

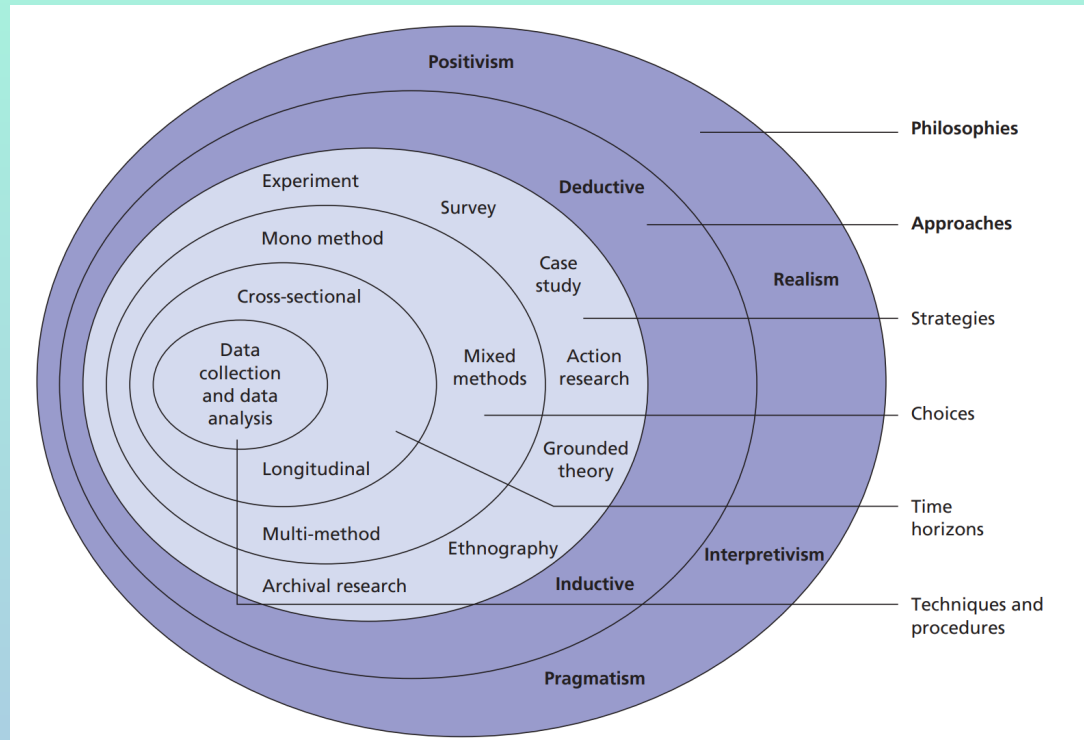


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# Dr Seena Joseph

# Research Design

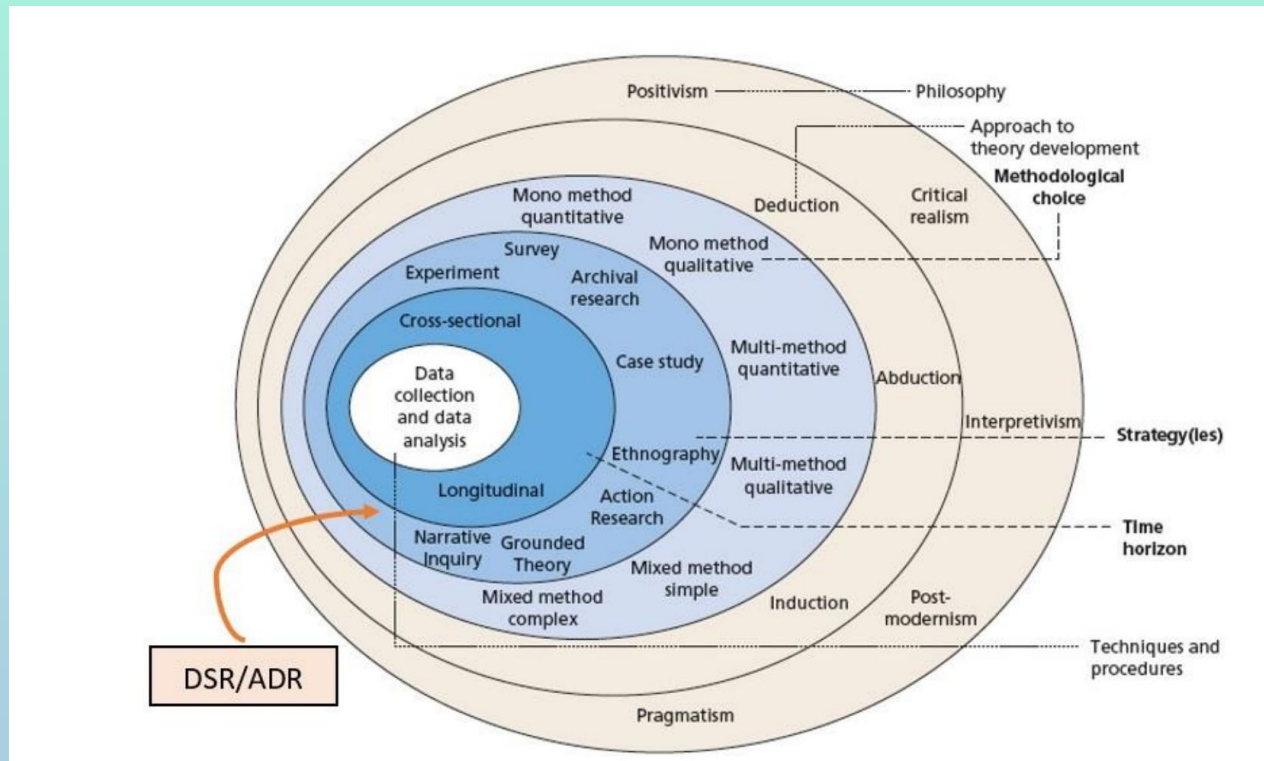
## Research Onion



(Saunders et al., [1] )

# Research Design

- Modified Research Onion



(Mardiana [2] )

DSR(Design Science Research); ADR (Action Design Research)

# Design Science Research

Design science research is an important research framework of several technical discipline such as computer sciences and engineering.

Design science research is characterized by the design and development of more effective and efficient solutions to the previously solved problems [3].

Thus design science research is considered as a fusion of practice, research and design and is comparable to the exploration of knowledge through focused design [4].

