Deep learning-enabled smartphone-based system for automated embryo assessments and evaluation

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Background

- Advancements in the field of artificial intelligence (AI) and convolutional neural networks (CNN) have allowed pattern recognition in images with unprecedented accuracy.
- This technology can be utilized in the embryology lab to evaluate human embryos.
- Prior studies from our lab have demonstrated high accuracy utilizing CNNs to classify cleavage and blastocyst stage development when using standard morphological embryo grades as the final outcome measurement.
- However, the primary goal for utilizing AI in the field of Assisted Reproduction is to develop an inexpensive system that can enhance our ability to select embryos with the highest potential for achieving a live birth.

Objectives

- To determine whether a CNN (Fig. 1), developed using embryo images and outcome data, can be used to accurately classify embryo development and improve embryo selection for transfer.
- To develop an inexpensive method for integrating Artificial Intelligence into an image recording device for automated embryo classification and selection purposes.

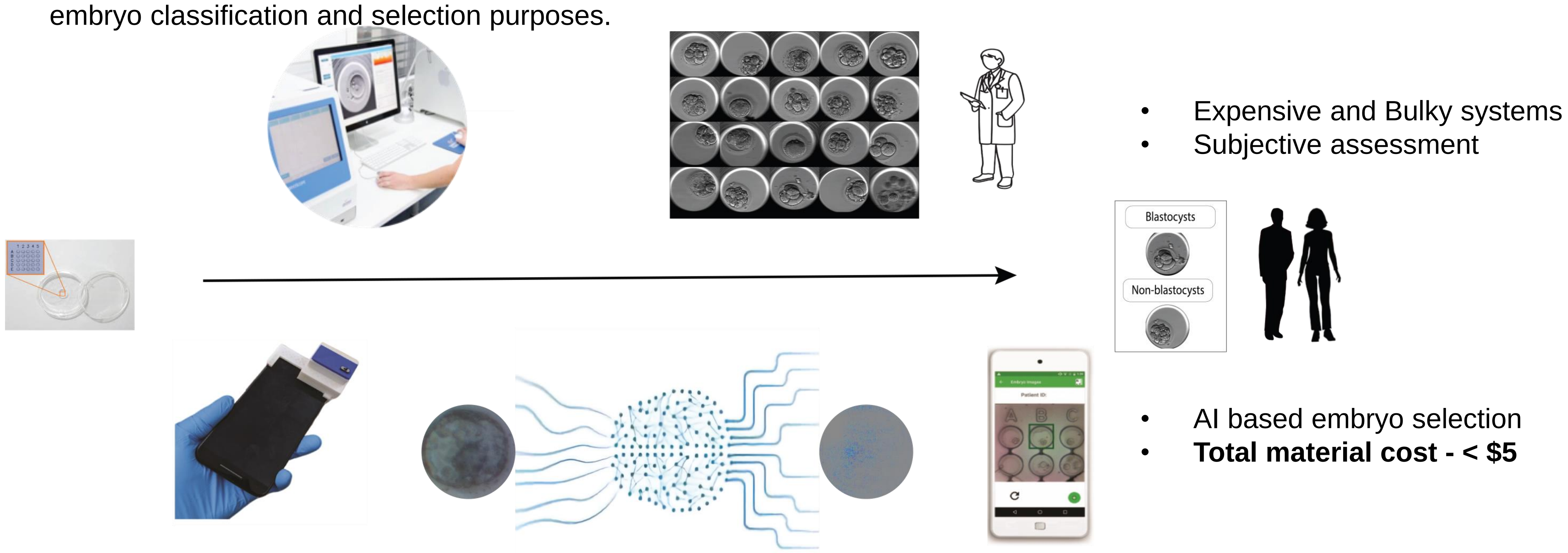


Figure 1: Embryo assessment with expensive systems and smartphone based system

Materials and Methods

- We developed an inexpensive (<$5) portable system to image embryos during in-vitro culture.
- Our device consisted of a 3D printed case that housed all imaging components including the objective lenses, light source, image sensors and a single board computer for data management and processing.
- The convolutional deep neural network was transfer learned, trained and validated with 2500 embryo images captured at 113 hrs post-insemination.
- The system evaluates embryos based on their morphology using a neural network.
- 58 donated embryos were imaged and evaluated using the portable system and classified based on their developmental status. The accuracy, sensitivity, specificity, positive and negative predictive values were calculated along with their 95% confidence intervals (CI).
- Furthermore, 30 images of PGT-A tested euploid blastocysts with known implantation outcomes were evaluated by our network to identify embryos that implanted.15 embryologists from 5 fertility centers were also asked to evaluate the same cohort of PGT-A tested embryos. The accuracies of both groups for predicting implantation were compared with each other through one-sample t-test with an alpha significance value of 0.01.

