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RESEARCH ARTICLE

Combigraphs

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Abstract

In the construction industry there is a frequent need to cover long distances with the precise combination of small size components. Diophantos the Greek mathematician dealt with the combination of integer numerals. He worked out both the Diophantine equation and the Diophantine diagram, which are still in use, (also in a slightly modified version). In England, Dunstone worked out another method – beyond the two combinative digits, later also for three. With the growth of industrialization and mass production the interest emerged for three and four digit methods, in order to have a larger selection of combinations. I have developed a rather simple method for a three and four digit version. Combining the Dunstone with Diophantine methods, has also made it possible to apply three and four digits.

Keywords

Combigraph · Diophantine diagram · Dunstone method · Böhönyey method

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Buildings designed with truss systems and bearing trusses with large spans are common in the practice of construction. Typically, the space-separation of these establishments is not solved with monolithic concrete, brick or hollow blocks, rather with prefabricated elements. Exterior and interior separations are usually constructed with the use of one storey high and 120-360 cm wide elements. Their material can be one of the several variations of prefabricated reinforced concrete, corrugated metal panels with insulation, steel, aluminium, plastic, gypsum or even timber. These elements are used particularly in the construction of industrial, agricultural, storage and sport establishments but also in public buildings. In the present article the early methods of prefabricated element combinations are reviewed and a unique method is presented and elaborated for certain purposes in Hungary.

The most economic solution is to produce only two different widths of these panels. When using them, a combination of the two dimensions has to be calculated for covering the given wall section. (Evidently, beyond the combination of the two dimensions, the level connections of elements also have to be solved, namely L-shaped, T-shaped and cross (+) shaped intersections.)

One of the early variations of element combination started with a special combination, called "bar-chart" by the British and Americans. First a horizontal sequence is created that appears to be long enough for the given wall section, then the width dimension of the combinative numerals is determined. The difference between the two numbers always has to be the divisor of both. Then, starting from above point 0, first the smaller digit is put into the chart and above it the larger one (see Fig.1). Suppose the smaller has the size of 3 digits and the larger 4 digits. Two 3 digit long elements are placed above the 4 digit long one and above them, one 3 digit long and one 4 digit long element. In this way, the covered width is expanded by enlarging the width of the combination one by one. In the beginning of the sequence there is a small distance which was typically impossible to cover; but in case of larger dimensions expanded one by one always more than one combinative variation presents itself for the covering of a certain distance. After finishing this, the wall parts to be covered and the number of used elements are put into the horizontal sequence with vertical lines.

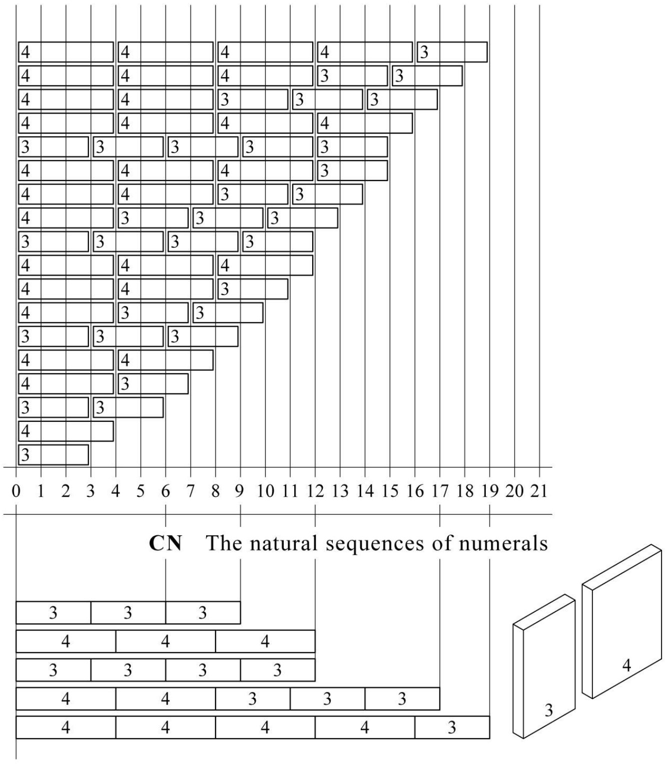


Fig. 1. Bar chart. CN= Critical Number (here 6) from where all distances can be covered

