Supervised Machine Learning for X-Ray CT Imaging

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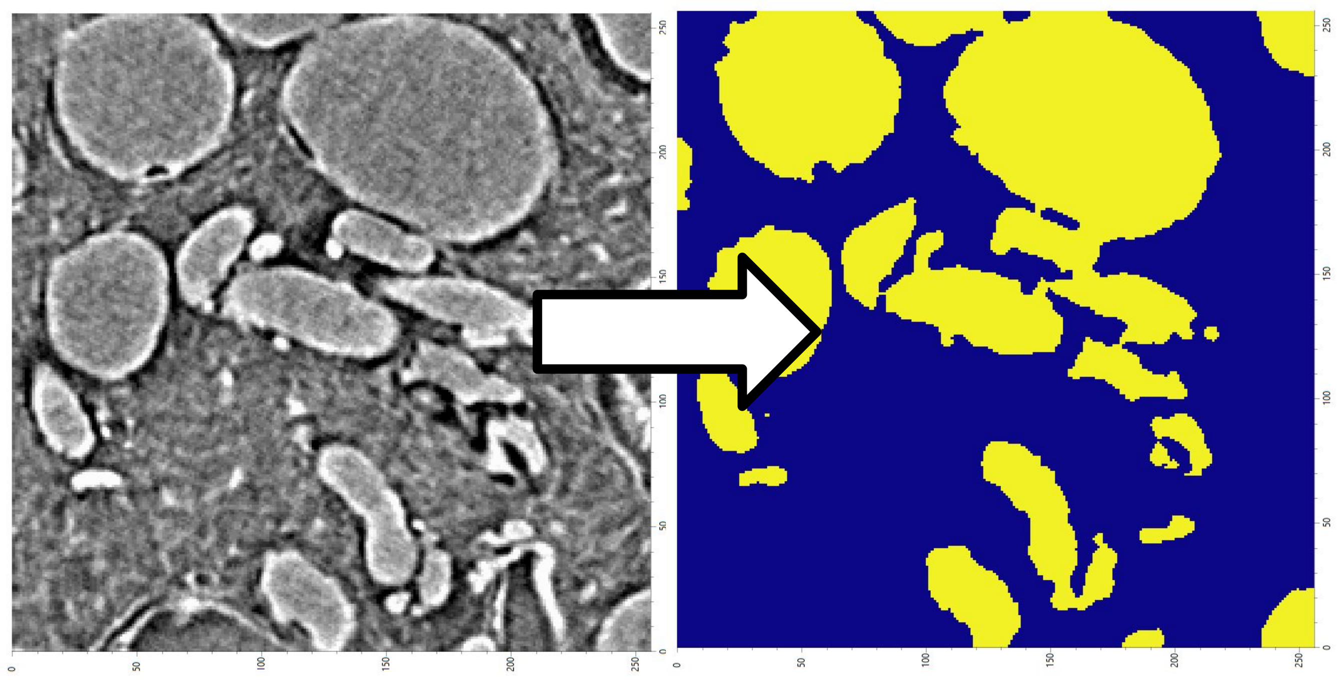
Introduction

