# Advisory Framework to Interconnect Distributed Water Bodies Targeting Agriculture Farms


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***Abstract* — There has been several instances of uneven distribution of water resources in villages, towns and cities of developing countries of South-east Asia, such as India, Indonesia, etc. Interconnection of distributed water bodies such that excess water from one water source to other deficit source of a stressed agriculture farm is always a challenge. Planning and implementation of efficient laying in already connected pipeline laid mechanisms are costly and time consuming. In this regard, this paper proposes a novel advisory framework named as Zobhana Jala Sambaddha (ZJS) to address the above problems and provide an automated solution as compared to manual pipe laying mechanisms. The proposed advisory Framework ZJS arrives at a solution space that connects multiple source and destination points. This multipath solution between any source and destination points are derived considering different parameters of interest such as: low-cost, less distance, low pumping power, geographical constraints etc. An image processing based data abstraction with multi constrained optimization framework provides an advisory solution. It is observed from different test case runs carried out in Sri City, that the proposed framework is more generic and automated; eliminates the need for time consuming surveys for pipe-laying; and in fact, reduces pipe-laying infrastructure by upto 36%.**



***Keywords* — *adaptive pipe-laying, constrained optimization, IoT, satellite image***


## I. Introduction

Water is an extremely essential need for human beings. Unfortunately, it is also one of the most under prioritized and misused natural resources. An excessive use and rapid depletion of water resources is threatening the sustainability of livelihoods dependent on water and agriculture. According to [1], the extraction of water from ground in countries such as in India; exceeds the recharge by a factor of two or more. Thus, water levels are being pulled down by 1 to 3 meters per year. This increases the energy and other costs of pump irrigation. As per [2], it is expected that India and other highly populated countries such as in south east Asia could lose 25 percent or more of its total crop production under such a scenario. Notably, water scarcity is mostly due to the mismanagement of the resource [3]. Most of the water bodies are distributed. For efficient utilization, it is essential to have a flexible yet optimum water distribution that can be modified periodically based on the needs. A possible solution is to design a real time framework that uses topographical databases, sensors, actuators, connectivity, satellite image processing and standard IoT protocol for better utilization of distributed water bodies in agriculture. In this regard, there has been several efforts in the past to effectively connect the water bodies. To begin with, a grid/ matrix-based approach is considered wherein the path is calculated considering only the topographical features [4]. Similarly, in the technique followed by [5], the configuration phase is divided into multi-scale grids. Herein, once the start and goal locations are given, feasible paths are found using path planning method based on Genetic Algorithm. A digital terrain elevation map is used, over which the path planning result is shown. However, the disadvantage is that the linear features are not well represented and does not conform to variability of the terrain. Hence it might not find the optimal solution to the defined problem in all cases [6]. Another method proposed in [7] involves path planning based on image processing techniques, where the image is captured from a camera and converted into a gray-scale image. However, only a binary decision is done for obstacle detection. Further, the technique in [8] divides the global environment into several sub-regions. Also, each sub-region corresponds to a base point, thereby finding a path on the interlaced network in the map model. However, none of these techniques satisfy the requirements of real-time, generic, scalable yet adaptive pipe-laying suggestion model in a constrained environment.

This paper proposes a generic framework Zobhana Jala Sambaddha (ZJS), representing Smart Water Interconnection. This framework is proposed to provide a low cost, optimal, scalable algorithm using image processing mechanisms. The paper is organized as follows. Section II describes the system model/Architecture of the proposed ZJS. The simulation and experimental results obtained are shown in section III. Finally, section IV concludes the paper.

## II. System Model / Architecture

The ZJS framework and sub modules proposed in this paper is shown in Fig. 1. ZJS is modelled by integrating both image processing and route planning algorithms to make it more generic and function in all cases. ZJS takes satellite image as the input and processes it for identifying water bodies, obstacles, roads etc. in the given image. The different attributes from satellite image is extracted by partitioning the image into multiple cells or grids. A matrix is formulated assuming fixed cost functions depending on the nature of terrain. The colour code for different parts of the satellite image are assumed due to lack of attribute information. For example, water bodies are represented with blue colour and obstacles/rock terrain are represented with different colour. Multiple objects of interest for this application prevalent in individual cell in the image are extracted from the colour code depicting the terrain. ZJS connects the identified water bodies by avoiding identified obstacles, roads, etc. with an optimal low cost path. The detailed steps involved in building the ZJS technique are discussed below.