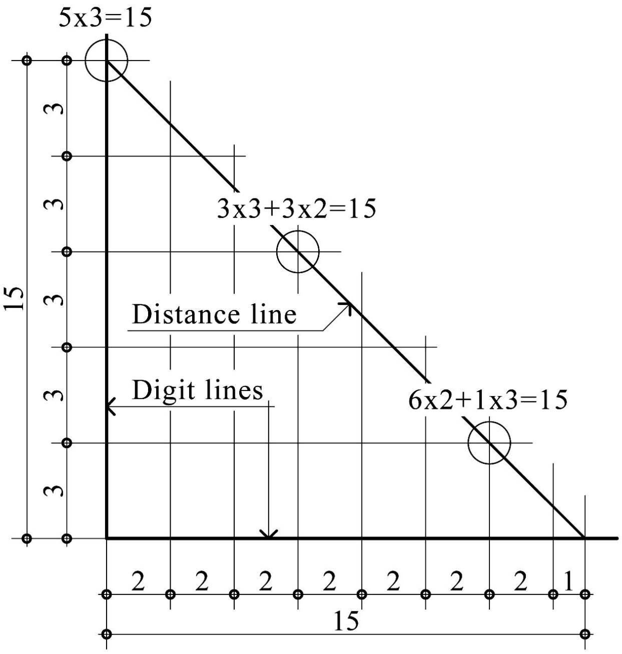


Fig. 2. Combigraph with Diophantine method. Distance to be covered: 15, combinative digits: 2, 3.

Over time another method has been developed, where two lines are drawn from a point 0 rising to an opposite direction (in a V-shape), the combinative numerals were chosen – let us have 3 and 4 again – and the multiples of one of them were put on the left line, the others on the right line of the V. From the digits of both sequences lines are drawn parallel to the other line of the V thus giving a trapezoid grid; and the starting digits of the lines are written to the intersections of the grid.

Originally not much effort has been given to the exact drawing of the grid just to the value of the numerals. However, once a variation was elaborated geometrically to a high standard and the researchers discovered that if equal numerals were at the intersection of the grids, these digits could always be found on the same horizontal line. They noticed that a new variation of the combinative chart had been created. Only the widest part of the trapezoid diagram has been used for this purpose since in the decreasing areas some of the combinations were missing (though sometimes the diagram was completed with one square).

The reason why we do not give an extra presentation of this variation among the examples is that this diagram has also been created by other initiations, the calculation system is the same, there is only a slight difference in the placing of point 0 – whether it is put on the vertical (y) or the horizontal (x) line or at the intersection of the two lines (x, y).

The Greeks also dealt with the combination of numerals. Diophantos the Greek mathematician, in his work "Arithmetica" examined some interrelations of the integer numerals, basically such problems which belong to the scope of "Theory of numerals" in our terminology. The a.i + b.j = n – called the Diophantine equation – where n is the distance to cover, – a and b the sizes of components, – i and j define how many of them are needed to cover n. To find the solution, Diophantos elaborated a diagram, called the Diophantine diagram. In it one of the two combinative digits was put on the horizontal, the other on the vertical line (axis), while the distance line at a 45^0angle touches both of the digit lines. From this all the combinative digits lines are drawn, parallel to the other, creating a grid. All these lines intersect the distance line. The solutions can be found where the lines intersect each other at the distance line (Fig. 2).