The approach of design science research commences with the conceptualization of a problem and concludes with the evaluation of the effects of the artifacts developed to ameliorate the identified problem [5].

# Design Science Research

This, design science research is focused on the successful creation and evaluation of artifacts [6].

These artifacts may comprise of constructs, algorithms, models, tools, methods, technical or social informational resources and instantiations [6], [7].

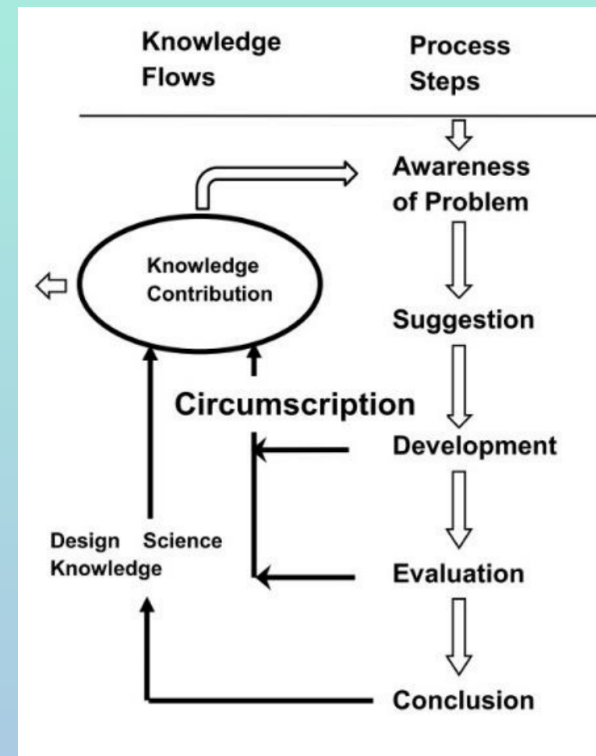
Hence the artifacts can be broadly defined as any designed object with an embedded solution to an identified research problem [8].

# Design Science Research

The final objective of design science research is to provide an effective and efficient artifacts embedded with the solution to the research problem.

