

ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ – СОФИЯ

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## ARTIFICIAL RAIN'S QUALITY SIMULATED STUDY OF RING ROTATING SPRINKLERS SITUATED IN SQUARE SCHEME

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**Keywords:** *sprinkler irrigation, artificial rain quality, square scheme, simulated numerical study*

**Research area:** *irrigation and drainage engineering*

### ABSTRACT

This work completes an presented in the International Science-Practice Jubilee Conference UACEG 2012 report [3], in which are evaluated: the experimental uniformity's determination by Christiansen of the artificial rain with classic field and laboratory trials in circular rotating sprinklers and center pivot systems, the conditions under which the results obtained by measurements of rain intensity  $i$ , mm/h in a finite number of points arranged in a particular way surface, approach best to real continuous process over the entire irrigated surface and the approach for the accepted standard schemes of the measure vessels disposition by comparison with an exact simulated uniformity's determination. In this work complementary is obtained and included a simulated artificial rain quality's determination - intensity and uniformity, for a square scheme of sprinklers' placement with an *arbitrary* square's size  $a$ , which may in many cases completely replace the field trials execution.

### 1. Summary, object of the study

In this research are obtained an algorithm, a logical bloc-scheme and program for numerical simulated artificial rain quality's determination – uniformity with the Christiansen's coefficient  $CU$  and variation's coefficient  $C_v$ , the rain's intensity  $i$ , its average value  $i_m$  and the discrete function  $i(S)$  of its distribution for ring rotated identical

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Sprinklers, located in square scheme with known function  $i(r)$  of rain change's intensity along the length of the radius of action  $R$ , and arbitrary square's side size  $a$ .

## 2. Formulation of the study

The formulation of this study is like to that in the reports [1,2,3].

It is accepted that:

- are examined working at the same time during one hour four identical sprinklers, situated at the corners of a square scheme with side size  $a$ ;

- is known (given) the function  $i(r)$  of rain change's intensity on the length of the radius of action  $R$ , obtained with experiments, accepted or recommended (examined), the same for all sprinklers and is linearized by sections ( $m$  in number) with an equal horizontal length;

- the rain's parameters (of the function  $i(r)$ ) are constant along the length of the radius  $R$  in the range of the complete sprinklers' turning in  $360^\circ$  during all the sprinkling, therefore the body of the rainfall over the surface's  $S$  water volume  $V$ ,  $m^3/h$  is symmetrical toward the axis of rotation and is not changing in the time, i.e. is excluded the wind's influence, as well as the shoves with the turn – Fig. 1;

- the rain's intensity  $i$  and uniformity and the  $i$  distribution's function are determined for the square's surface with volume of the fallen on him artificial rain, the same as the volume, given by one of the four sprinklers where  $R \leq a$  (for the formation of the full volume each of them participates with one quarter of its own given volume);

- when are used relative quantities, then  $R_* = 1$ ,  $i_{\max}^* = 1$ ,  $r_* \leq 1$  and  $i(r)_* \leq 1$ ;

- the determined with simulated exact values of the coefficients of uniformity  $CU$ , of variation  $Cv$  and the function  $i(S)$  of the intensity's distribution  $i$ , mm/h of the fallen artificial rain are for fictitious measuring trial points (vessels) with accepted placement corresponding to the standard square scheme from Fig. 2 for the realization of full field trials [6] with  $n$  measuring points in line and  $n$  measuring points in square's column, with total number  $n^2$  of the measuring points – Fig. 3, taking into account the influence of  $n$  on the precision.

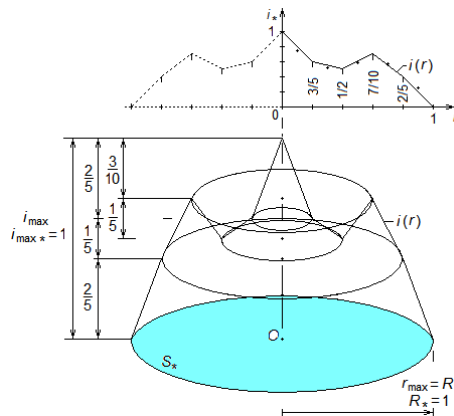


Fig. 1. Body of the water volume  $V_*$  artificial rain fallen from a single Sprinkler on the irrigated by him surface  $S_*$

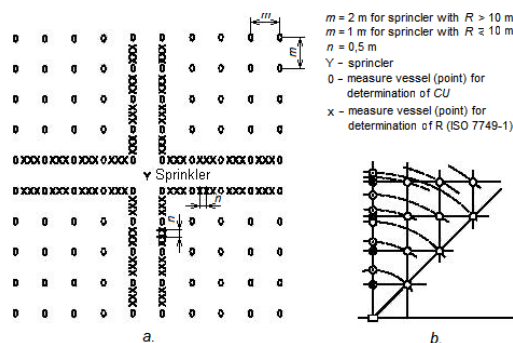


Fig. 2. Standard placement of the measuring vessels for square scheme as GOST ISO 7749-2-2004 [6]

### 3. Succession and algorithm of the solution

The study is conducted in the following sequence:

