Advances in Intelligent Systems Research, volume 167

International Scientific and Practical Conference "Digitization of Agriculture - Development Strategy" (ISPC 2019)

Software package for optimum design of rice maps

Mihail Korobochkin
Department of Computer Science
State university of land use planning
Moskow, Russia
korobochkin2008@rambler.ru

Elena Dmitrieva
Department of Computer Science
State university of land use planning
Moskow, Russia
landlady2002@mail.ru

***Abstract*—In order to solve the problems of optimal division of rice irrigation map into checks, "RIS" software package was developed which implements dynamic programming methods and works on the basis of Windows operating system. The algorithm of design block operation is described based on a dynamic programming algorithm by R. Bellman and using the functional equation made by the authors. An example of "RIS" software package operation is given. The original task was the optimal (with minimum costs of earthworks) division of rice map with the size of 8x72 into checks. Design results are given below. This package provides a powerful tool for case analysis, reasonable selection of restrictions and obtaining optimal solutions. Operational tests of "RIS" software package showed its indispensability in setting restrictions on several design parameters simultaneously. Mathematical relief design methods implemented in "RIS" software package are useful for relief design of other irrigated lands too, for example, where drip irrigation systems are installed. "RIS" software package is an intelligent system that provides a powerful tool for case analysis, reasonable selection of restrictions and obtaining optimal solutions for the design of rice paddies and some other cultivated lands.**

Keywords*— *software system, the rice map, rice check, the method of dynamic programming, the optimization of earthworks.

I. Introduction

Rice growing in areas with sufficient freshwater sources is one of the most profitable spheres of agriculture. Rice irrigation systems include the so-called irrigated rice maps consisting of separate checks. A rice map is a part of a rice paddy (as a rule, an elongated rectangle), bounded on the long sides by irrigation and drainage channels. Checks made inside of the map look like horizontal platforms of different levels separated by bunds. Such map design is necessary because when planting rice, seeds should be poured with water so that they are covered with water layer of strictly specified thickness.

II. Literature review

For any possible variant of dividing the rice paddy into maps and rice map into checks, the overall cost of earthworks depends on the size of each map and the specific position of its borders on the plan and on the size of each check inside of the map and specific position of its borders on the plan [1].

In order to solve the problems of optimal division of rice map into checks, "RIS" software package was developed that works on the basis of Windows family operating systems [2, 3, 4, 5]. This package contains blocks for source data preparation, design, saving and return of results.

III. Research methodology

An algorithm based on dynamic programming method by R. Bellman [6, 7, 8, 9, 10] using functional equation that we constructed [11, 12, 13, 14] is implemented in design block:

$$F_t = \min_i \left(F_{i-1} + V(i,t)\right), \quad (1)$$

where for each value of t, i parameter varies within

$$t - \Delta_2 + 1 \le i \le t - \Delta_1 + 1. \quad (2)$$

Whereas, if $t - \Delta_2 + 1 \le 1$, then $i = 1$ (Δ_1, Δ_2 minimum and maximum allowable check width).

Here $V(i,t)$ – check estimation (i, t), F_{i-1} – the best estimation of map division containing the columns of marks from the first column to column i - 1, F_t - the best estimation of map division containing the columns of marks from the first column to column t.

In accordance with functional equation (1), the solution of the original problem is replaced by the solution of a certain sequence of essentially simpler problems.

This multi-step process is divided into two stages.

The first stage is going through the map from the start to the end when for each current column t $(t = \Delta_1, \Delta_1 + 1, \Delta_1 + 2, \ldots, n - \Delta_1, n)$ the conditional optimal division is selected and the conditional minimum of earthworks is calculated. (Conditional optimal division refers to the optimal division of map from the start to the current column t).

The second stage is going through the map from the end to the start when the optimal (no longer conditional) division borders of the map containing n columns are determined.

Let us show each stage in more details.

At the first stage, only sub-plots that satisfy the conditions for their size are considered.

For each dimensionally acceptable sub-plot, the required optimal design surface is constructed.

Design and working marks are determined and the estimation for this sub-plot is calculated. For simplicity, the volume of earthworks can be taken as an estimate:

$$V(i,t) = \sum_{j \in (i,t)} \beta_j \left| h_j \right|, \ (3)$$

where i и t are the numbers of the leftmost and rightmost columns of the sub-plot, respectively.