*A. Partition of the Satellite Image into Grids:*

As shown in Fig. 1 block a, the satellite imagery of target village is examined and a competent image is selected. The image is then divided into grids as depicted in Fig. 1, block b.

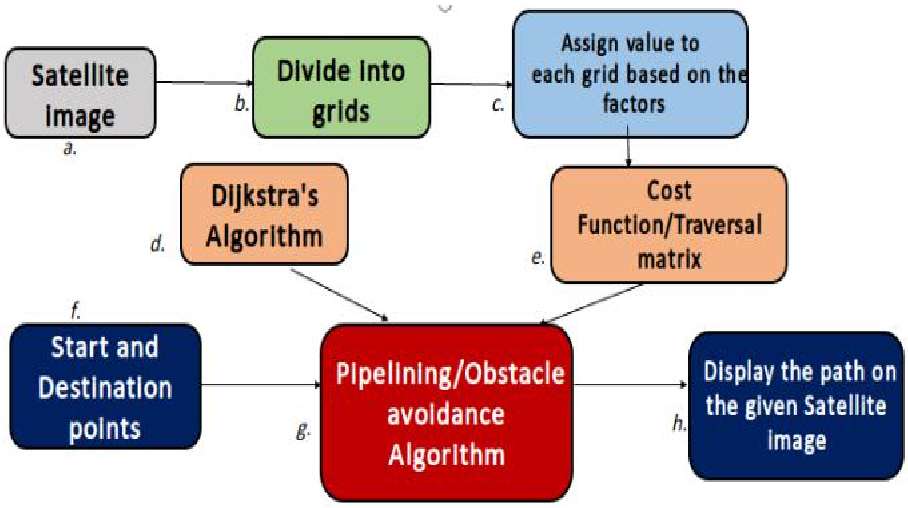


Fig. 1: Block Diagram of complete ZJS Technique

A smaller grid size is preferred such that even the smallest obstacle is detected, while ensuring that the computation cost does not increase significantly. Hence, a trade-off is essential between performance and computation cost. For an n x n size grid, the complexity of ZJS would be O(n2)

*B. Assigning Cost Value to each Grid:*

Each cell is allocated a cost value determined from the cost function; that is governed by multiple attributes of the terrain. This step is represented in Fig. 1, block c. The satellite image has a high resolution with a zoom level of 0.3. Typically, it includes buildings, houses, water bodies, roads and other obstacles. The objective is to choose areas that would result in low-cost pipe laying. Notably, a higher cost value is assigned to obstacles with increased expenditure. An important point to be noted is that even if two grids depict plain lands, the ZJS technique distinguishes them based on the terrain, identified by the colour. For instance, the brown colour depicts a rocky terrain, whereas green terrain represents a plain land for low cost pipeline. In the image, the higher the intensity of brown colour across the unit grid size, the higher is the value of the cost function; as shown in Fig. 1, block e. In the satellite input image, the colour gradients of RGB can be clearly observed that would distinguish between several categories of obstacles thereby allocating different ranges of cost values to the grids.

*C. Construction of Graph:*

Once the matrix of cells corresponding to the grids on the image is framed in ZJS, an input graph is generated. It is constructed in such a way that each cell is made into a node and its corresponding 8 adjacent cells in the matrix. An edge is added between two nodes, say node i and node j, wherein j is the neighbour of i; and the edge length equal to the total sum of cost values of node i and node j. This maintains constant edge length, irrespective of measuring from node i to j or vice-versa. To begin with, cell padding is done on all the four sides of the matrix with highest cost function value. This ensures a uniformity in the graph where a typical node of interest will have exactly 8 neighbours. An optimal route planning algorithm (In this case, Dijkstra's algorithm) is used to calculate the optimal route for pipe-laying; as shown in Fig. 1 block d. Further, this pipeline route is plotted on the given satellite image.

## III. III. SIMULATION AND EXPERIMENTAL RESULTS

As per the proposed ZJS framework, the images are partitioned into grids and cost is allocated to each grid. The satellite image varies from one location to another; due to diverse obstacles such as buildings, road paths, soils, etc. Having said that, the cost value is high for terrain with obstacles than that for obstacle-free region. It is observed from Fig. 2a that, based on color coding schemes under image processing, specifically RGB channelled image, the value of G in RGB channel is inversely proportional to the intensity of green area. Hence the average value of G within a grid is considered as the cost value, i.e., Topological Cost = G. In Fig. 2b, the blue coloured grids are the water bodies, indicating the source and destination points of the pipes to interconnect. The selected path is shown green in colour.