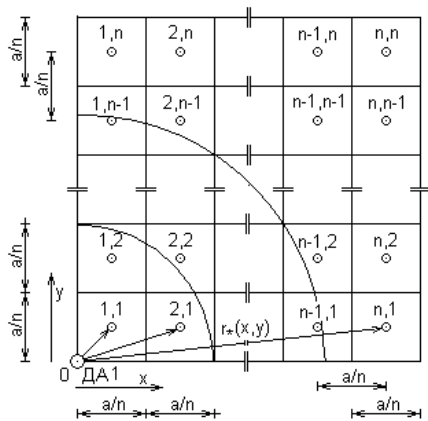
*Input data* is the obtained experimentally, given (recommended) or accepted *function*  $i(r)$ , mm/h of rain change's intensity  $i$  along the length of sprinkler's radius of action  $R$ , m. It is represented analytically, tabular or most frequently graphically and in the study *is linearized by sections with equal horizontal lengths* along the radius  $R$ , devised in  $m$  equal parts.

A right-handed coordinate system is introduced with axes  $x$  coinciding with the base of irrigated square surface and beginning at the place of Sprinkler 1 in its lower left corner – Fig.3. The side of the square is  $a$ , m, while using relative quantities  $a_* = a/R$  is a dimensionless number, indicating the ratio between it and the Sprinkler's radius of action (when  $R_* = 1$ , then  $a_* = a$ ). Accepted number of measuring points (vessels) is  $n$  numbers in square line and  $n$  numbers in column with total number of points  $n^2$ . The horizontal and vertical distance between the vessels is  $a/n$ , as they are identified by the "coordinates"  $(x, y)$  when  $x = 1, 2, \dots, n-1, n$  and  $y = 1, 2, \dots, n-1, n$ . For the first line these coordinates are  $(1,1), (2,1), \dots, (n-1,1), (n,1)$ , for the second line are  $(1,2), (2,2), \dots, (n-1,2), (n,2)$  etc. With these coordinates are determined their relative radii  $r_*(1,1), r_*(2,1), \dots, r_*(n,1), \dots$  to the place of the corresponding Sprinkler. Of the rectangular triangle with catheti  $x$  and  $y$  and hypotenuse the radius vector to this place (for Sprinkler1 this is the origin of the coordinate system) to each measuring point (vessel) is determined the hypotenuse's size which coincides with the radius  $r_*(x, y)$  to it.

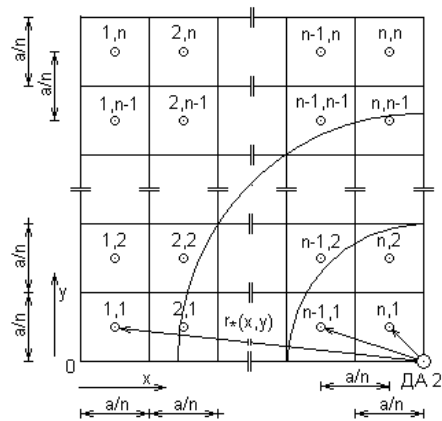
In Fig. 3a-d are given the points' coordinates and the calculation in cycles of  $r_*(x, y)$  (in prepared program they are  $R(x, y)$ ) separately for Sprinkler 1, Sprinkler 2, Sprinkler 3 and Sprinkler 4, taking into account their location to the introduced coordinate system, as

$$\begin{aligned}
 &\text{for sprinkler 1} \quad R(x, y) = \text{SQR}((a/n*(y-0.5))^2 + (a/n*(x-0.5))^2), \\
 &\text{for sprinkler 2} \quad R(x, y) = \text{SQR}((a/n*(y-0.5))^2 + (a/n*(n-x+0.5))^2), \quad (1)
 \end{aligned}$$

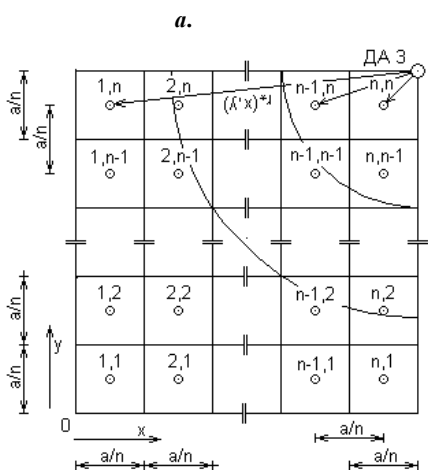
for sprinkler 3  $R(x, y) = \text{SQR}((a/n * (n - y + 0.5))^2 + (a/n * (n - x + 0.5))^2)$ ,  
 for sprinkler 4  $R(x, y) = \text{SQR}((a/n * (n - y + 0.5))^2 + (a/n * (x - 0.5))^2)$ .