Later the diagram was partly modified. At the bottom there is a horizontal scale, from its origin a vertical line is rising – from the mid-height point of the latter start the two digit lines in an absolute symmetrical angle between 30-90 degrees. From the digits – as before – lines are drawn, forming a grid and intersecting the triple intersections with the distance line. The distance line rises from the scale from the point of its value (Fig. 3).

Nevertheless all the other arrangements, proceedings – as shown here – are functioning exactly the same way.

Most of the methods discussed above have used similar elements in their solutions. It was about the middle of the last century, when an English mathematician, P. H. Dunstone (with Hardig and Valance, members of the Building Research Station) developed another method for the combination of dimensions (he is the first who called this graph "combigraph"). His method is rather unique, and takes the following steps:

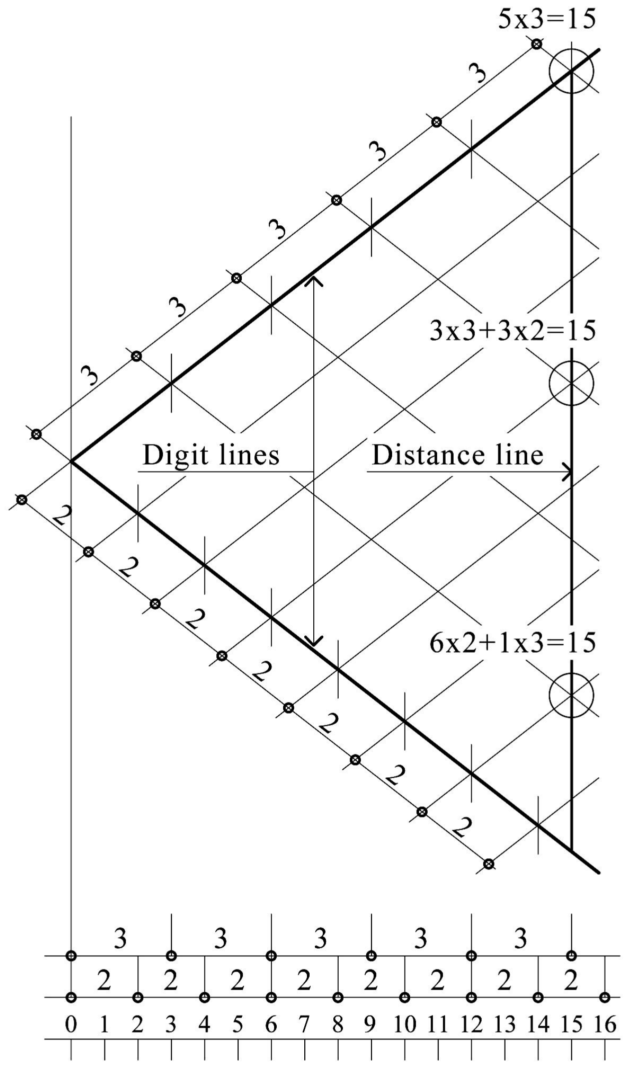


Fig. 3. Combigraph with modified Diophantine method. Distance to be covered: 15, combinative digits: 2, 3.