Fig. 2. Terrain along with result of ZJS Implementation

The pseudo-code of the ZJS is shown in Algorithm 1.

***Algorithm 1: Pseudo code of ZJS Algorithm***

**Input**: Start point, Destination point, Satellite image

**Output**: Resultant path from Source to destination

1. Read the Satellite image and divide it into grids.
2. **for** each grid in grids:

```
        for each point(x, y) in grid:
            totalRed+ = image[x][y][2]
            totalGreen+ = image[x][y][1]
            totalBlue+ = image[x][y][0]
        end for
        finalRed = totalRed/length(grid)
        finalGreen = totalGreen/length(grid)
        finalBlue = totalBlue/length(grid)
        rgbList.append(finalRed,finalGreen,finalBlue,grid)
end for
N = len(grids)
TraversalMatrix[NxN]=1000
    for R, G, B, grid in rgbList:
        R=255-R; G=255-G; B=255-B;
        if R+G+B <= 255; then TopologicalCost = 255
          else if X <= Y (see for X, Y, Z in cases below)
             Topological Cost = Z
          else TopologicalCost = B
        end if
        TraversalMatrix[grid] = TopologicalCost +
        AddCost
    end for
for i in range(N):
    for j in range(N):
        TM = TraversalMatrix
        Cost = TM[i][j] + TM[i +1][j]
            Add edges between each cell
            cells in the matrix with edge cost = Cost
        end for
end for
    path = FindPath(source, destination, cost)
    Display the path on the satellite image.
```

Further, the case-wise results of ZJS are discussed below.

*A. ZJS Implementation in a Village:*

To begin with, a rural area/village is considered for ZJS implementation. Fig. 3a provides a view of a rural area, comprising of a combination of fields, plain land, soil roads, buildings etc. The variables in ZJS: X, Y and Z make the threshold adaptive to the geographical nature of the image depicted through colour gradients. In this work, the values taken are: X = G, Y = 120, Z = 15 through visual interpretation of color gradients within the image. In Fig. 3a, the green fields/ plain land is treated as region of interest (RoI) for laying a pipeline whereas the area of buildings is considered as the obstacle region. Fig. 3b shows the results between two grids, assumed to be source and destination water bodies, with appropriate cost function allocated to each split of the grid, within the image obtained from satellite.

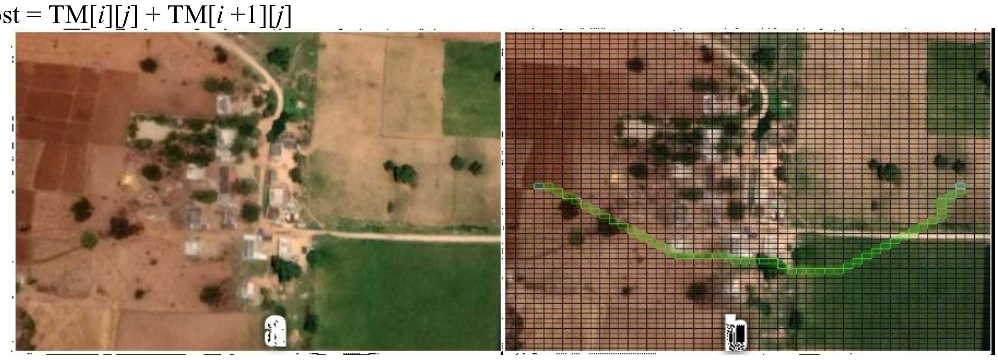


Fig. 3. (a). Village-level view, (b). Result of ZJS on (a)

*B. ZJS on Semi-Urban Areas:*

Fig. 4a shows a semi-urban area with a combination of densely populated buildings along with green patches and roads. The variables from ZJS Algorithm: X, Y, Z are set by manually observing the colour gradients within the image where X = B, Y = 90, Z = R. In Fig. 4b, the blue coloured grids are the water bodies. ZJS provides multiple paths in the same image given multiple sets of source and destination connecting multiple water bodies. The resultant paths are coloured in green.