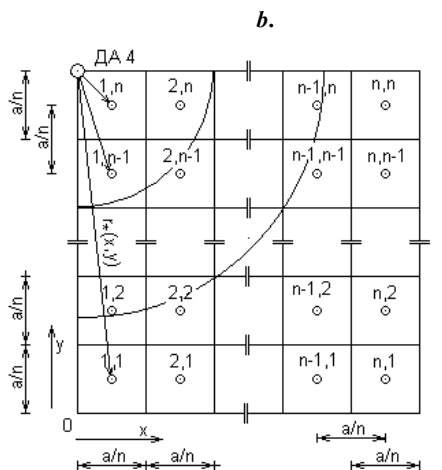
```
FOR y = 1 TO n
FOR x = 1 TO n
r*(x,y)=SQR((a/n*(y-0,5))^2+(a/n*(x-0,5))^2)
NEXT x
NEXT y
```



```
FOR y = 1 TO n
FOR x = 1 TO n
r*(x,y)=SQR((a/n*(y-0,5))^2+(a/n*(n-x+0,5))^2)
NEXT x
NEXT y
```



```
FOR y = 1 TO n
FOR x = 1 TO n
r*(x,y)=SQR((a/n*(n-y+0,5))^2+(a/n*(n-x+0,5))^2)
NEXT x
NEXT y
```



```
FOR y = 1 TO n
FOR x = 1 TO n
r*(x,y)=SQR((a/n*(n-y+0,5))^2+(a/n*(x-0,5))^2)
NEXT x
NEXT y
```

**Fig. 3. Determination of the radii  $r_*(x, y)$  (in the program they are  $R(x, y)$ ) to the measuring points (vessels) by their relative coordinates in the case of separate action of Sprinklers 1, 2, 3 and 4**

The intensities  $i_*(x, y)$ , corresponding to the measuring points' coordinates, are reading by the given function  $i_*(r_*)$  of rain change's intensity on the length of the radius of sprinkler's action  $R_*$ , which, it is stressed strongly again, is linearized by sections, parts ( $m$  in number) with an equal horizontal length (or  $R_*$  is divided in  $m$  equal parts!).

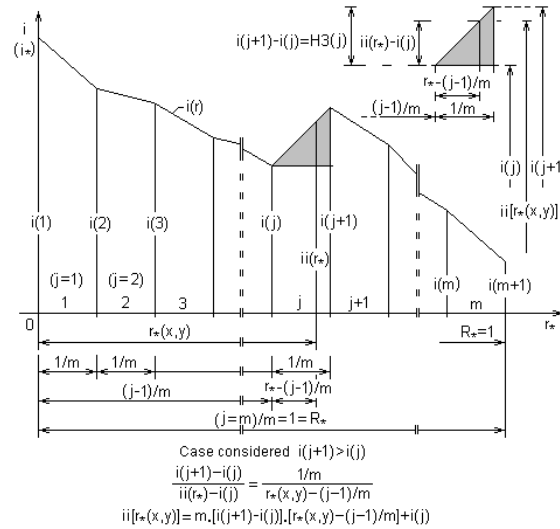
Figures 4a, b illustrate the relation's deduce between the before obtained coordinates  $r_*(x, y)$  of the measuring points (vessels) and their corresponding values  $ii[r_*(x, y)]$  by the linearized in parts ( $m$  in number) function  $i(r_*)$ . The values of  $i$  ( $i_*$  in dimensionless form) at the section's borders where the radius  $r$  increase, are  $i(1), i(2), \dots, i(j), i(j+1), \dots, i(m)$  and  $i(m+1)$ , as the lasts two enclose the  $m$ -th section (using relative quantities they are  $i_*(1), i_*(2), \dots$  etc.). The  $j$ -th section of  $i(r_*)$  (respectively of  $i_*(r_*)$ ) is examined, bounded by  $i(j)$  and  $i(j+1)$  with  $r_*(x, y)$  inside in it, and corresponding intensity  $ii[r_*(x, y)]$  of the linearized part:

- when  $i(j+1) = i(j)$ , inside the section  $ii[r_*(x, y)]$  has the same constant value:

$$ii[r_*(x, y)] = i(j) = i(j+1), \text{ when } i(j+1) = i(j); \quad (2)$$

- when  $i(j+1) > i(j)$ ,  $ii[r_*(x, y)]$  is determined by the scheme of Fig. 4a;

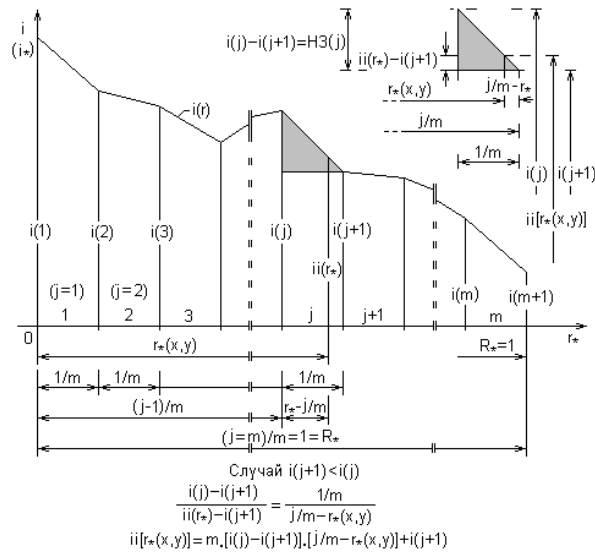
- when  $i(j+1) < i(j)$ ,  $ii[r_*(x, y)]$  is determined by the scheme of Fig. 4b.