Minimum allowable size of a sub-plot for dividing is equal to the parameter Δ_1, therefore the leftmost column of the first considered sub-plot will be the 1st, and the rightmost column will be Δ_1 column. Value of $V(1, \Delta_1)$ is calculated. Since there is only one variant of division, the conditional optimal estimate of the column Δ_1, which we denote as $F_{\Delta 1}(1, \Delta_1)$ equals to $V(1, \Delta_1)$.

Sub-plots with border extreme columns are considered similarly: $(1, \Delta_1 + 1)$, $(1, \Delta_1 + 2)$,… and so on. The last participant in this analysis will be the sub-plot: $(1, \Delta_1 + \Delta_1 - 1)$. For these sub-plots, the following volumes are determined: $V(1, \Delta_1 + 1)$, $V(1, \Delta_1 + 2)$, … , $V(1, 2\Delta_1 - 1)$.

Thus, we obtain estimates of F_t, where

$t = \Delta_1, \Delta_1 + 1, \ldots, \Delta_1 + \Delta_1 - 1$.

For obtaining estimates for the following columns (with numbers greater than $2\Delta_1 - 1$), you should have regard to the best possible division variants – now they are more than one.

For this, the following functional equation should be solved:

$$F_t = \min_i \left\{ F_{i-1} + V(i,t) \right\}, \ (4)$$

where t is the number of the column to be estimated;

i is the number of the left column of the sub-plot $i - t$ ($t - \Delta_2 + 1 <= i <= t - \Delta_1 + 1$);

$V(i,t)$ is the estimate of the sub-plot between columns i и t.

F_{i-1} is the conditional optimal estimate of column $i - 1$;

F_t is the conditional optimal estimate of column t.

Thus, at each step, with a given right column t, $F_i = F_{i-1} + V(i,t)$ estimate is carried out for all valid division variants. Minimum F_i value determines the choice of conditional optimal division and the estimate of current column t, which is equal to F_t (4). As a result, for each column t ($t = \Delta_1, \ldots, n$) the conditional optimal estimate F_t and number i of the left column of sub-plot (i,t) which led to this optimal estimate, will be found.

So, the stage of conditional optimization of division ends, and the stage of unconditional optimization – construction of optimal division – starts.

Here, for already existing optimal estimate F_n of the rightmost column n of the strip, the number of left column $i = n_{k-1}$ of the last sub-plot leading to this optimal estimate is restored, and so on, until the number of the leftmost column is equal to one.

The resulting division $n_0 = 1$, $n_1, \ldots, n_{k-1}$, $n_k = n$ will be the optimal one.

"RIS" software package provides a powerful tool for case analysis, reasonable selection of restrictions and obtaining optimal solutions. Operational tests showed its indispensability in setting restrictions on several design parameters simultaneously [3, 15].

Mathematical methods for relief design implemented in **"RIS"** software package are useful for relief design of other irrigated lands too, for example, where drip irrigation systems are installed [16, 17, 18].

Let us give an example of **"RIS"** software package operation. The original task was the optimal (with minimum costs of earthworks) division of rice map with the size of 8x72 into checks. Input data are entered from the file of the following structure: size of the side of the project grid square, in meters ($a=20$); size of the rice map: number of lines, number of columns and weight of working marks ($m=8$, $n=72$, $\beta=200$); restrictions for the minimum and maximum width of checks ($\Delta_1=4$ и $\Delta_2=72$); restrictions on benches between adjacent checks and on the size of cutoffs and fills ($\Delta z=1$, $-\Delta_h=-1$, $\Delta_h=1$); the number of fixed (limited in height) points ($N=0$); then n lines of restrictions for fixed points (i, j, z_{ijmin}, z_{ijmax}). After design parameters, an array of initial marks H_j of the map is entered containing m lines and n columns. (If a non-rectangular map is inscribed in the $m \times n$ rectangle, then the marks of points that do not belong to the map are assumed to be zero and do not participate in the design process).

