A DEVICE FOR STUDYING ALGORITHMS FOR REGULATING STREET TRAFFIC

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S. V. Yablonskii, A. M. Gilman, I. V. Kotelnikov, and P. M. Potylitsyn

A DEVICE FOR STUDYING ALGORITHMS FOR REGULATING STREET TRAFFIC

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The growth in the intensity of urban transport traffic leads to an expansion of the means of regulation; the use of automatic devices appears especially promising. Simple automatic devices have become widespread, in which the traffic regime changes periodically. Recently there have been reports of the creation of more complex automatic devices. It is clear that the structure of an automatic device must depend both on the character of the traffic flow and on the requirements connected with optimality of regulation. However, as shown by the studies of V. K. Korobkov, carried out by him in 1956–1958 at Moscow State University, the mathematical calculation of such automatic devices is extremely complicated even in the simplest case. In this connection the question arose of creating a device for selecting the optimal control algorithm. In 1959 a device of this kind was created at Gorky State University; the present note sets forth the principles of operation of this device.

1. In order to make more precise the problem of finding the optimal control algorithm, let us clarify the basic elements with which the movement of transport through an intersection is connected.

First of all, it is necessary to single out the flow. Usually, when approaching an intersection, transport is arranged in several rows, which may be divided into three groups: the 1st group (counting from right to left) makes a right turn; the 2nd group moves straight ahead, and the 3rd group makes a left turn and a U-turn.

A flow may have the most varied structure. Thus, a flow will be deterministic if a column of cars is moving, or if at certain moments of time transport is admitted at a neighboring intersection in the direction of the intersection under consideration. In many cases the appearance of cars at an intersection may be regarded as a random event. Here the flow will be random. In calculations, as a rule, there is no need to know the entire structure of the flow; it is sufficient to know some of its characteristics, such as the average density of the flow or the parameters of the law of distribution of the appearance of cars, etc.

Another element is the intersection itself. From a geometrical point of view, intersections are divided into T-shaped, four-way, etc. Each intersection is characterized by the conditions of passage through it. The streets adjoining an in-

Fig. 1

Figure 1: Fig. 1

tersection may have one-way or two-way traffic; for each direction in the vicinity of the intersection a permissible number of lanes is specified; there are various kinds of signs and lines indicating the direction of permitted traffic, etc. Finally, each intersection is characterized by the type of traffic light (three-aspect, four-aspect, etc.).

The third element is the control algorithm. Each possible position of the traffic light determines the directions in which movement is permitted, i.e., a certain mode. In the case of a four-way intersection with a three-aspect traffic light there are 2 main modes and one transitional mode; with a four-aspect traffic light there are 6 main modes (see Fig. 1) and 15 transitional modes.

At each moment of time the intersection is in a certain state, i.e., within some fixed neighborhood of the intersection the traffic occupies a certain position. The control algorithm is

Fig. 1

a rule which, for each moment of time, determines the mode on the basis of information about the traffic-light mode and the state of the intersection at preceding moments of time. Thus, the following rule of control will be an algorithm: the modes $A, B, D, , , E$ are switched on successively, each for a certain number of units of time. After mode E, mode A is switched on again. When switching from one main mode to another, the corresponding preparatory mode is switched on.

2. From the preceding it is clear that for one and the same intersection and flow structure many control algorithms can be proposed. For example, if in the preceding example one varies the duration for which the main modes are switched on, different algorithms are obtained. In order for the problem to have a definite meaning, it is necessary to agree on the indicators by which the algorithms are to be compared. They can be compared by estimating the average waiting time of each car, the total delay of cars at the intersection over some period of time T, the maximum length of a possible queue, the complexity of the circuits implementing the algorithm, etc. From this point of view, for example, we may assert that algorithms with a periodic change of modes (automata without feedback), generally speaking, are worse than algorithms that take into account information about the state of the intersection (automata having feedback with the flow), if one strives for a minimal waiting time. In the general case, a mathematical comparison of algorithms is a difficult problem, from the solution of which we are still far. But if an automaton is installed at a particular intersection, then observations can always be used to indicate its weak points. However, experiments at a real intersection require a

Fig. 2

Figure 2: Fig. 2

great expenditure of time and labor. In this connection there arises the question of creating a device with a stand that would make it possible, under laboratory conditions, to observe the movement of the flow under a specified control algorithm. The latter, in view of the convenience of visual observation, would give a clear advantage over the evaluation of control algorithms carried out on universal computers.