## Design Science Research Cycle

- Identification of problem
- Objective definition
- Artifact design and development
- Evaluation
- Communicating the results



Source: Mardiana, [2]

# Design Science Research

The research process is structured in a sequential order of these design components.

Six-phase framework for the design and development of design science research artifacts (Figure 1).

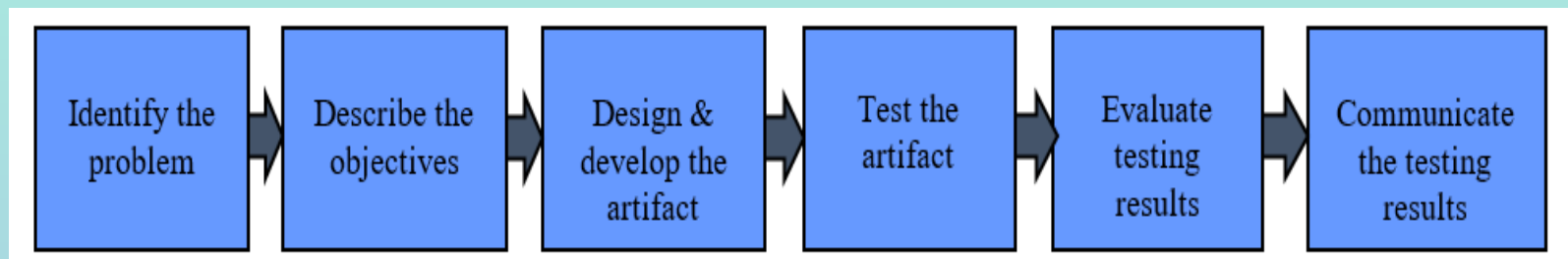


Figure 1 : Design and development framework (Ellis and Levy , [5])

# Design Science Research

## DSR Process

**Identification of the problem** is the crucial starting stage in the design science research as this phase assists to provide a solution by developing an effective artifact [5, 8, 9].

A problem is the difference between the current state and the goal state or a research/literature gap. This difference/gap can be mitigated or eliminated with an effective artifact [9].

# Design Science Research

## DSR Process - Identification of the problem

- **Example of a problem ( Problem 1)**
  - *Due to the heterogeneous properties of images, an effective and efficient segmentation method for a diverse class of image is still an open problem. Myriads of classical image segmentation algorithms have been developed over the years yet generalization and universal optimum performance are far away from ideal levels (Xu and Wunsch 2005; Pereira et al. 2020; Nikbakhsh, Baleghi and Agahi 2021). Further, the clustering based image segmentation algorithms are largely hooked on the initial cluster count because an incorrect selection of initial cluster counts results in an incongruous segmentation output. Identification of an optimum cluster count is a common issue in clustering based image segmentation. Hence this study aims to develop a general clustering based segmentation algorithm that can address the aforementioned problem of clustering based segmentation algorithms to some extent.*

# Design Science Research

## DSR Process - Identification of the problem

- **Example of a problem statement ( Problem 2)**
  - *Medical image classification is a critical task in healthcare, aiding in the early diagnosis of diseases such as cancer, pneumonia, and diabetic retinopathy. However, traditional deep learning models require large labeled datasets, which are often difficult to obtain in the medical domain due to data scarcity and privacy concerns (Citation...). Transfer learning, which leverages pre-trained models on large-scale datasets, has shown promise in improving classification performance with limited data (Citation...). However, existing studies (Citation....) often fail to explore domain-specific fine-tuning techniques for optimizing performance. Therefore, there is a need to design a transfer learning-based medical image classification model that effectively adapts pre-trained deep learning models to specific medical imaging tasks, improving classification accuracy while minimizing data annotation efforts.*

# Design Science Research

## DSR Process - Identification of the problem

- **Example of a problem statement ( Problem 3)**
  - *Cybersecurity datasets are often high-dimensional, containing redundant and irrelevant features that can negatively impact the performance of threat detection models. Traditional rule-based detection systems struggle with efficiently processing large amounts of security data, leading to high false positive rates and slow response times (Citation...). Machine Learning (ML)-based feature extraction techniques, such as Principal Component Analysis (PCA) and Recursive Feature Elimination (RFE), can help improve detection accuracy by selecting the most relevant features (Citation...). . However, an optimized feature extraction framework is needed to enhance cyber threat detection while reducing computational overhead.*