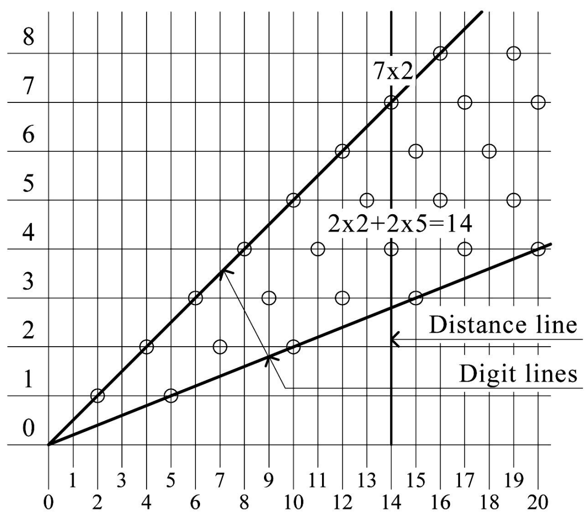
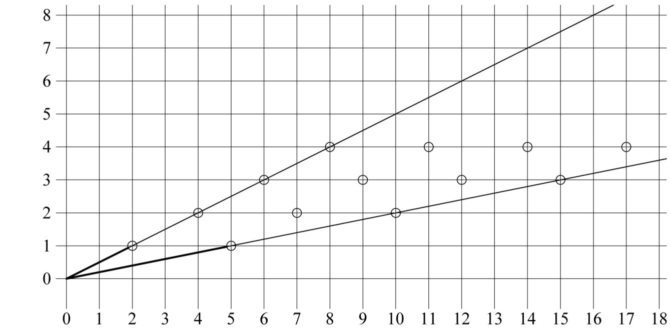
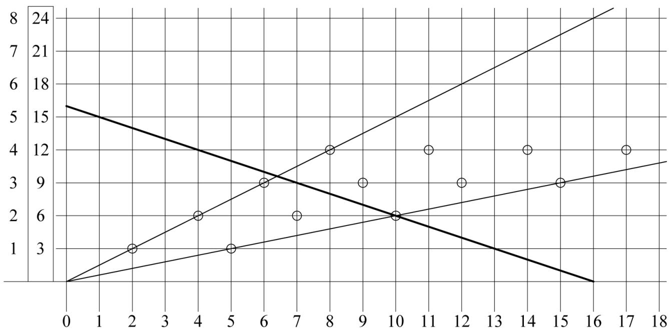


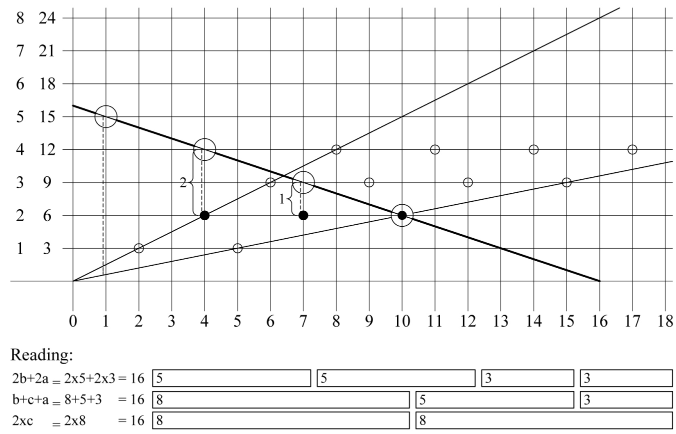
Fig. 4. Combigraph with Dunstone method. Distance to be covered 14, combinative digits 2, 5. The vertical distances are doubled for the sake of better reading



(a) The two larger combinative digits (5,8) have to be reduced by the smallest (3). 5-3=2, 8-3=5. They are illustrated on the diagrams as such nevertheless they maintain their original value).



(b) 5/2 To the vertical scale a new one is added with the increment of the smallest digit (3). The distance to be covered (16) is marked by a line starting from the X axis at 16, arriving to the Y axis at 16 of the modified 3 as increment) scale.



(c) The triple intersections of the grid lines and the line of the distance to be covered (marked with circles) are identified. The distance between the triple intersection is always identical with the smallest combinative digit (3). If the vertical lines down from them intersect multiples or combinations, there are solutions. Read as with the pair of digits diagrams, plus add the number of the grids between – marked with broken lines – these represent the smallest of the triplet (3).

Fig. 5. Dunstone triple diagram. Combinative digits 3(a), 5(b), 8(c). Distance to be covered: 16.