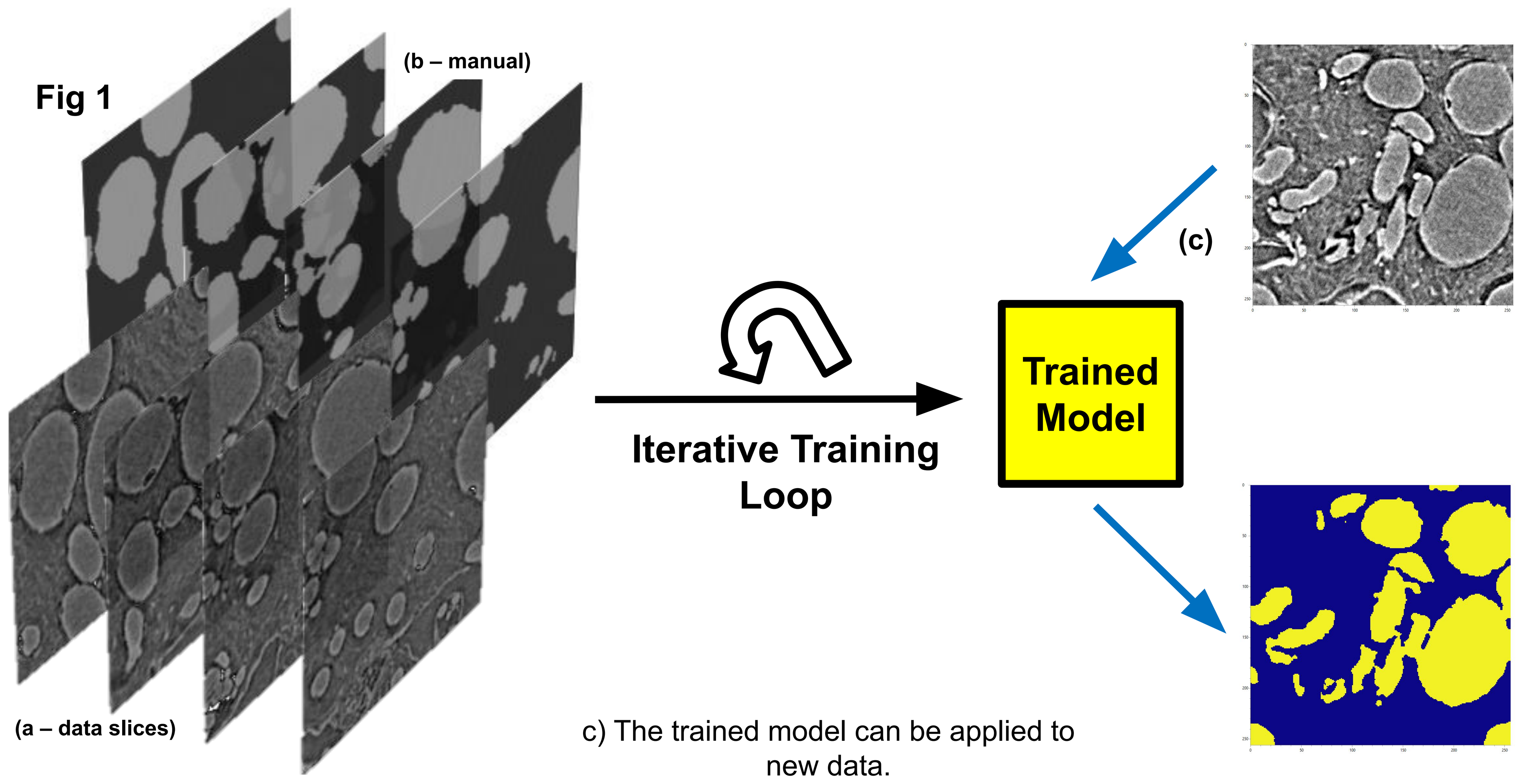
- The aim of semantic segmentation is to **assign a label to each pixel in an image** from a set of possible categories.
- Manual processing of a single dataset can take **several hours of work** by a subject expert, hence there is a requirement for computer-assisted methods.
- Machine-learning (ML) can be used to accelerate the segmentation workflow by utilising supervised learning to **train a Convolutional Neural Network (CNN) to replicate human labelling**.
- The model is trained on samples of hand-created ground truth data. It can then be applied to new, previously unseen, examples **(Fig 1c)**.



Methods – 2D Segmentation

- A human manually labels a subset of the reconstructed CT data.
- Convert the volume into individual slices **(Fig 1a, 1b)**, this becomes the 2d training dataset.
- The dataset is used to train a U-Net model [5,4]. During training, the model learns a mapping from input image to mask.