# Design Science Research

## DSR Process - Identification of the problem

- Example of a problem statement ( Problem 4)
  - *In e-commerce, understanding customer behavior is crucial for delivering personalized recommendations and targeted marketing campaigns. Traditional segmentation methods, such as demographic-based grouping, often fail to capture diverse shopping behaviors, leading to ineffective marketing strategies (Citation...). Clustering techniques allow businesses to segment customers based on purchasing patterns, browsing history, and engagement metrics (Citation...). However, selecting the most relevant features and deploying a scalable system for real-time segmentation remains a challenge. Therefore, this study aims to develop an ML-based customer segmentation model for e-commerce using optimized feature selection and deploy it as a web API for real-time personalized marketing.*

# Design Science Research

## DSR Process

### Define the objectives

This phase is closely link to the previous phase as the objectives are clearly related to the problem and must be inferred directly from the specified problem [8].

Knowledge about the current state of the problem and the existing solution is of paramount important to derive the objectives.

# Design Science Research

## DSR Process - Define the objectives

### Example of objective based on problem statement 1

- To perform a systematic literature review on existing clustering and saliency-based image segmentation algorithms to understand the current trends in image segmentation based on clustering and saliency.
- To identify a set of salient image features that work well on a diverse class of images.
- To construct and validate a novel clustering-based image segmentation algorithm that automatically identifies the optimum cluster count and exploits the identified salient features to achieve an effective and efficient image segmentation process.

# Design Science Research

## DSR Process - Define the objectives

### Example of objective based on problem statement 2

- To select and fine-tune a pre-trained deep learning model (e.g., ResNet, VGG, or EfficientNet) for medical image classification.
- To develop a transfer learning framework incorporating domain-specific feature adaptation techniques to improve image classification performance.
- To evaluate the model's effectiveness using benchmark medical image datasets and assess performance using well known evaluation metrics.
- To deploy the trained model as a web-based application to enable real-time medical image classification and accessibility for end-users.

# Design Science Research

## DSR Process - Define the objectives

### Example of objective based on problem statement 3

- To apply machine learning-based feature extraction techniques to reduce the dimensionality of cybersecurity data.
- To evaluate the impact of feature extraction on the performance of different ML classifiers in cyber threat detection.
- To improve the efficiency and accuracy of cyber threat detection models by selecting the most relevant features.
- To develop and deploy a lightweight ML-based cybersecurity detection system as a real-time web API for threat identification.

# Design Science Research

## DSR Process - Define the objectives

### Example of objective based on problem statement 4

- To preprocess and analyse e-commerce customer data, including purchase history, browsing behaviour, and engagement metrics.
- To apply machine learning clustering techniques for customer segmentation.
- To evaluate and validate segmentation results using well known metrics
- To develop and deploy a real-time customer segmentation system as a web API for personalized product recommendations and targeted marketing campaigns.

# Design Science Research

## DSR Process

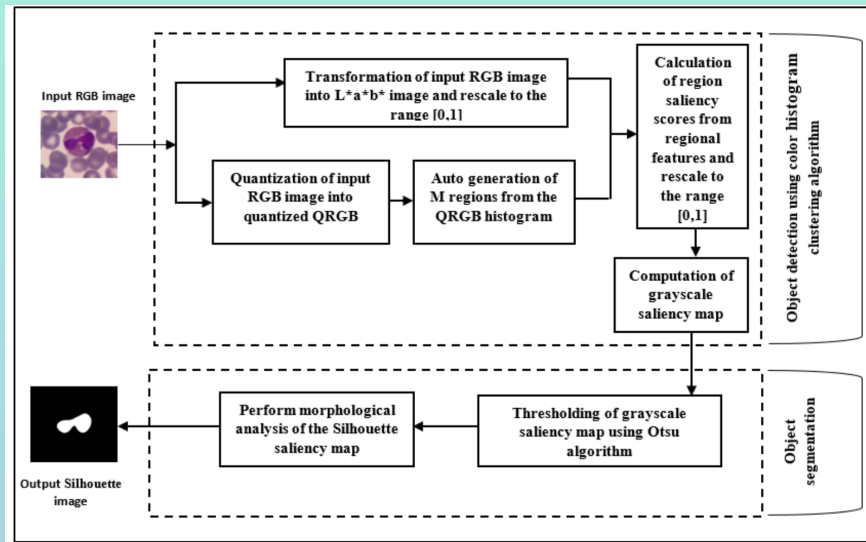
### Design and develop the artifact

- This phase includes the creation of an artifact and it comprises of the determination of the preferred functionality of the artifact, designing the architecture and the actual development of artifacts [8].
- The theoretical knowledge to bear the effective solution for the identified problem is the essential resource for the movement from objectives to design and development.