Initial data are prepared in a text file (Fig. 1). In this case, all restrictions except $\Delta_1=4$ are accepted as non-limiting.

```
20
8       72      200
4       72
1       -1      1
0
5.08    5.10    5.18    5.22    5.3     5.44    5.56    5.69    5.8     5.95    6.1     6.2     6.31
5.08    5.2     5.25    5.3     5.4     5.52    5.66    5.9     6.0     6.1     6.29    6.4     6.48
5.08    5.32    5.35    5.4     5.53    5.6     5.91    6.09    6.2     6.31    6.41    6.5     6.54
5.0     5.3     5.48    5.61    5.75    5.9     6.02    6.22    6.35    6.43    6.51    6.55    6.58
5.13    5.42    5.6     5.71    5.8     5.95    6.11    6.3     6.4     6.49    6.59    6.6     6.7
5.19    5.52    5.7     5.78    5.82    6.0     6.2     6.35    6.46    6.58    6.7     6.7     6.7
5.19    5.52    5.74    5.82    5.9     6.15    6.32    6.45    6.58    6.65    6.7     6.7     6.7
5.2     5.5     5.71    5.85    6.0     6.23    6.4     6.49    6.6     6.65    6.68    6.7     6.7
```

Fig. 1. File with design parameters and initial marks.

After launching "RIS" program, initial data from the prepared file are entered by "Data input" button. Optimal map division is performed using "Design" command. Fig2.

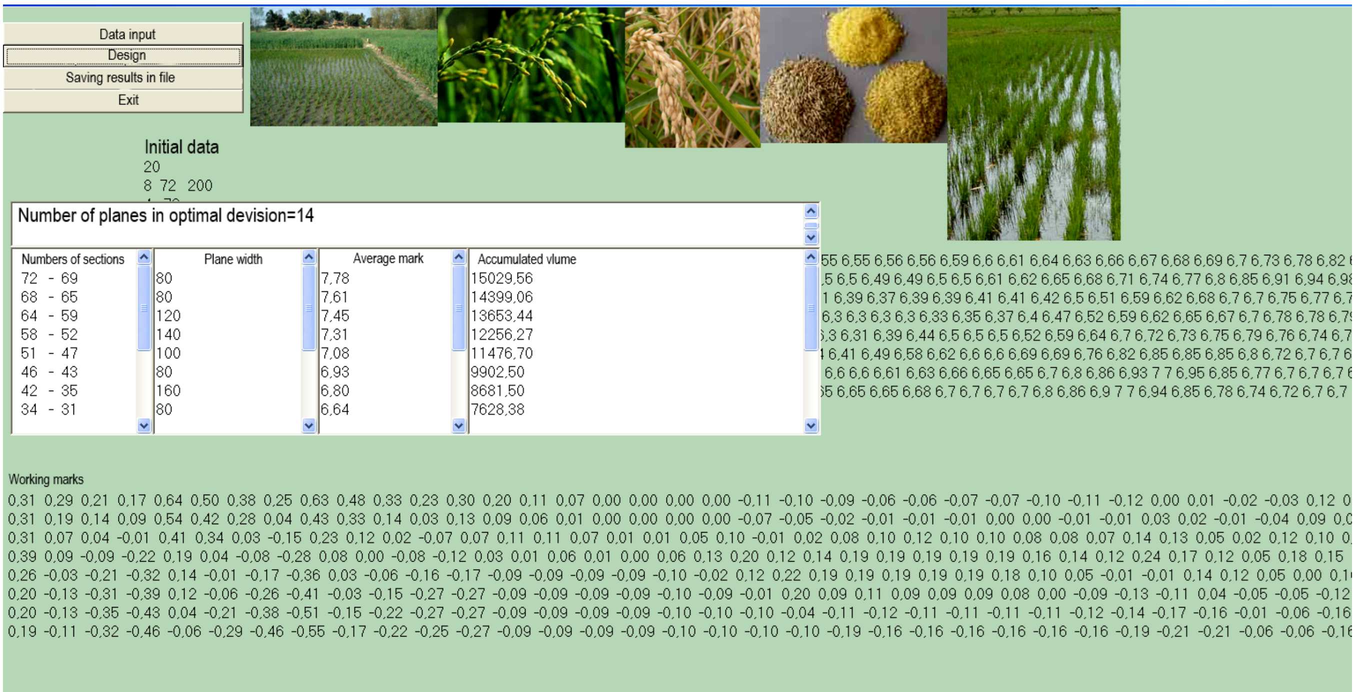
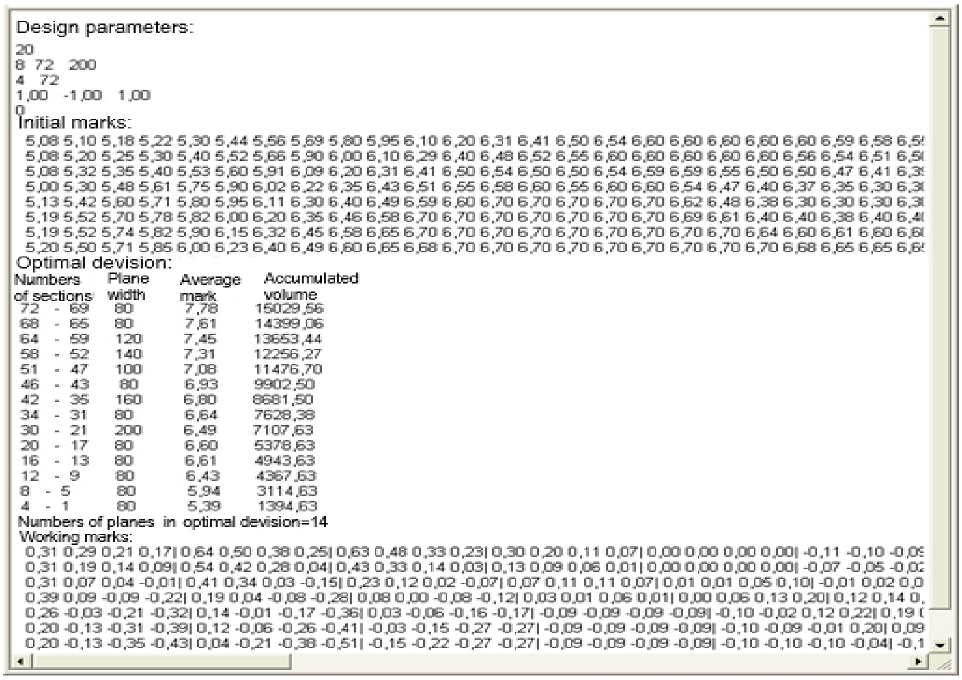