**Fig. 4a. Determination of intensity  $ii[r_*(x, y)]$  in the case of section with  $i_*(r_*)$  increased function when  $R_*$  increases**

The  $j$ -th part of  $i_*(r_*)$  in Fig. 4a, is examined. The catheti's proportion of the two dark similar triangles included into each other (leaded also at the side), gives:

$$ii[r_*(x, y)] = m \cdot [i(j+1) - i(j)] \cdot [r_*(x, y) - (j-1)/m] + i(j), \text{ when } i(j+1) > i(j). \quad (3)$$



**Fig. 4b. Determination of intensity  $ii[r_*(x, y)]$  in the case of section with  $i_k(r_*)$  decreased function when  $R_*$  increases**

The value of the intensity  $ii[r_*(x, y)]$  of Fig. 4b is defined as shown in Fig. 4a:

$$ii[r_*(x, y)] = m \cdot [i(j) - i(j+1)] \cdot [j/m - r_*(x, y)] + i(j+1), \text{ when } i(j+1) < i(j). \quad (4)$$

The zone of action of each Sprinkler is only from zero to  $r_* \leq R_*$  and

$$ii[r_*(x, y)] = 0 \text{ for } r_*(x, y) > R_*. \quad (5)$$

The fallen artificial rain's total intensity  $ii(x, y)$  in each measuring point (vessel) is sum of the obtained with eq.(2÷5) and four values of the different for each of situated in the irrigated square corners four Sprinklers intensities, marked with  $i_{1-4}(x, y)$ , as

$$ii_k(x, y) = \sum_{k=1}^4 i_k(x, y). \quad (6)$$

The last part of algorithm includes calculation of the middle relative intensity  $i_{m,*}$ ,  $CU$  and  $Cv$  according to known dependences, written with the accepted in the program symbols, as the number of measuring points (vessels) is  $c = n^2$ :

$$i_{m,*} = \frac{1}{c} \cdot \sum_{i=1}^c ii_{i,*}, \quad CU = 100 \cdot \left[ 1 - \frac{\sum_{i=1}^c |i_{m,*} - i_{i,*}|}{c \cdot i_{m,*}} \right], \quad Cv = \sqrt{\frac{\sum_{i=1}^c (i_{m,*} - i_{i,*})^2}{(c-1) \cdot (i_{m,*})^2}}. \quad (7)$$

#### 4. Logical bloc-scheme of the program

The presented in fig. 5 logical bloc-scheme of the prepared computer program accorded with the developed algorithm, visually gives the computing operations' succession. It permits in the base of this algorithm to improve the research and develop also another programs with analogical direction, possibly used another programming language.