# Design Science Research

## DSR Process - Design and develop the artifact

### Example of an artifact for Problem statement 1



Flowchart of the proposed algorithm

#### Algorithm 1 Color Histogram Clustering

Input:  $M \times N \times 3$  RGB color image (Input), distance scaling parameter ( $n$ ) such that  $0.1 \leq n \leq 1.0$   
Output:  $M \times N$  Silhouette image (Output), number of clusters automatically detected ( $K$ )

% Constant parameters

NIC=3; % number of image components

IQL=8; % image quantization level

NCD=IQL^3; % maximum number of desired colors

LCL=1; % lab color light

LCA=2; % lab color A

LCB=3; % lab color B

PXC=4; % pixel x-coordinate

PYC=5; % pixel y-coordinate

PDC=6; % pixel distance to image center

CPC=7; % cluster pixel count

CPL=8; % cluster pixel label

CCC=8; % cluster color contrast

CSS=9; % cluster saliency score

```
1. K=0;
2. Index=ImageQuantization(Input, IQL);
3. Input=rgb2lab(Input);
4. Input=rescaleImage(Input, [0,1]);
5. for x = 1 to M do
6.   for y = 1 to N do
7.     Palette(index(x, y), CPC)=Palette(index(x, y),CPC)+1;
8.     Palette(index(x, y), LCL)=Palette(index(x, y), LCL)+Input(x, y), LCL);
9.     Palette(index(x, y), LCA)=Palette(index(x, y), LCA)+Input(x, y), LCA);
10.    Palette(index(x, y), LCB)=Palette(index(x, y), LCB)+Input(x, y), LCB);
```

Part of the proposed algorithm

# Design Science Research

## DSR Process

- **Test the artifact**
- This phase involves the experimentation, simulation or any similar activity used to demonstrate the ability of the artifacts to meet the functionalities and requirements established during the design and development phase [5,8]
- It is important to ensure the applicability of the developed artifacts in the proposed context and demonstration of the reasonable solution in addressing the problem.

# Design Science Research

## DSR Process - Test the artifact

- Testing the proposed algorithm in terms of evaluation metrics such as Accuracy, Precision, Recall, F Measure, MAE etc.
- Example of test results for Problem statement 1

