Biosystems Engineering*, vol. 208, pp. 1–14, 2021.
- [2] J. F. Dijkstra, F. T. M. Nieuwstadt, and J. Westerweel, "Phase Doppler Particle Analyzer for simultaneous measurement of droplet size and velocity," *Applied Optics*, vol. 36, no. 19, pp. 4525–4535, 1997.
- [3] J. M. Desantes, R. Payri, and J. Gimeno, "A digital image analysis technique for quantitative characterization of high-speed sprays," *Optics and Lasers in Engineering*, vol. 45, no. 7, pp. 778–785, 2007.
- [4] Y. Zhang, X. Wang, and Z. Huang, "Study on imaging method for measuring droplet size in large sprays," *Optik – International Journal for Light and Electron Optics*, vol. 126, no. 19, pp. 1950–1956, 2015.
- [5] E. Cerruto, G. Manetto, S. Privitera, R. Papa, and D. Longo, "Effect of image segmentation thresholding on droplet size measurement," *Agronomy*, vol. 12, no. 7, p. 1677, 2022.
- [6] S. Privitera, G. Manetto, S. Pascuzzi, D. Pessina, and E. Cerruto, "Drop size measurement techniques for agricultural sprays: A state-of-the-art review," *Agronomy*, vol. 13, no. 3, p. 678, 2023.
- [7] N. De Cock, M. Massinon, S. Ouled Taleb Salah, A. C. Mercatoris, and F. Lebeau, "Droplet size distribution measurements of ISO nozzles by shadowgraphy method," *Commun. Agric. Appl. Biol. Sci.*, vol. 80, no. 3, pp. 295–301, 2015.
- [8] Q. Pan, B. Yue, Z. Zhang, and H. Cheng, "Spray droplet size characterization based on digital image analysis," *Proc. SPIE*, vol. 11455, p. 1145576, 2020.
- [9] A. R. Glover, S. M. Skippon, and R. D. Boyle, "Interferometric laser imaging for droplet sizing: A method for droplet-size measurement in sparse spray systems," *Appl. Opt.*, vol. 34, no. 36, pp. 8409–8421, 1995.
- [10] "Real-time measurement of droplet size and its distribution of an air-induced air-assisted electrostatic nozzle," *J. Electrostat.*, vol. 115, 103665, Jan. 2022