Fig. 4: (a). Taluka-level view, (b). Result of ZJS on (a)

*C. Comparison - Existing Pipeline with ZJS:*

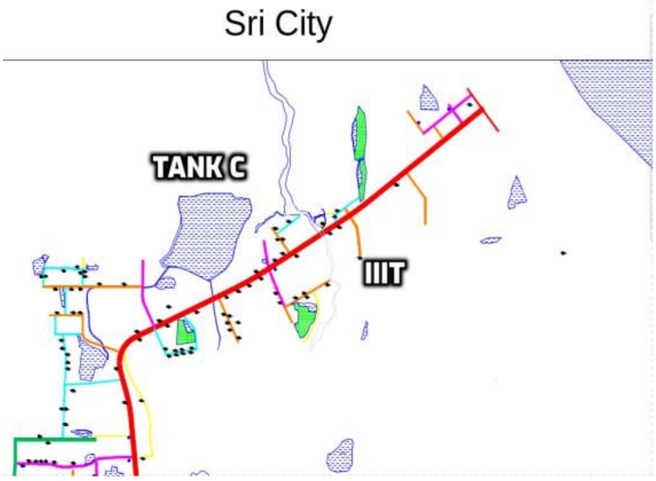


Fig. 5: Existing layout of Sri City water-pipeline

In this case, output of ZJS framework is compared with existing pipeline for a known location as a case study. The test was conducted in Sri City, a small yet planned city. Sri City is an integrated business city of 8,000 acres in the border of two south Indian states - Andhra Pradesh and Tamil Nadu [9]. To begin with, the satellite images obtained for Sri City were first cross-verified with the existing geographical layout along with manual pipe laying mechanism; the blueprints of which were gathered from Sri City foundation. Fig. 5 shows the existing pipeline infrastructure marked in red colour. Fig. 6 shows the real time data of water bodies, marked in blue colour. Further, the industrial, residential areas, etc. are marked as black dots.

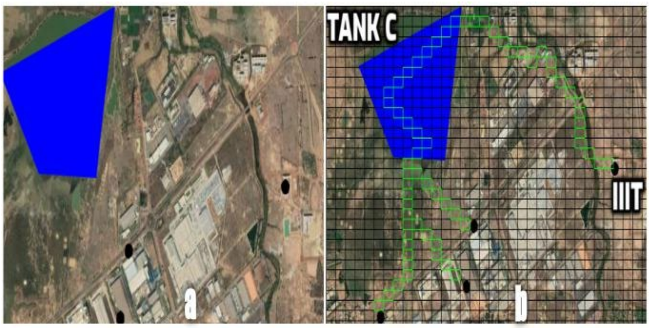


Fig. 6 a. Plots of real time data in: Sri City, India. b. Result of ZJS

ZJS results in a constrained yet optimized path by avoiding obstacles. It can be observed from Fig. 6b that this results in an output where the pipeline between Tank C and IIIT Sri City is significantly less than the existing path between them in Fig. 5. The saving in the pipe laying mechanism due to reduction in distance is 36%; as compared to the scenario if the pipe would have been laid in a straight path. Further, the route savings increment from unconstrained path to constrained path is 16.6%. These are significant reduction in the pipe laying distance; obtained by using ZJS framework.

## CONCLUSION

This paper proposes a smart advisory framework, ZJS (Zobhana Jala Sambaddha); for interconnecting different water sources (ponds, lakes, wells, etc.). ZJS provides an adaptive, scalable and a low-cost path for optimal pipe-laying mechanisms. The proposed framework takes satellite images of the target location and uses image processing to extract the details of water bodies. Further, a cost function-based value factor is added to each possible route defining clear paths and obstacles such as building, rocky terrain, etc. Particularly, the performance of the proposed advisory route laying mechanism is validated through a real-world deployment. The satellite images of Sri City, an upcoming integrated, business city is obtained. Further, it is corroborated with the current layout of the buildings, industries, etc. along with the existing manual pipe laying mechanism; and is confirmed with the blueprints gathered from Sri City Foundation. Given that Sri City is at nascent stage of development, results of our advisory framework showed significantly improvement in terms of distance reduction (upto 36%) and reduced infrastructure requirement for connecting different water bodies. This is a significant observation. This shows the importance of precise use of satellite-based image processing and intelligent connection mechanisms for efficient water distribution.

Notably, the use of ZJS is not just restricted to one rural area, but can be extended to any such areas in India or other developing/developed country. Having said that, there are several enhancements that could be generated from this work. In this regard, the next step would be to analyze ZJS's performance across different city/ district-level routes, taking into account several more layers of obstacles and constraints.

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