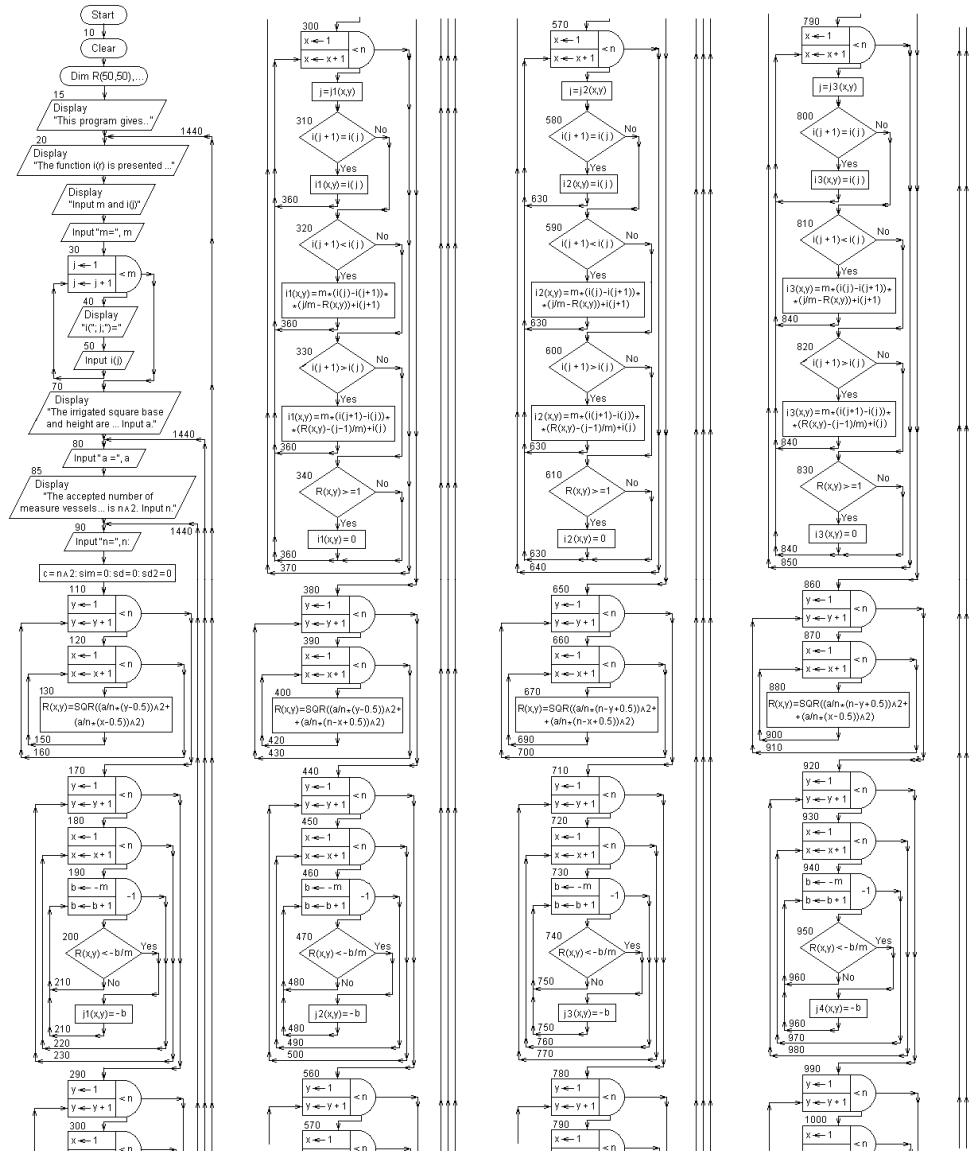
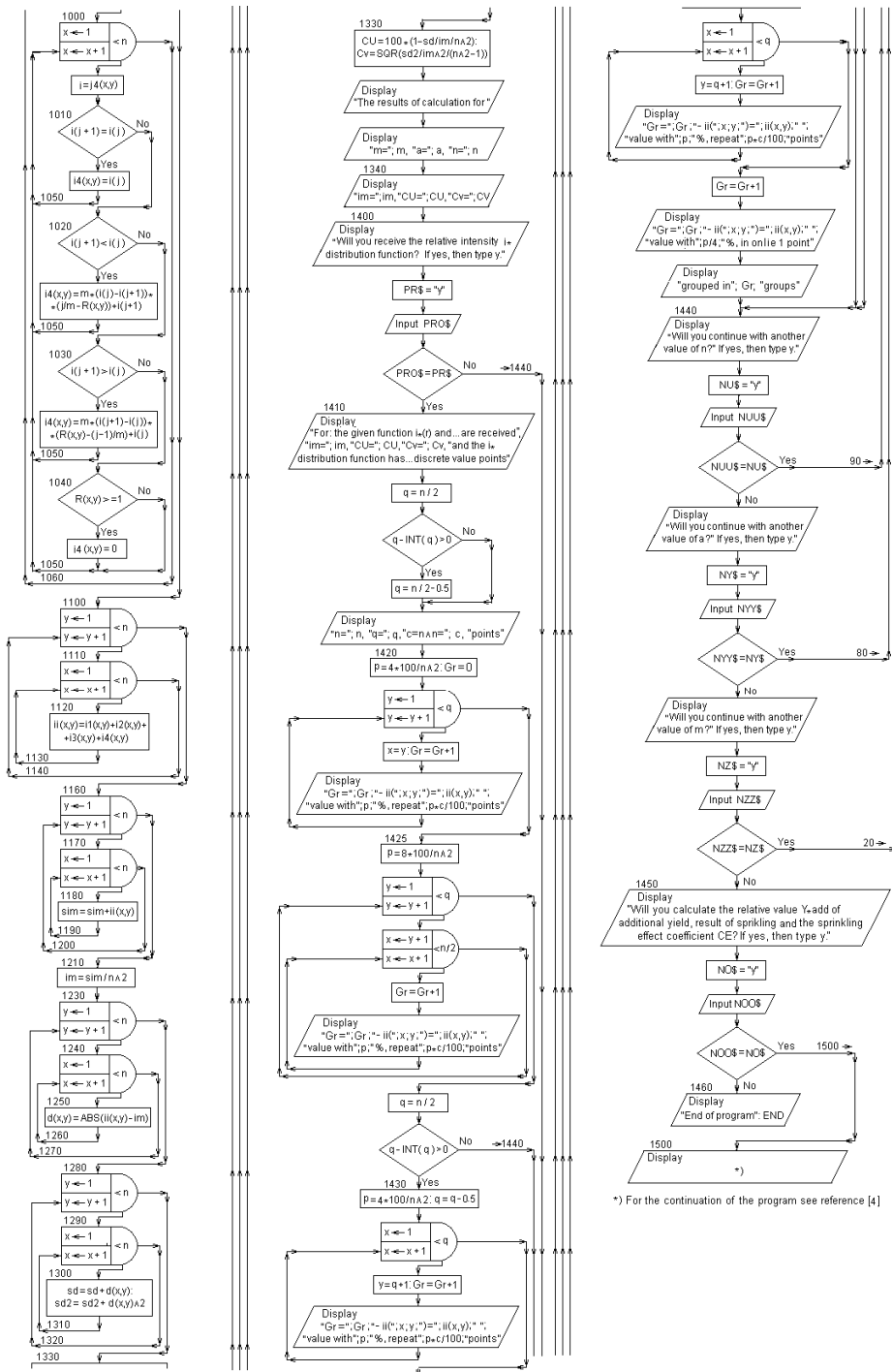