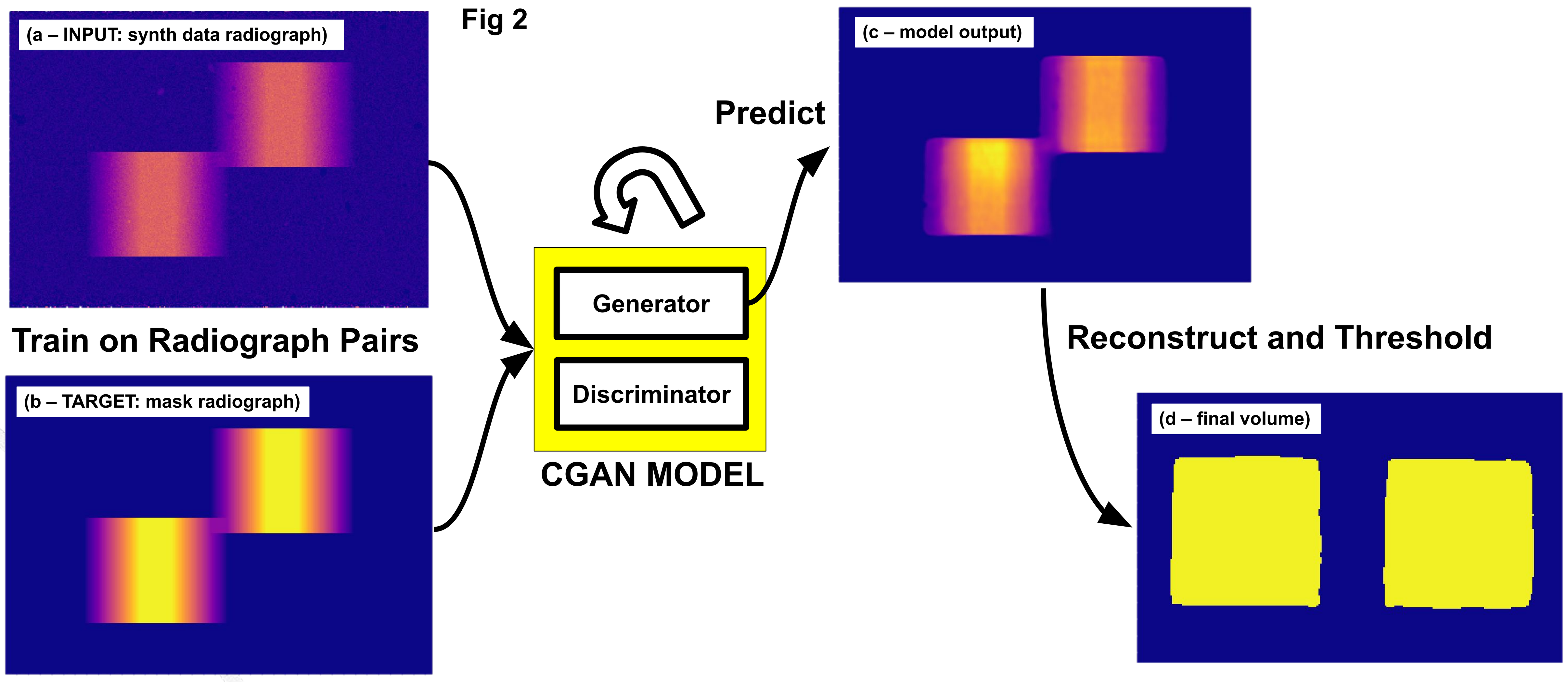
Fig 1



Methods – 2.5D Segmentation

- Process radiographs instead of on the reconstructed data.
- Posed as an Image-to-image translation problem (map data radiograph to label radiograph)
- Uses a conditional generative adversarial network (CGAN), based on 'pix2pix' [8].
- These networks learn:
  1. A mapping from input image to output image.
  2. An 'adversarial' loss, which is combined with a traditional loss function during training.
- Tomopy [7] is used to generate simulated radiograph stacks, with individual (data radiograph, label radiograph) pairs taken as samples for the supervised training.
- Model outputs radiographs, which are stacked and reconstructed using the Gridrec algorithm.
- A threshold is applied to the reconstructed label volume, optimal upper and lower bounds are found using a parameter search on the training dataset.