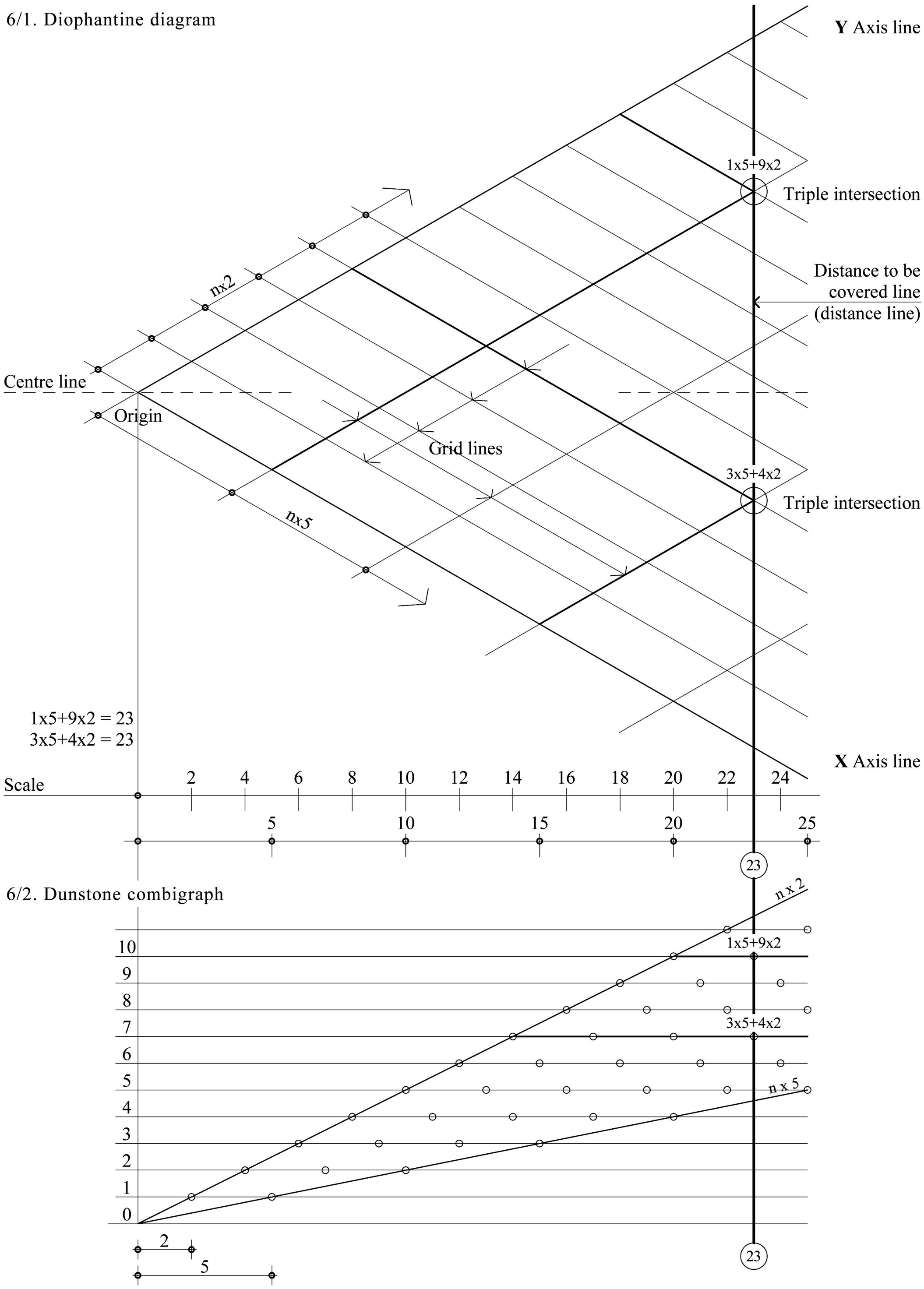


Fig. 6. Combigraphs of 2 digits with Diophantine method (1) and Dunstone method (2). Distance to be covered: 23, combinative digits: 2, 5.