Smartphone-based system

Device properties:

- Dimensions: 82 × 34 × 48 mm.
- Lens used : Acrylic lens
- Total material cost - $3
  - PLA: $1
  - Lens: $1
  - Battery: $0.4
  - LED switches and wires: $0.08

Figure 2: Exploded view of the smartphone - based imaging system

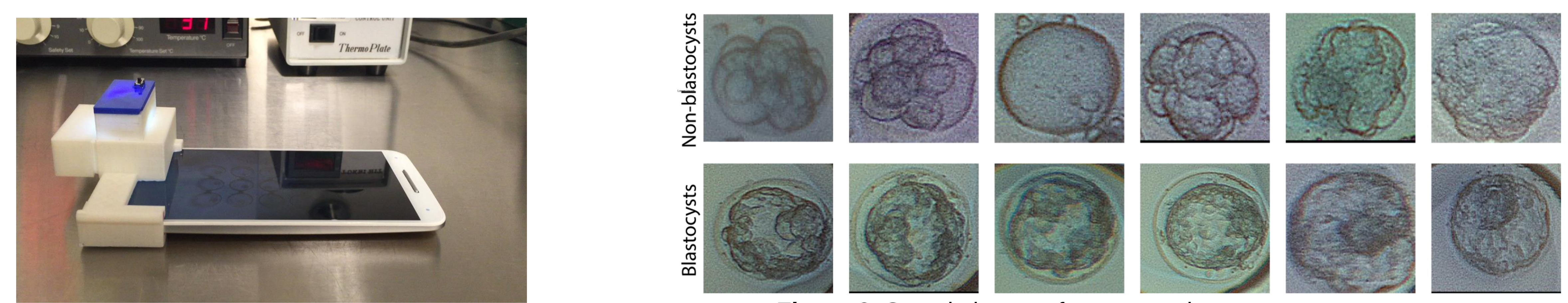
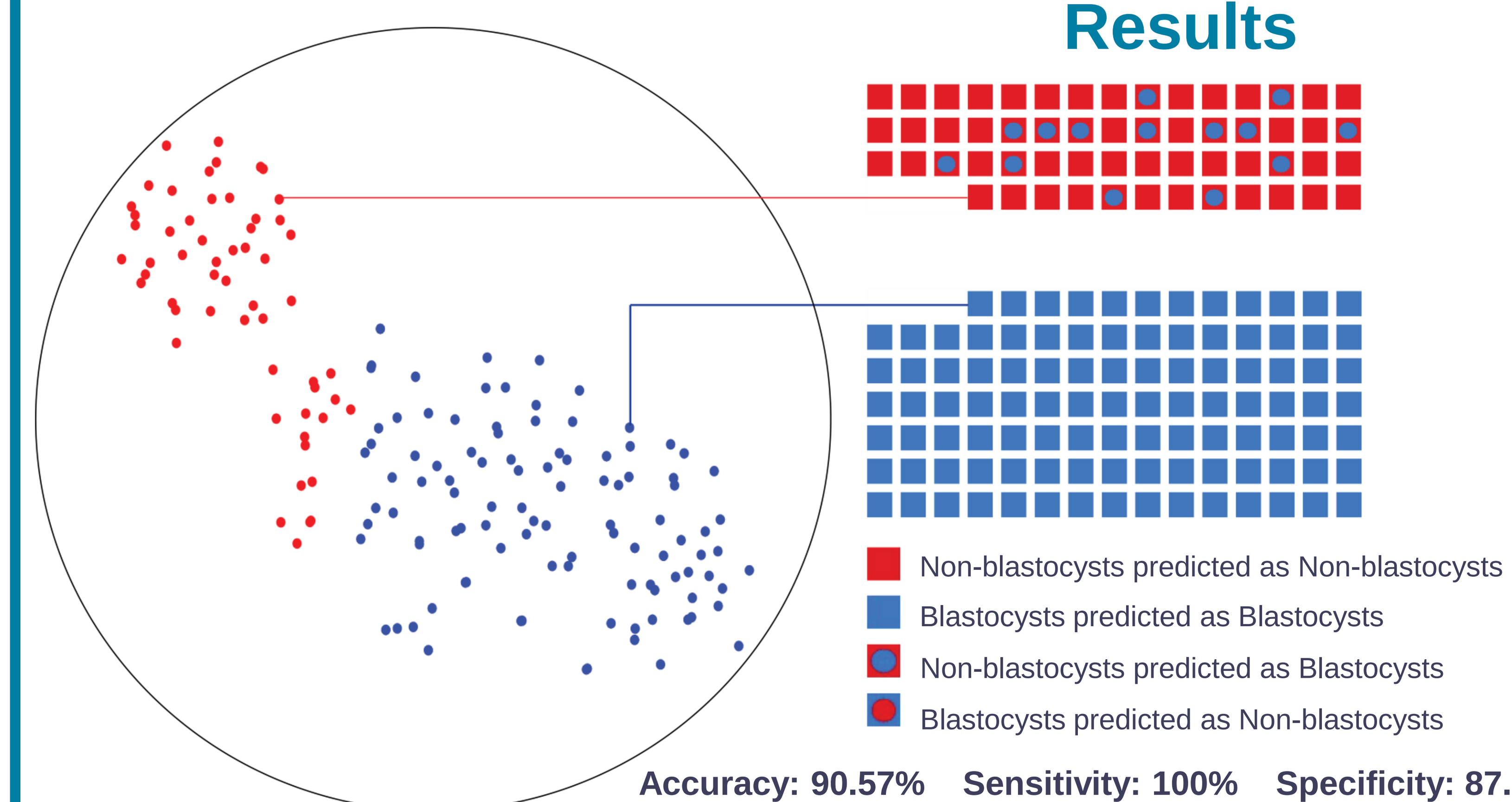
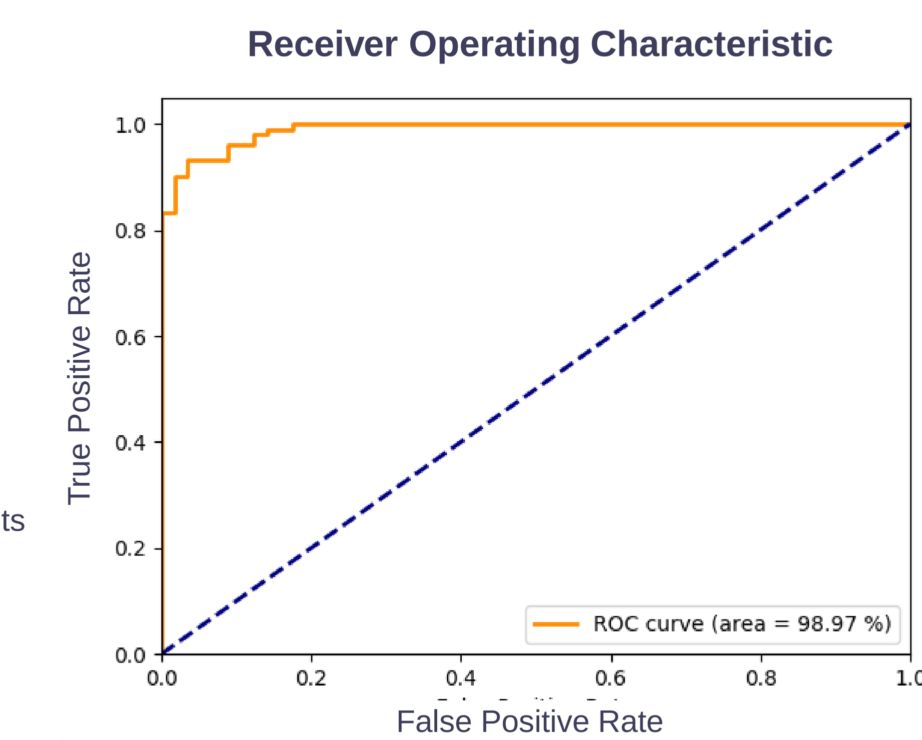


Figure 3: Sample images from smartphone system

Results





Accuracy: 90.57% **Sensitivity: 100%** **Specificity: 87.18%**

Figure 4: System performance along with TSNE, saliency and dot matrix visualizations (n = 159)

Figure 5: ROC analysis for embryo assessment

Conclusions

- We report the **first smartphone imaged embryo** assessment system.
- The developed imaging system costs **<$5** in material costs.
- The AI component achieves automated analysis of embryos imaged by the smartphone **without user input**.
- The analysis is performed locally, i.e., **without internet, in <3s**.
- The AI is highly **accurate (>90%)** and **consistent** in its analysis.

Acknowledgements

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