3. In modeling control at an intersection, we have to simplify the situation somewhat. First of all, the flow is discretized in time. Let us introduce discrete time $t = t_0 + k\tau$. The time step τ is chosen on the basis of the average time required in the neighborhood of the intersection for a car to traverse a distance equal to its own length and the interval between cars. We assume that along each track, modeling one of the lanes, at the moments of time corresponding to all integer values of k, a car either approaches the intersection or does not approach it. Next we chose the type of intersection, stopping at the cha-

in the characteristic case of a four-way intersection, to which streets with two-way traffic adjoin. The size of the vicinity, i.e., the length of each lane up to the intersection, is characterized by the time $l\tau$ of unobstructed travel by a car over this distance. The quantity l is the maximum number of moving cars that can be placed along the entire length of a lane in the vicinity of the intersection. We assume that the intervals between cars in motion and at rest are the same. We neglect the transient processes during starting from rest and braking, assuming that they occur instantaneously.

Next we assume that control is carried out by means of a four-aspect traffic light. With such a signaling system, a right turn is usually permitted on any light except yellow, i.e., in essence the right turn is not controlled. Therefore we have neglected the flows of cars making a right turn. For this reason the model has only 8 lanes, each of which models one group. By choosing the value of τ, it can always be assumed that a group contains exactly one row. Finally, the algorithm issues regimes for times that are multiples of τ, using information from the entire vicinity of the intersection, i.e., taking into account the presence of at most $8l$ cars.

Fig. 2

Figure 2 shows the block diagram of traffic regulation at an intersection that underlies the construction of the model. The random flow of cars is modeled by means of 8 noise generators strobed by a clock generator. These generators give different random distributions of the number of pulses generated during some preassigned number of clock periods. Each pulse "represents" a car that has approached the vicinity of the intersection. The clock frequency is chosen

Fig. 3

Figure 3: Fig. 3

so that the time interval τ_1, on a certain scale, represents the real time τ. In modeling, τ_1 is selected for convenience of visual observation. In the constructed model it was taken that $\tau_1 = 15$ sec.

The generators provide for adjustment, making it possible to change the flow density, the average number of cars over a specified interval of time, etc. Since a separate generator operates for each direction, it is possible to model different "loads" in different directions.

To count the pulses "representing" approaching cars, 8 reversible binary counters, implemented with relays, were used. In the model it was taken that $l = 15$. Each counter had 4 digits. If passage through the intersection in a certain direction is prohibited, the corresponding counter operates in addition mode. If passage is permitted, then for the duration of the strobing pulse the counter changes its operating mode. First it operates in subtraction mode (a car leaving the intersection), then in addition mode. In this way the possibility of cars simultaneously approaching the intersection and leaving through the intersection is modeled. When adjusting the generators, i.e., when selecting the distribution parameters, one should be guided by statistical data on the flows at the intersection under study. Deterministic flows of cars can be modeled by means of punched tape. The advance of the punched tape must be strobed by the clock generator. The data on the punched tape can be transferred directly from the intersection under study.

On the panel of the observation console (see Fig. 3), the arriving cars were recorded by means of a line of 15 incandescent lamps for each direction. The inputs of these lamps were connected to the outputs of the relays of the reversible count-

through a special decoder. The traffic-control algorithm is implemented in the programming unit (P. U.). In the code-conversion unit (U. P. K.), information received from the intersection is processed in accordance with the algorithm; as a result, instructions are produced for controlling the flow of cars. On the basis of these instructions, signals are generated that switch on the traffic light. On the observation panel (Fig. 3), a four-lamp traffic light, made with incandescent lamps covered by colored caps, is installed for each direction. The processing of information performed in the U. P. K. is associated with carrying out arithmetic operations, such as comparing counter readings, determining the total waiting time of cars while taking into account the time for an individual car to approach the intersection, etc. The functions of the P. U. and U. P. K. can be performed by a universal digital computer. In this connection, the model provides for the possibility of connecting the GIFTI digital computer as the element indicated in the block diagram by a dotted line.

Fig. 3

However, for testing many algorithms of practical interest, comparatively simple specialized digital devices can be used as the P. U. and U. P. K. In the model, such a device, made with relays, was used. This device made it possible to implement the algorithm given above, as well as an improved algorithm in which the traffic mode is switched off immediately after the queue of waiting cars has been exhausted, and the switching-on of the traffic mode is blocked if the number of cars waiting for this mode to be switched on is less than a certain number j $(0 \leqslant j \leqslant 4)$. The number j was set in advance by means of a plug-in device.

Research Institute of Physics and Technology
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Note: Figure translations are in progress. See original paper for figures.