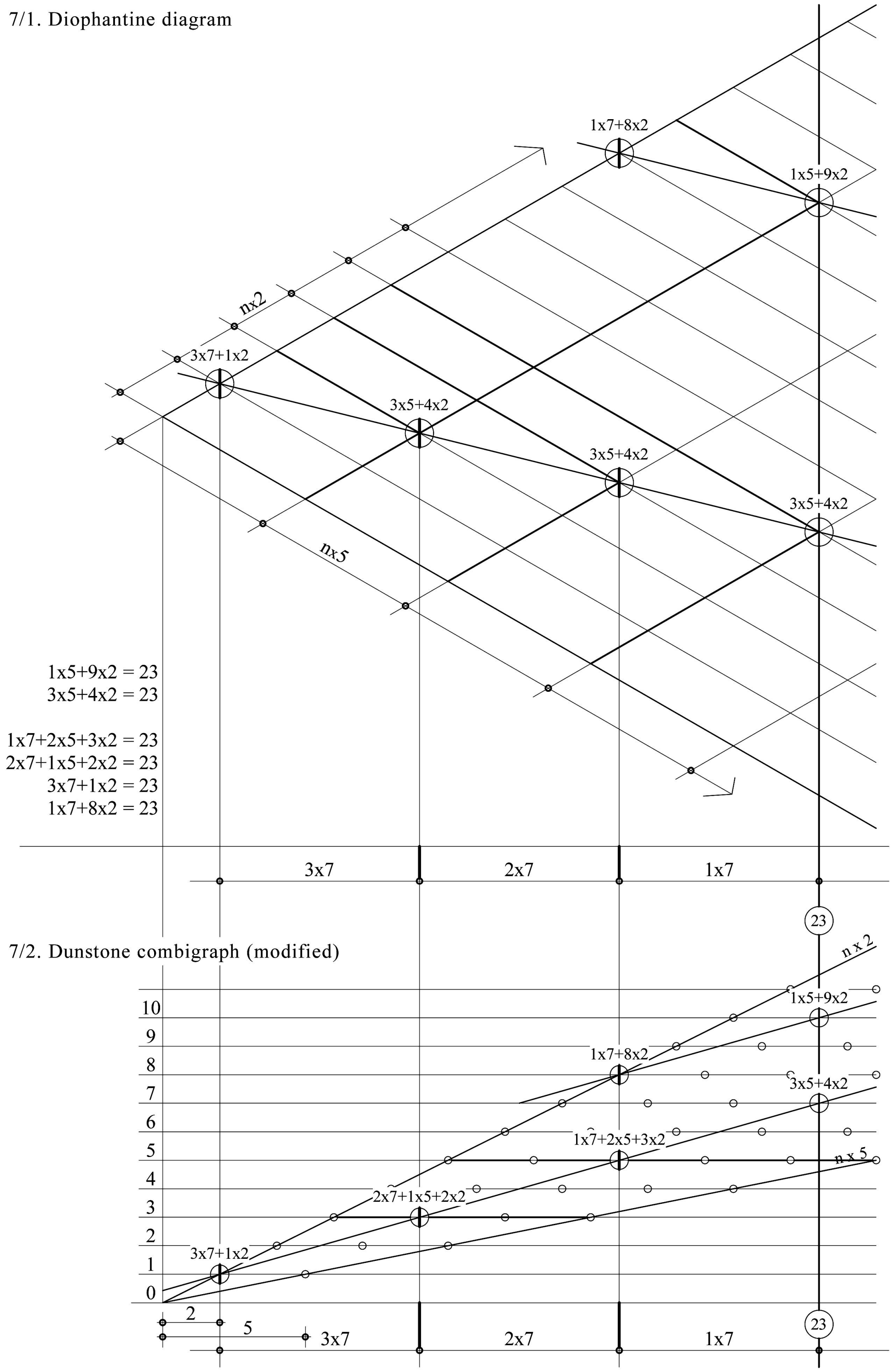


Fig. 7. Combigraphs of 3 digits with Diophantine and B method (1) and Dunstone and B method (2). Distance to be covered: 23, combinative digits: 2, 5, 7.

