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Bed net damage assessment from images using a digital segmentation tool and image processing

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Can we accurately measure a bed net's total hole area by simply using digital photographs?

Introduction

The current method to estimate ITN physical integrity requires improvement.

Currently, the assessment of the fabric integrity of insecticide-treated nets (ITNs) is performed using the World Health Organization's (WHO) standard method. This technique consists in manually counting the holes and tears, classifying them by size into four categories (thumb, fist, head, larger than head).

Disadvantages

- Labor-intensive.
- Time-consuming.
- Approximative: computes hole surface area per category based on average size.
- Inaccurate: overestimates hole surface area and is subject to operator bias [1].

Figure 1. Field workings manually measuring hole surface area using the WHO standard guidelines.

For this reason, there is a need for a fast, reliable method to automatically calculate ITN's total hole area to enable the adequate bed net distribution campaigns in malaria-endemic countries.

As a first step towards a fully automatized method, this work investigates whether digital photographs could be used to rapidly and accurately assess hole surface area.

Materials & methods

We employ digital image analysis to automate hole surface area estimation

Materials

- 10 ITNs.
- Frame of known size fitted with a black cloth showing a white grid.
- Image data: close-ups of each hole for real area estimation and full side images were collected for hole area estimation using image analysis.

Graphical User Interface (GUI)

- Developed in Python 3 to obtain additional data for Deep Learning model training.
- Includes functions for hole segmentation and placement of white grid's landmarks.

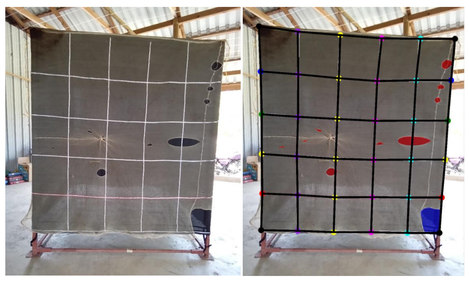

Figure 2. Left: sample image displaying one side of an ITN placed on the grid fitted with a black cloth displaying a white grid. Right: image with segmentation masks overlayed on top and with the grid point landmarks selected using the GUI.

Hole surface area estimation methods

WHO standard method
- Division of holes by size into 4 categories.
- Area calculated using average size of category.

Image analysis
- Segmentation masks to obtain pixel count.
- Area calculated using known grid dimensions.

Results

- We report the percentage error of the WHO standard and the image analysis area estimation methods with respect to the real area obtained using close-up images of all holes.

Table 1. Comparison of the percentage error results obtained when estimating hole surface area using the selected three methods.

WHO standard	Image analysis
371.73 ± 310.64	**12.50 ± 11.54**

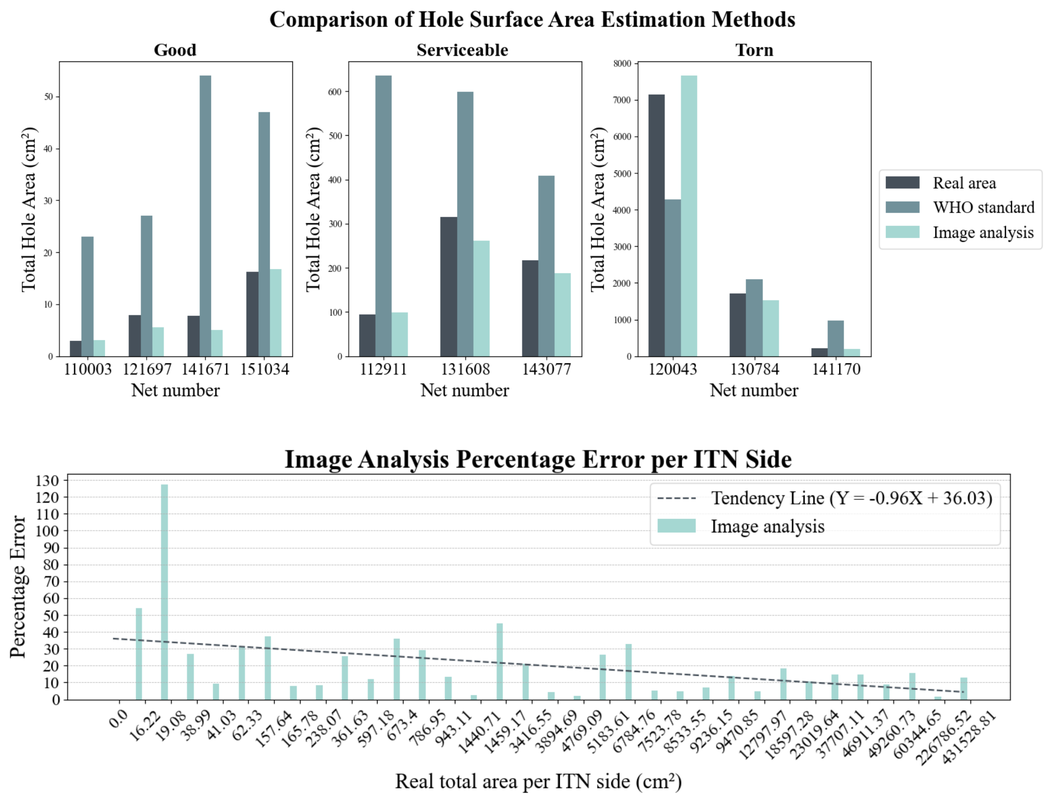

Figure 4. Validation results for hole surface area estimation using image analysis. Top: comparison of real hole surface area computed from close-up images (grey) versus the WHO standard (dark teal) and the image analysis estimations (teal) in cm². Bottom: analysis of the evolution of image analysis percentage error with the increase in hole surface area for each ITN side.

Discussion

- The WHO standard method overestimates hole surface area with a percentage error above 370%.
- Image analysis is up to 30 times more accurate than the WHO standard hole surface area estimation, changing for 2 ITNs their physical condition classification (WHO guidelines).
- Area estimation percentage error decreases with hole surface area size, diminishing the impact of errors on hole surface area estimation.

Conclusion

Hole surface area can effectively be estimated using digital photographs, making image analysis a faster & more accurate tool for ITN condition monitoring.

Outlook

- Further work is needed to improve these results by removing distortions caused by the wind.
- Future work will automate this process employing Deep Learning to:
  - Enable the fast, large-scale assessment of ITN physical condition during field surveys.
  - Prediction an ITN's condition 12 months later to aid malaria control programs in the maintenance of high ITN coverage.

References

[1] Jodi L Vanden Eng et al. "Assessing bed net damage: comparisons of three measurement methods for estimating the size, shape, and distribution of holes on bed nets". In: Malaria Journal 16 (2017), pp. 1–13.

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