| Boundary Image                                                                                                                                                                                                                                                             | <u>Center Images</u> | Complex background | Overlap images |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|--------------------|----------------|--------------|--------------|-------|------------|--------------|-------|--------------|--------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-----------|------------|--------------|---------|-------|------------|--------------|-------|-------|-------|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-----------|------------|--------------|---------|-------|------------|--------------|-------|--------------|--------------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------------|-------------|--------------|-------------|-------|-------------|-------|------|-------|-----|-------|
| <table><tr><th>Metric</th><th>CHC</th></tr><tr><td>Precision↑</td><td><b>0.945</b></td></tr><tr><td>Recall↑</td><td>0.891</td></tr><tr><td>F-measure↑</td><td><b>0.932</b></td></tr><tr><td>MAE↓</td><td>0.062</td></tr><tr><td>OR↑</td><td><b>0.844</b></td></tr></table> | Metric               | CHC                | Precision↑     | <b>0.945</b> | Recall↑      | 0.891 | F-measure↑ | <b>0.932</b> | MAE↓  | 0.062        | OR↑          | <b>0.844</b> | <table><tr><th>Metric</th><th>CHC</th></tr><tr><td>Precision↑</td><td><b>0.949</b></td></tr><tr><td>Recall↑</td><td>0.889</td></tr><tr><td>F-measure↑</td><td><b>0.934</b></td></tr><tr><td>MAE↓</td><td>0.067</td></tr><tr><td>OR↑</td><td><b>0.846</b></td></tr></table> | Metric | CHC       | Precision↑ | <b>0.949</b> | Recall↑ | 0.889 | F-measure↑ | <b>0.934</b> | MAE↓  | 0.067 | OR↑   | <b>0.846</b> | <table><tr><th>Metric</th><th>CHC</th></tr><tr><td>Precision↑</td><td><b>0.933</b></td></tr><tr><td>Recall↑</td><td>0.753</td></tr><tr><td>F-measure↑</td><td><b>0.885</b></td></tr><tr><td>MAE ↓</td><td><b>0.120</b></td></tr><tr><td>OR↑</td><td>0.710</td></tr></table> | Metric | CHC       | Precision↑ | <b>0.933</b> | Recall↑ | 0.753 | F-measure↑ | <b>0.885</b> | MAE ↓ | <b>0.120</b> | OR↑          | 0.710        | <table><tr><th>Metric</th><th>CHC</th></tr><tr><td>Precision↑</td><td><b>0.986</b></td></tr><tr><td>Recall↑</td><td>0.767</td></tr><tr><td>F-measure↑</td><td>0.925</td></tr><tr><td>MAE↓</td><td>0.134</td></tr><tr><td>OR↑</td><td>0.757</td></tr></table> | Metric   | CHC         | Precision↑  | <b>0.986</b> | Recall↑     | 0.767 | F-measure↑  | 0.925 | MAE↓ | 0.134 | OR↑ | 0.757 |
| Metric                                                                                                                                                                                                                                                                     | CHC                  |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Precision↑                                                                                                                                                                                                                                                                 | <b>0.945</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Recall↑                                                                                                                                                                                                                                                                    | 0.891                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| F-measure↑                                                                                                                                                                                                                                                                 | <b>0.932</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| MAE↓                                                                                                                                                                                                                                                                       | 0.062                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| OR↑                                                                                                                                                                                                                                                                        | <b>0.844</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Metric                                                                                                                                                                                                                                                                     | CHC                  |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Precision↑                                                                                                                                                                                                                                                                 | <b>0.949</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Recall↑                                                                                                                                                                                                                                                                    | 0.889                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| F-measure↑                                                                                                                                                                                                                                                                 | <b>0.934</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| MAE↓                                                                                                                                                                                                                                                                       | 0.067                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| OR↑                                                                                                                                                                                                                                                                        | <b>0.846</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Metric                                                                                                                                                                                                                                                                     | CHC                  |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Precision↑                                                                                                                                                                                                                                                                 | <b>0.933</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Recall↑                                                                                                                                                                                                                                                                    | 0.753                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| F-measure↑                                                                                                                                                                                                                                                                 | <b>0.885</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| MAE ↓                                                                                                                                                                                                                                                                      | <b>0.120</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| OR↑                                                                                                                                                                                                                                                                        | 0.710                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Metric                                                                                                                                                                                                                                                                     | CHC                  |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Precision↑                                                                                                                                                                                                                                                                 | <b>0.986</b>         |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Recall↑                                                                                                                                                                                                                                                                    | 0.767                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| F-measure↑                                                                                                                                                                                                                                                                 | 0.925                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| MAE↓                                                                                                                                                                                                                                                                       | 0.134                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| OR↑                                                                                                                                                                                                                                                                        | 0.757                |                    |                |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| ECCSD Data set                                                                                                                                                                                                                                                             | HKU-IS Dataset       | SOC dataset        | Ham Dataset    |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| <table><tr><th>Method</th><th>Precision</th><th>Recall</th><th>F-measure</th><th>MAE</th><th>OR</th></tr><tr><td>CHC</td><td><b>0.853</b></td><td>0.635</td><td><b>0.790</b></td><td><b>0.163</b></td><td><b>0.573</b></td></tr></table>                                   | Method               | Precision          | Recall         | F-measure    | MAE          | OR    | CHC        | <b>0.853</b> | 0.635 | <b>0.790</b> | <b>0.163</b> | <b>0.573</b> | <table><tr><th>Method</th><th>Precision</th><th>Recall</th><th>F-Measure</th><th>MAE</th><th>OR</th></tr><tr><td>CHC</td><td><b>0.813</b></td><td>0.673</td><td>0.776</td><td>0.144</td><td></td></tr></table>                                                             | Method | Precision | Recall     | F-Measure    | MAE     | OR    | CHC        | <b>0.813</b> | 0.673 | 0.776 | 0.144 |              | <table><tr><th>Method</th><th>Precision</th><th>Recall</th><th>F-Measure</th><th>MAE</th><th>OR</th></tr><tr><td>CHC</td><td><b>0.650</b></td><td>0.531</td><td><b>0.618</b></td><td><b>0.202</b></td><td><b>0.389</b></td></tr></table>                                    | Method | Precision | Recall     | F-Measure    | MAE     | OR    | CHC        | <b>0.650</b> | 0.531 | <b>0.618</b> | <b>0.202</b> | <b>0.389</b> | <table><tr><th>Accuracy</th><th>Sensitivity</th><th>Specificity</th><th>Dice</th></tr><tr><td><b>0.91</b></td><td>0.77</td><td><b>0.99</b></td><td>0.82</td></tr></table>                                                                                    | Accuracy | Sensitivity | Specificity | Dice         | <b>0.91</b> | 0.77  | <b>0.99</b> | 0.82  |      |       |     |       |
| Method                                                                                                                                                                                                                                                                     | Precision            | Recall             | F-measure      | MAE          | OR           |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| CHC                                                                                                                                                                                                                                                                        | <b>0.853</b>         | 0.635              | <b>0.790</b>   | <b>0.163</b> | <b>0.573</b> |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Method                                                                                                                                                                                                                                                                     | Precision            | Recall             | F-Measure      | MAE          | OR           |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| CHC                                                                                                                                                                                                                                                                        | <b>0.813</b>         | 0.673              | 0.776          | 0.144        |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Method                                                                                                                                                                                                                                                                     | Precision            | Recall             | F-Measure      | MAE          | OR           |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| CHC                                                                                                                                                                                                                                                                        | <b>0.650</b>         | 0.531              | <b>0.618</b>   | <b>0.202</b> | <b>0.389</b> |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| Accuracy                                                                                                                                                                                                                                                                   | Sensitivity          | Specificity        | Dice           |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |
| <b>0.91</b>                                                                                                                                                                                                                                                                | 0.77                 | <b>0.99</b>        | 0.82           |              |              |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                                            |        |           |            |              |         |       |            |              |       |       |       |              |                                                                                                                                                                                                                                                                             |        |           |            |              |         |       |            |              |       |              |              |              |                                                                                                                                                                                                                                                              |          |             |             |              |             |       |             |       |      |       |     |       |