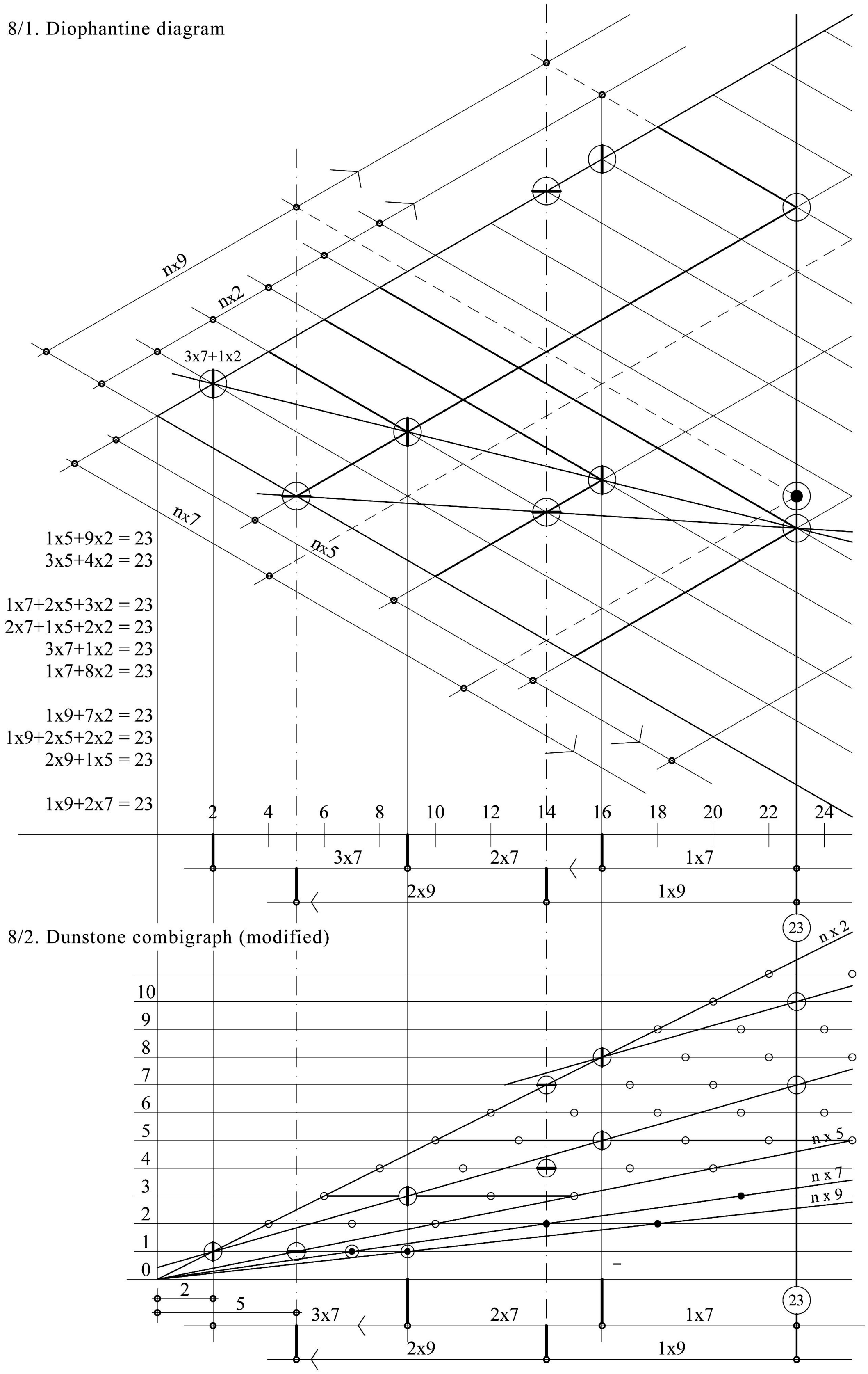


Fig. 8. Combigraphs of 4 digits with Diophantine method and B (1) and Dunstone and B method (2).