Fig. 5. Logical bloc-scheme of the computer program (first part)



\*) For the continuation of the program see reference [4]

Fig. 5. Logical bloc-scheme of the computer program (end)

## 5. Program

The program SPR7.BAS is written in BASIC language.

```
10 CLEAR : DIM R(50, 50), j1(50, 50), i1(50, 50), j2(50, 50), i2(50, 50), j3(50, 50),
    i3(50, 50), j4(50, 50), i4(50, 50), ii(50, 50), d(50, 50), Yadd(50, 50), p(50), q(50)
15 PRINT "This program gives the values of Christiansen coefficient CU and the"
    PRINT "coefficient Cv for the artificial rain's uniformity of deployed in"
    PRINT "square scheme ring rotating sprinklers and center pivot systems"
    PRINT "with given function i(r) of the rain changes intensity i, mm/h on the"
    PRINT "length of the radius of action R. (i and R are in relative quantities"
    PRINT "R*=1, imax,*=1)."
20 PRINT " "
    PRINT "The function i(r) is presented with a linear in parts approximation,
    PRINT "the radius of action R is divided in m equal parts and the i(r) values"
    PRINT "in their borders are i(j), j=1,2,...,m+1, in r increase direction."
    PRINT "Input m and i(j)."
    INPUT "m=", m
    FOR j = 1 TO m + 1
    PRINT "i("; j; ")="
    INPUT i(j)
    NEXT j
70 PRINT "The irrigated square base and height are a.R, but R is presented in"
    PRINT "relative quantity R*=1, or a.R*=a. Input a."
80 INPUT "a=", a
    PRINT "The accepted number of measure vessels, situated in symmetric square"
    PRINT "scheme in n ranges, n vessels in range, is n^2. Input n."
90 INPUT "n=", n: c = n ^ 2: sim = 0: sd = 0: sd2 = 0
110 FOR y = 1 TO n
120 FOR x = 1 TO n
130 R(x, y) = SQR((a / n * (y - .5)) ^ 2 + (a / n * (x - .5)) ^ 2)
150 NEXT x
160 NEXT y
170 FOR y = 1 TO n
180 FOR x = 1 TO n
190 FOR b = -m TO -1
200 IF R(x, y) < -b / m THEN j1(x, y) = -b
210 NEXT b
220 NEXT x
230 NEXT y
290 FOR y = 1 TO n
300 FOR x = 1 TO n
    j = j1(x, y)
310 IF i(j + 1) = i(j) THEN il(x, y) = i(j)
320 IF i(j + 1) < i(j) THEN il(x, y) = (i(j) - i(j + 1)) * m * (j / m - R(x, y)) + i(j + 1)
330 IF i(j + 1) > i(j) THEN il(x, y) = (i(j + 1) - i(j)) * m * (R(x, y) - (j - 1) / m) + i(j)
340 IF R(x, y) >= 1 THEN il(x, y) = 0
360 NEXT x
370 NEXT y
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```

380 FOR y = 1 TO n
390 FOR x = 1 TO n
400 R(x, y) = SQR((a / n * (y - .5)) ^ 2 + (a / n * (n - x + .5)) ^ 2)
420 NEXT x
430 NEXT y
440 FOR y = 1 TO n
450 FOR x = 1 TO n
460 FOR b = -m TO -1
470 IF R(x, y) < -b / m THEN j2(x, y) = -b
480 NEXT b
490 NEXT x
500 NEXT y
560 FOR y = 1 TO n
570 FOR x = 1 TO n
    j = j2(x, y)
580 IF i(j + 1) = i(j) THEN i2(x, y) = i(j)