# Design Science Research

## DSR Process

### Evaluate testing results

- Observation and the measurement of the performance of the artifacts in supporting the solution to the problem is addressed in this phase.
- During this evaluation phase, the validity of the developed artifact is assessed based on the nature of the problem.
- This phase includes the qualitative and quantitative comparison of the obtained results to the predicted solution.
- Knowledge of significant evaluation metrics and analysis techniques are the required resource to accomplish the evaluation phase.

# Design Science Research

## DSR Process – Evaluate Testing results

- Example of Evaluation for **Problem statement 1**
- Quantitative comparison

| Datasets | HKU-IS       |              |              |              |              | SOC          |              |              |              |              |
|----------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Metrics  | Precision    | Recall       | F-Measure    | MAE          | OR           | Precision    | Recall       | F-Measure    | MAE          | OR           |
| DCLC     | 0.724        | 0.653        | 0.707        | 0.160        | 0.517        | 0.558        | 0.499        | 0.543        | 0.215        | 0.236        |
| DGL      | 0.725        | 0.672        | 0.712        | 0.189        | 0.528        | 0.568        | 0.505        | 0.552        | 0.263        | 0.244        |
| DRFI     | 0.753        | <b>0.755</b> | 0.754        | 0.144        | 0.577        | 0.560        | <b>0.563</b> | 0.561        | 0.219        | 0.356        |
| MSNSD-A  | -            | -            | <b>0.837</b> | <b>0.071</b> | -            | -            | -            | -            | -            | -            |
| MSNSD    | -            | -            | <b>0.837</b> | <b>0.071</b> | -            | -            | -            | -            | -            | -            |
| MCDL     | -            | -            | 0.743        | 0.093        | -            | -            | -            | -            | -            | -            |
| CHC      | <b>0.813</b> | 0.673        | 0.776        | 0.144        | <b>0.578</b> | <b>0.650</b> | 0.531        | <b>0.618</b> | <b>0.202</b> | <b>0.389</b> |

