Notes about the programming of the Urban Metric System

1. Step 1: Only input of the program: the disaggregated spatial distribution of dwellers and workers.
2. Step 2: compute and illustrate the vectors at each square of the grid (graph of page 2 illustrates step 2; to add two vectors originating from the coordinates 150 and 40, we and ending at points whose coordinates are 160 and 50, and 158 and 25, we must translate the coordinates in such a way that coordinates 150 and 40 become coordinates 0 and 0, which implies that coordinates 160 and 50 become +10 and +10, and coordinates 158 and 25 become +8 and -15; then the resultant starts at point 0, 0, and ends at 10 + 8 = +18 and 10 – 15 = -5; if there numerous vectors starting at point 0, 0, the extremity of their resultant is given by the sum of all the y-values and by the sum of all the x-values of the extremities of the added vectors).
3. Step 3: Find the urban area center, which corresponds to the main point where all the neighboring vectors converge.
4. Step 4: Draw 120 rays (or more) originating from the urban area center.
5. Step 5: Start with a very obvious divergence point (surrounded with outward-oriented vectors).
6. Step 6: Find the optimum on that ray. To do so, see graph of page 3. Select point A1 and compute the resultant of all the attractive and repulsive forces exerted on that point by all the dwellers and workers in the considered space. Then project the resultant on the ray in a perpendicular way. This is done easily if the ray has been rotated around the center in order to make it parallel to the y-axis. On the graph of page 3, the projected resultant points towards the center, so the optimal point must be farther from the center. We then select point B, which is farther; we compute the resultant of all the forces at that point, and we project it on the ray. The projected resultants points towards the opposite direction of the center. So we must select a new point of the ray that is located between A1 and B. We do this till the projected resultant is null.
7. Step 7: The optimal point having been selected on the first ray, we select, on the next ray, point A2  located at the same distance as the one that separates the center from the optimum on the previous ray (see graph of page 3). Rotate the second ray and make it parallel to the y-axis.
8. Step 8: Find the optimum on the second ray, and proceed the same way for the 118 following rays. Proceed that way clockwise after having proceeded counterclockwise.
9. Step 9: Compare the clockwise and counterclockwise layouts to identify the problem zones.
10. Step 10: In order to fix the problems, two approaches: 1) Proceed from the highest “zero resultant radius” and reduce it by a distance getting smaller and smaller as we get closer to the center, while eliminating all the dwellers and workers located outside the boundaries computed at each step (this is likely to considerably reduce the number of problem cases); 2) To fix the remaining problems, apply the 5 following rules:
    1. If the vectors of a problematic zone are part of a flow oriented towards the center, the problematic zone must be included;
    2. If the vectors of a problematic zone are part of an outward oriented flow, the problematic zone must be excluded;
    3. If the vectors of a problematic zone are oriented in all directions, the median boundary must be chosen;
    4. If the vectors of a problematic zone are converging toward the center of the problematic zone, the problematic zone must be excluded;
    5. If a problematic zone is very small, the median boundary must be chosen.
11. Step 11: Link the various optimal points by means of a smooth curve.
12. Step 12: Compute the urban areas populations and densities on inhabited surfaces (excluding the uninhabitable surfaces, e.g. rivers, lakes, oceans, etc.). Compute the “onion rings” densities in order to determine the rural/urban limit separating densities higher and lower than 100 persons per km2. Compute three urban sprawl indices:
    1. Urban sprawl index 1: S1 = surface of the area between the rural/urban limit at time 1 and at time 1+z;
    2. Urban sprawl index 2: S2 = (density of outer suburbs) / (density of the central city);
    3. Urban sprawl index 3: *S3i* = (*yi* /*yw*), where :

*yi*  = mean distance to the center of metropolitan area ***i*** having a dweller-and-worker population *xi* ;

*yw*  = value of function MDC for a population *xi* ;

MDC function is the following: (mean distance of residents and workers from the center) = f (number of residents and workers of a metropolitan area), this function being estimated by means of the application of the Urban Metric System to most metropolitan areas of the world.

If *S3i* < 1 , the metropolitan area is considered **compact**.

If *S3i* = 1 , the metropolitan area is considered **standard**.

If *S3i* > 1 , the metropolitan area is considered **sprawled**.

The larger *S3i* is, the more the metropolitan area is sprawled.

The smaller *S3i* is, the more the metropolitan area is compact.