590 IF i(j + 1) < i(j) THEN i2(x, y) = (i(j) - i(j + 1)) * m * (j / m - R(x, y)) + i(j + 1)
600 IF i(j + 1) > i(j) THEN i2(x, y) = (i(j + 1) - i(j)) * m * (R(x, y) - (j - 1) / m) + i(j)
610 IF R(x, y) > 1 THEN i2(x, y) = 0
630 NEXT x
640 NEXT y
650 FOR y = 1 TO n
660 FOR x = 1 TO n
670 R(x, y) = SQR((a / n * (n - y + .5)) ^ 2 + (a / n * (n - x + .5)) ^ 2)
690 NEXT x
700 NEXT y
710 FOR y = 1 TO n
720 FOR x = 1 TO n
730 FOR b = -m TO -1
740 IF R(x, y) < -b / m THEN j3(x, y) = -b
750 NEXT b
760 NEXT x
770 NEXT y
780 FOR y = 1 TO n
790 FOR x = 1 TO n
    j = j3(x, y)
800 IF i(j + 1) = i(j) THEN i3(x, y) = i(j)
810 IF i(j + 1) < i(j) THEN i3(x, y) = (i(j) - i(j + 1)) * m * (j / m - R(x, y)) + i(j + 1)
820 IF i(j + 1) > i(j) THEN i3(x, y) = (i(j + 1) - i(j)) * m * (R(x, y) - (j - 1) / m) + i(j)
830 IF R(x, y) > 1 THEN i3(x, y) = 0
840 NEXT x
850 NEXT y
860 FOR y = 1 TO n
870 FOR x = 1 TO n
880 R(x, y) = SQR((a / n * (n - y + .5)) ^ 2 + (a / n * (x - .5)) ^ 2)
900 NEXT x
910 NEXT y
920 FOR y = 1 TO n
930 FOR x = 1 TO n

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940 FOR b = -m TO -1
950 IF R(x, y) < -b / m THEN j4(x, y) = -b
960 NEXT b
970 NEXT x
980 NEXT y
990 FOR y = 1 TO n
1000 FOR x = 1 TO n
    j = j4(x, y)
1010 IF i(j + 1) = i(j) THEN i4(x, y) = i(j)
1020 IF i(j + 1) < i(j) THEN i4(x, y) = (i(j) - i(j + 1)) * m * (j / m - R(x, y)) + i(j + 1)
1030 IF i(j + 1) > i(j) THEN i4(x, y) = (i(j + 1) - i(j)) * m * (R(x, y) - (j - 1) / m) + i(j)
1040 IF R(x, y) > 1 THEN i4(x, y) = 0
1050 NEXT x
1060 NEXT y
1100 FOR y = 1 TO n
1110 FOR x = 1 TO n
1120 ii(x, y) = i1(x, y) + i2(x, y) + i3(x, y) + i4(x, y)
1130 NEXT x
1140 NEXT y
1160 FOR y = 1 TO n
1170 FOR x = 1 TO n
1180 sim = sim + ii(x, y)
1190 NEXT x
1200 NEXT y
1210 im = sim / n ^ 2
1230 FOR y = 1 TO n
1240 FOR x = 1 TO n
1250 d(x, y) = ABS(ii(x, y) - im)
1260 NEXT x
1270 NEXT y
1280 FOR y = 1 TO n
1290 FOR x = 1 TO n
1300 sd = sd + d(x, y): sd2 = sd2 + d(x, y) ^ 2
1310 NEXT x
1320 NEXT y
1330 CU = 100 * (1 - sd / im / n ^ 2): Cv = SQR(sd2 / im ^ 2 / (n ^ 2 - 1))
    PRINT " ", "The results of calculation for"
    PRINT "m="; m, "a="; a, "n="; n
1340 PRINT "im="; im, "CU="; CU, "Cv="; Cv
1400 PRINT " "
    PRINT "Will you receive the relative intensity i* distribution's"
    PRINT "discretized function? If yes, then type y.": PR$ = "y"
    INPUT PRO$: IF PRO$ = PR$ THEN 1410
    GOTO 1440
1410 PRINT " ", "For:"
    PRINT "the given function i*(r) and accepted", "a="; a, "and n="; n
    PRINT "are received", "im="; im, "CU="; CU, "Cv="; Cv, "and"
    PRINT "the i* distribution function has the next discrete value points:"
    PRINT " "