Proposed model

| Method                                            | Accuracy    | Sensitivity | Specificity | Dice        |
|---------------------------------------------------|-------------|-------------|-------------|-------------|
| SSLS (Ahn <i>et al.</i> 2015) <sup>a</sup>        | 0.85        | 0.75        | <b>0.98</b> | 0.78        |
| ASLM (Pennisi <i>et al.</i> 2016) <sup>a</sup>    | 0.90        | 0.80        | 0.97        | 0.83        |
| (Youssef <i>et al.</i> 2018) <sup>b</sup>         | 0.89        | <b>0.92</b> | 0.87        | 0.87        |
| (Rajput, Tanwar and Raman 2021) <sup>a</sup>      | 0.86        | 0.83        | 0.92        | 0.88        |
| (Patiño, Avendaño and Branch 2018) <sup>a</sup>   | 0.90        | 0.91        | 0.89        | 0.89        |
| SDI+ (Guarracino and Maddalena 2019) <sup>a</sup> | 0.91        | <b>0.92</b> | 0.90        | 0.85        |
| (Salih and Viriri 2020) <sup>a</sup>              | 0.92        | 0.84        | 0.96        | <b>0.90</b> |
| SPCA (Bi <i>et al.</i> 2016) <sup>b</sup>         | 0.87        | 0.73        | 0.95        | 0.80        |
| YOLO (Ünver and Ayan 2019) <sup>b</sup>           | <b>0.93</b> | 0.84        | 0.94        | 0.88        |
| CHC <sup>a</sup>                                  | 0.92        | 0.85        | <b>0.98</b> | 0.89        |

Proposed model

<sup>a</sup> unsupervised method; <sup>b</sup> supervised method.

# Design Science Research

## DSR Process – Evaluate Testing results

### Evaluate testing results (Problem statement 1)

- Example of Evaluation for Problem statement 1
- Quantitative comparison

Proposed model →

|       | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-------|---|---|---|---|---|---|---|---|---|----|
| Image |   |   |   |   |   |   |   |   |   |    |
| GT    |   |   |   |   |   |   |   |   |   |    |
| CHC   |   |   |   |   |   |   |   |   |   |    |
| SFCA  |   |   |   |   |   |   |   |   |   |    |
| SDI+  |   |   |   |   |   |   |   |   |   |    |

→

| (a) ECSSD |   |   |   |   |   |   |   |   |   |    |
|-----------|---|---|---|---|---|---|---|---|---|----|
|           | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Image     |   |   |   |   |   |   |   |   |   |    |
| GT        |   |   |   |   |   |   |   |   |   |    |
| CHC       |   |   |   |   |   |   |   |   |   |    |
| AC        |   |   |   |   |   |   |   |   |   |    |
| RRFG      |   |   |   |   |   |   |   |   |   |    |
| CA        |   |   |   |   |   |   |   |   |   |    |
| CNS       |   |   |   |   |   |   |   |   |   |    |

| Dataset | Image | GT | CHC | CNS | DCLC | DGL | DRFI | DSR | GR |
|---------|-------|----|-----|-----|------|-----|------|-----|----|
| SOC     | 1     |    |     |     |      |     |      |     |    |
|         | 2     |    |     |     |      |     |      |     |    |
|         | 3     |    |     |     |      |     |      |     |    |
|         | 4     |    |     |     |      |     |      |     |    |

# Design Science Research

## DSR Process

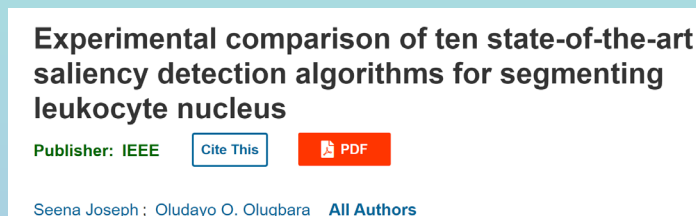
### Communicate the testing results

- This phase entails the contribution to the body of knowledge by providing a complete communication of results and the conclusion of the study.
- The research problem, artifacts, the utility and novelty of artifacts, effectiveness of the artifacts are reported and communicated in this phase using scholarly research publications.
- The research problem, the designed artifacts and the results are published in a scholarly journal.

# Design Science Research

## DSR Process – Communicate the testing results

### Example – Publications (Problem statement 1)



# Reference

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