Distance to be covered: 23, combinative digits: 2, 5, 7, 9.

A gridded sheet is used, and since the lines of the combinative digits are in a rather acute angle, for the sake of easier reading the vertical scale of the grid it is often doubled (see Fig. 4). Starting from the origin, the lines of the combinative digits rise one vertical unit and as many horizontal units as the number which they represent. Consequently the horizontal distance between the two digits is always a multiple of the first. These also correspond to the number of the lines on which they can be found (i.e. if the number of the line is 6, then there are 6 intervals), and each multiple or combination of 6 components.

The line of the distance to be covered is drawn from the horizontal scale and marked by a vertical line, checking to see if the vertical line intersects with a multiple or a combination within the area defined by the lines. If the intersection falls on a multiple, the value of the intersection is equal to the value of the line. If the intersection is through a combination (a combination always affects two multiples) the rule of the intermediate combinations is as such: starting from the left side multiple, at every intersection the multiple is reduced by one, and the right one increases by one.

Dunstone and his colleagues were ambitious enough to also try and find the solution for a triple combination. The effort was successful. While it's a bit complicated, this paper puts together the stages of the diagram drawings and the explanatory texts; see Figs. 5a, b, and c!

At the Technical University of Budapest we have developed such a variation for this, where the diagram has only a lower horizontal numeral sequence, from its point 0 a vertical line is drawn, and from the mid-height of which the two lines with the horizontal axis of the 'V' of the combinative numerals start. These axis are closed by the vertical line of the "distance line" intersecting the horizontal sequence (in this way only one sequence is needed). Besides this, the variability of the horizontal V-shape and its angle is very favourable for example when a very long sequence is needed.

After a while there were suggestions to extend the number of digits to 3 and 4, to increase the number of digit combinations. I have succeeded in working out a method (also called "B" method).

The third digit is represented by vertical lines, starting from the distance line, parallel to it, and approaching the origin. The gap between the verticals equals to the third digit (7). The value of the line increases approaching to the origin (7, 2×7, 3×7, etc.). The vertical third digit lying at triple intersections with the grid lines of the two smallest digits are marked by circles and listed (it is like all the multiples of the third digits were distance lines) (Fig. 7/1) – This is the combination of three digits.

The combination of the fourth digit runs exactly the same way as the third one, just the gaps between correspond with the fourth digit, in our case 9 (Fig. 7/1).

For the sake of completion, the two last multiples (7,9) are also placed on the axes lines to check whether they perform further triple intersections. If yes, they are marked. Nevertheless, most of the users, having more than enough combinations, leave it off. This also shows that it would make no sense to force the combination of further digits. In Hungary there is also an excellent computer program for 6 combinative digits, produced by Árpád Borbély, a superb, self explanatory production.

The discussed method can also be applied together with the Dunstone combigraphs- both for 3 or 4 combinative digits.

- The inclination of the two digit lines are to be made as usual with the Dunstone combigraphs.
- Then the vertical lines of the third and fourth digits must be placed, as described with the "B" diagrams. (That is the only thing to adopt.) They must be in the range of the 3 and 4 digits from the distance line and each other (Figs. 7/2, 8/2).
- The reading of the multiples and combinations operates again in the usual Dunstone way.

These combinative methods are very simple and very fast, which ensures their use. Beyond that, a good idea in any circumstances, may create several others, even in totally different areas.

In completing this brief survey of the combigraphs, I have also tried to provide a little historical background. Of course in reality the computer is faster, performances are better, even superb; nevertheless "ideas" may also have their part to play and their own intrinsic value.

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