Fig. 2. Optimal division of rice map into checks

Design results created by **"RIS"** software package are shown in Figure 3.

For the optimal solution, the map should be divided into 14 checks with the width of 80 to 200 meters. At the same time, the total (accumulated) volume of earthworks is 15,029.56 cubic meters (Fig. 3).



Design parameters:
20
8 72 200
4 72
1,00 -1,00 1,00
0
Initial marks:
5,08 5,10 5,18 5,22 5,30 5,44 5,56 5,69 5,80 5,95 6,10 6,20 6,31 6,41 6,50 6,54 6,60 6,60 6,60 6,60 6,60 6,59 6,58
5,08 5,20 5,25 5,30 5,40 5,52 5,66 5,90 6,00 6,10 6,29 6,40 6,48 6,52 6,55 6,60 6,60 6,60 6,60 6,60 6,56 6,54 6,51
5,08 5,32 5,35 5,40 5,53 5,60 5,91 6,09 6,20 6,31 6,41 6,50 6,54 6,50 6,50 6,54 6,59 6,59 6,55 6,50 6,50 6,47 6,41
5,00 5,30 5,48 5,61 5,75 5,90 6,02 6,22 6,35 6,43 6,51 6,55 6,58 6,60 6,55 6,60 6,60 6,54 6,47 6,40 6,37 6,35 6,30
5,13 5,42 5,60 5,71 5,80 5,95 6,11 6,30 6,40 6,49 6,59 6,60 6,70 6,70 6,70 6,70 6,70 6,62 6,48 6,38 6,30 6,30 6,30
5,19 5,52 5,70 5,78 5,82 6,00 6,20 6,35 6,46 6,58 6,70 6,70 6,70 6,70 6,70 6,70 6,70 6,69 6,61 6,40 6,40 6,38 6,40
5,19 5,52 5,74 5,82 5,90 6,15 6,32 6,45 6,58 6,65 6,70 6,70 6,70 6,70 6,70 6,70 6,70 6,70 6,70 6,64 6,60 6,61 6,60
5,20 5,50 5,71 5,85 6,00 6,23 6,40 6,49 6,60 6,65 6,68 6,70 6,70 6,70 6,70 6,70 6,70 6,70 6,70 6,70 6,68 6,65 6,65
Optimal devision:

Numbers of sections	Plane width	Average mark	Accumulated volume
72 - 69	80	7,78	15029,56
68 - 65	80	7,61	14399,06
64 - 59	120	7,45	13653,44
58 - 52	140	7,31	12256,27
51 - 47	100	7,08	11476,70
46 - 43	80	6,93	9902,50
42 - 35	160	6,80	8681,50
34 - 31	80	6,64	7628,38
30 - 21	200	6,49	7107,63
20 - 17	80	6,60	5378,63
16 - 13	80	6,61	4943,63
12 - 9	80	6,43	4367,63
8 - 5	80	5,94	3114,63
4 - 1	80	5,39	1394,63

Numbers of planes in optimal devision=14
Working marks:
0,31 0,29 0,21 0,17| 0,64 0,50 0,38 0,25| 0,63 0,48 0,33 0,23| 0,30 0,20 0,11 0,07| 0,00 0,00 0,00 0,00| -0,11 -0,10
0,31 0,19 0,14 0,09| 0,54 0,42 0,28 0,04| 0,43 0,33 0,14 0,03| 0,13 0,09 0,06 0,01| 0,00 0,00 0,00 0,00| -0,07 -0,05
0,31 0,07 0,04 -0,01| 0,41 0,34 0,03 -0,15| 0,23 0,12 0,02 -0,07| 0,07 0,11 0,11 0,07| 0,01 0,01 0,05 0,10| -0,01 0,02
0,39 0,09 -0,09 -0,22| 0,19 0,04 -0,08 -0,28| 0,08 0,00 -0,08 -0,12| 0,03 0,01 0,06 0,01| 0,00 0,06 0,13 0,20| 0,12 0,14
0,26 -0,03 -0,21 -0,32| 0,14 -0,01 -0,17 -0,36| 0,03 -0,06 -0,16 -0,17| -0,09 -0,09 -0,09 -0,09| -0,10 -0,02 0,12 0,22| 0,19
0,20 -0,13 -0,31 -0,39| 0,12 -0,06 -0,26 -0,41| -0,03 -0,15 -0,27 -0,27| -0,09 -0,09 -0,09 -0,09| -0,10 -0,09 -0,01 0,20| 0,09
0,20 -0,13 -0,35 -0,43| 0,04 -0,21 -0,38 -0,51| -0,15 -0,22 -0,27 -0,27| -0,09 -0,09 -0,09 -0,09| -0,10 -0,10 -0,10 -0,04|

Fig. 3. File with design results.

Not only the result itself is very important, but also the guarantee that there is no better result than suggested one.

We should also emphasize the following circumstance. When solving the problem of dividing a plot into sub-plots with limiting restrictions of several parameters, only a program can effectively check the compatibility of conditions and ensure the necessary adjustments.

For example, if in the previous example, we make harder limits on the joining of checks (Δ_z=0.40) and on the cutoff size (-Δ_h=0.40), then there will be no permissible solution. If we slightly weaken the second limit (Δ_h=0.45), then we get the solution where the map is divided into 10 checks with the volume of earthworks of 24,638 cubic meters. That is, the volume will increase by more than 60 percent.

IV. Practical significance

Studies have been carried out on the economic efficiency of optimizing earthworks using "RIS" complex [15]. With the help of field compilation optimization on the areas of about 100 hectares, about 2.4 million rubles can be saved on earthworks at 2019 values.

Operational tests of the "RIS" software package showed its indispensability in setting restrictions on several design parameters simultaneously.

V. Conclusion

1. RIS software package allows you to quickly receive projects for division of rice maps into checks and of land plot into rice maps according to specified technical requirements. Time is spent only on preparing initial data for the program.

2. If there are several permissible solutions for the design site, an optimal one will be found that results in minimum earthworks.