```

```

q = n / 2
IF q - INT(q) > 0 THEN q = n / 2 - .5
PRINT "n="; n, "q="; q, "c=n^n="; c, "points"
1420 p = 4 * 100 / n ^ 2: Gr = 0
FOR y = 1 TO q
x = y: Gr = Gr + 1
PRINT "Gr="; Gr; "- ii("; x; y; ")="; ii(x, y); ""; "value with"; p; "%, repeat in";
p * c / 100; "points"
NEXT y
1425 p = 8 * 100 / n ^ 2
FOR y = 1 TO q
FOR x = y + 1 TO n / 2: Gr = Gr + 1
PRINT "Gr="; Gr; "- ii("; x; y; ")="; ii(x, y); ""; "value with"; p; "%, repeat in";
p * c / 100; "points"
NEXT x
NEXT y
q = n / 2
IF q - INT(q) > 0 THEN 1430
GOTO 1440
1430 p = 4 * 100 / n ^ 2: q = q - .5
FOR x = 1 TO q
y = q + 1: Gr = Gr + 1
PRINT "Gr="; Gr; "- ii("; x; y; ")="; ii(x, y); ""; "value with"; p; "%, repeat in";
p * c / 100; "points"
NEXT x
Gr = Gr + 1
PRINT "Gr="; Gr; "- ii("; x; y; ")="; ii(x, y); ""; "value with"; p / 4; "%, in only 1 point"
PRINT "grouped in"; Gr; "groups."
1440 PRINT " ", "Will you continue with another value of n? If yes, then type y."
NU$ = "y": INPUT NUU$: IF NUU$ = NU$ THEN 90
PRINT "Will you continue with another value of a? If yes, then type y."
NY$ = "y": INPUT NYU$: IF NYU$ = NY$ THEN 80
PRINT "Will you continue with another values of m and i(j)? If yes, then type y."
NZ$ = "y": INPUT NZU$: IF NZU$ = NZ$ THEN 20
1450 PRINT " ", "Will you calculate the relative value Y*add of additional yield,"
PRINT "result of sprinkling and the sprinkling effect coefficient CE,"
PRINT "using a given/accepted relation water-yield? If yes, then type y."
NO$ = "y": INPUT NOU$: IF NOU$ = NO$ THEN 1500
1460 PRINT "End of program": END
1500 PRINT " "
→ for the extension of program see reference [4].

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Example. With the program SPR7.BAS to determine the values of the average relative intensity  $i_{m,*}$ , of the coefficients of uniformity  $CU$  and of variation  $C_V$  in both irrigation with four equal sprinklers, disposed in square scheme with the following data:  $m = 5$ ,  $i_{1,*} = 1$ ,  $i_{2,*} = 0,6$ ,  $i_{3,*} = 0,5$ ,  $i_{4,*} = 0,7$ ,  $i_{5,*} = 0,4$  and  $i_{6,*} = 0$  for  $n = 5$ ,  $n = 10$ ,  $n = 20$ ,  $n = 30$  and  $a_* = 1,20$ ,  $a_* = 1,41$ ,  $a_* = 1,60$  (for  $a_* = 1,60$  remains no irrigable surface in the square center).

The results are given in the next table:

$a_*$	$n = 5$			$n = 10$		
	$i_{m,*}$	$CU$	$C_V$	$i_{m,*}$	$CU$	$C_V$
1,20	0,9613925	79,86184	0,2446630	0,9543338	80,23720	0,2349343
1,41	0,6661603	78,18231	0,3235111	0,6911848	76,38774	0,2981980
1,60	0,5416602	75,84406	0,3354326	0,5389464	74,73506	0,3455425

$a_*$	$n = 20$			$n = 30$		
	$i_{m,*}$	$CU$	$C_V$	$i_{m,*}$	$CU$	$C_V$
1,20	0,9538174	78,81630	0,2374206	0,9541857	79,08933	0,2369870
1,41	0,6912891	76,25793	0,2902335	0,6910858	76,09603	0,2892130
1,60	0,5366849	75,15692	0,3439500	0,5364982	75,14490	0,3437097

The data analysis from the table been shown that a full quality's valuation of the sprinkling with ring rotated sprinklers on the yields and for optimum effect should be considered complete:

- the artificial rain's uniformity with the Christiansen's coefficient  $CU$  (or with another analogical of him coefficient of uniformity [5]),
- the average (middle) rain's intensity  $i_{m,*}$  and
- the discrete function  $i_*(S_*)$  of intensity  $i_*$  distribution on the sprinkled surface  $S_*$ .

At the same high value of  $CU$ , but at a lower value of  $i_{m,*}$  the net (final) effect of irrigation is lower.

## 6. Conclusion

For Sprinklers disposed in square scheme in the study is given a numerical simulated artificial rain quality's determination of uniformity with the Christiansen's coefficient  $CU$  and variation's coefficient  $C_V$ , of the rain's intensity  $i$ , and the function  $i(S)$  of its distribution for ring rotating sprinklers for known (given) function  $i(r)$  of rain change's intensity  $i$  on the length of the radius of action  $R$  and for an arbitrary side size  $a$  of the square. In many cases this determination may completely replace the classic labor-intensive field and laboratory trials execution with a limited number of measuring points. It can also be searched in advance a suitable function  $i(r)$  for the desired values of  $CU$ ,  $C_V$ ,  $i_m$  and effect of irrigation.

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## СИМУЛАЦИОННО ИЗСЛЕДВАНЕ НА КАЧЕСТВОТО НА ИЗКУСТВЕНИЯ ДЪЖД ПРИ РАЗПОЛОЖЕНИ В КВАДРАТНА СХЕМА КРЪГОВО ВЪРТЯЩИ СЕ ДЪЖДОВАЛНИ АПАРАТИ

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*Ключови думи:* дъждуване, качество на изкуствения дъжд, квадратна схема, симулационно числено изследване

*Научна област:* хидромелиорации

### РЕЗЮМЕ

Работата допълва доклад [3], изнесен на Международна научно-приложна конференция УАСГ2012, в който се оценяват: определянето с полски или лабораторни опити на равномерността на изкуствения дъжд по Христиансен при кръгово въртящи се дъждовални апарати и машини, условията, при които получените резултати чрез измервания на интензивността на дъжда  $i$ , mm/h в краен брой разположени по определен начин точки на площта се приближават най-добре до реалния непрекъснат процес върху цялата напоявана площ и приближението за приетите стандартни схеми на разполагане на мерните съдове чрез сравнение със симулирано точно определяне на равномерността. Тази работа допълнително включва симулирано числено определяне на качеството на изкуствения дъжд – интензивност и равномерност за квадратна схема на разполагане на дъждовалните апарати при произволна големина на страната на квадрата, което определяне в редица случаи може напълно да замени провеждането на полски опити.

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