Fig 2

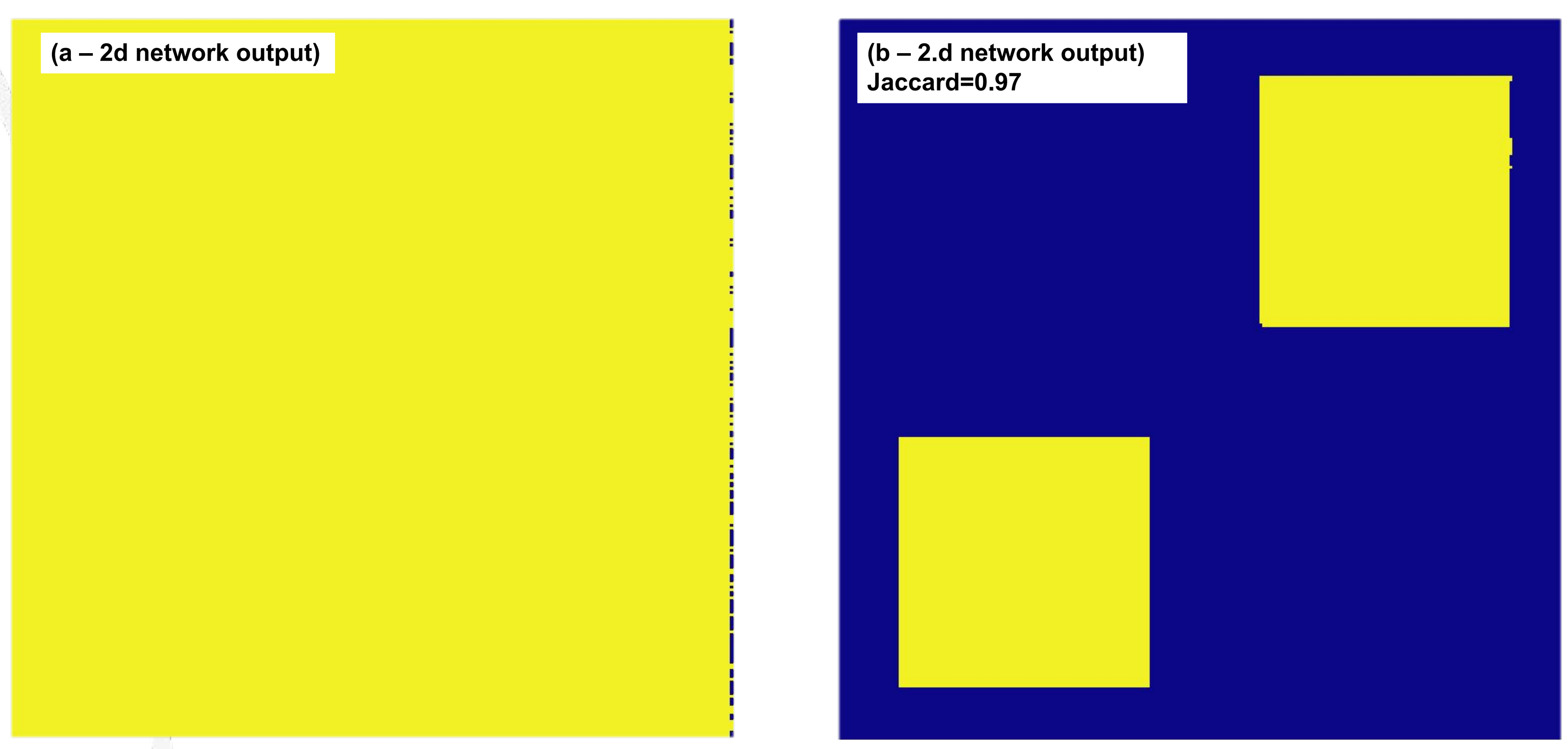


Results and Discussion

- Initial suggestions that working on radiographs using the GAN can result in better invariance to previously unseen noise.
- In this extremely simple example of separating cubes from background **(Fig 2,3)**, both models perform well when inferring on data like that in the training dataset.
- When previously unseen noise is introduced at test time, the 2d model operating on the volume slices fails to generate useful predictions **(Fig 3a)**, whereas the 2.5D network can continue performing well despite the noise **(Fig 3b)**.

- In all tests, training was limited to 30 epochs (or until early-stopping measured on validation loss, with a time limit of 10 epochs). Training used the Adam optimizer [6] with normal network initialisation . A cosine annealing learning rate scheduler with warm restarts [3] on every epoch was used for all networks.
- Training dataset was split into train/validation subsets 80%/20%, with separate test examples generated.
- All networks implemented in python using PyTorch with PyTorch Lightning and MLflow for model lifecycle management and tracking.

Fig 3



Acknowledgements and Citations

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