3. If there are no permissible solutions for given limits, the program allows you to instantly identify this situation and to obtain an optimal solution with the adjusted limits.

4. Due to the optimal design, a decrease in earthworks volume is on the average 12.7%, and cost reduction is 24 thousand rubles per hectare.

"RIS" software package is an intelligent system that provides a powerful tool for case analysis, reasonable selection of limits and obtaining optimal solutions for the design of rice paddies and some other cultivated lands.

References

[1] M.I. Korobochkin, and E.E. Dmitrieva, "Design of rice irrigation systems using dynamic programming method," Land improvement and water management, vol 1, pp. 28-31. 2012.

[2] M.I. Korobochkin, and E.E. Dmitrieva, "Field compilation optimization for relief design," Land management, land monitoring and cadaster, No. 11, pp. 80-85. 2012

[3] M.I. Korobochkin, and E.E. Dmitrieva, "Field compilation relief design using dynamic programming methods," Earth Sciences, No. 2, pp. 13-19. 2012.

[4] E.E. Dmitrieva, "Information technologies for relief design," Land management, land monitoring and cadaster, No. 7, pp.79-83. 2017

[5] E.E. Dmitrieva, "Software for optimal relief design," Coll. of articles of the XVI International Scientific and Practical Conference "INTERNATIONAL INNOVATION RESEARCH" - Penza: "Science and Enlightenment" International Center for Scientific Cooperation, pp.178-181. 2019.

[6] R.E. Bellman, and R.E. Kalaba, "Dynamic Programming and Feedback Control," RAND Corporation, pp. 1778. 1959.

[7] R. Bellman, "Dynamic programming," Moscow: Inostrannaya literatura, 1960.

[8] R. Bellman, and E. Angel, "Dynamic programming and partial differential equations," Moscow: Mir, 1974.

[9] R. Bellman, and S. Dreyfus, "Applied problems of dynamic programming," Moscow: Nauka. Chief editorial board for physics and mathematics literature, 460 p. 1965.

[10] N.K. Obrosova, and A.A. Shananin, "Study of the bellman equation in a production model with unstable demand," Computational Mathematics and Mathematical Physics, Vol. 54, No. 9, pp. 1411-1440. 2014.

[11] M.I. Korobochkin, and E.E. Dmitrieva, "Mathematical support for the optimal relief design for land surface areas," Coll. of articles of the XII International Scientific and Practical Conference: "INTERNATIONAL INNOVATION RESEARCH". In 3 parts. Part 1 - Penza: "Science and Enlightenment" International Center for Scientific Cooperation. pp. 221-224. 2018.

[12] M.I. Korobochkin, and E.V. Kalinova, Development of theory, methods and technologies for mathematical modeling of geospatial data: Electronic scientific and practical guide – Moscow: GUZ, 248 p. 2015.

[13] M.I. Korobochkin, Mathematical modeling in geodesy: Manual for students of higher educational institutions with specialty 120101 – Applied Geodesy – Moscow: GUS, 316 p. 2012.

[14] M.I. Korobochkin, E.V. Kalinova, and A.D. Tikhonov, Mathematical modeling of geospatial data: Manual for students higher educational institutions with specialty 21.05.01 – Applied Geodesy, and with training program 21.03.03 – Geodesy and remote sensing – Moscow: GUZ, 396 p. 2017.

[15] M.I. Korobochkin, and E.E. Dmitrieva, "Efficacy of field compilation optimization in the design of rice maps and checks," Land management, land cadastre, and land monitoring, No. 10, pp. 20-26. 2013.

[16] M.I. Korobochkin, E.E. and Dmitrieva, "Perspectives of mathematical programming methods for relief design of drip irrigation systems," Land management, land cadastre, and land monitoring, -No. 3, pp.10 - 13. 2019.

[17] A.K. Semerjyan, and A.V. Ben, "Experience in the design and construction of drip irrigation systems in the Krasnodar Krai," Nature Management, No. 4, pp. 85-88. 2018.

[18] V.N. Shchedrin, A.S. Shtanko, and V.N. Shkura, "Methodological base for the design of self-pumped drip irrigation systems," Land improvement and water management, No. 2, pp. 36-42. 2018.