MOVEMENT AUTHORITY SETTING ALGORITHM FOR MOVING BLOCK SYSTEM

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Abstract:
Now a day, the Korean National Railroad is taking new age with the opening of KTX (Korea Train Express). Korean National Railroad is planning using the GSM-r for put KTX and existing equipment to a good. GSM-R is radio communication method selected by ERTMS (European Rail Traffic Management System). So a new algorithm for train movement is necessary to radio communication form. This paper is come up with an algorithm for like that situation.

Keywords: Train, Algorithm for GSM-r, Radio communication.

1. INTRODUCTION

Communication based train control system is applied regularly worldwide. And this system may be used in domestic soon. Communication based train control system does not depend on conventional track circuit. Therefore, position and distance control of train to prevent collision with leading train may become important safety factor. This paper developed train control algorithm using movement authority of several units efficiently for this.

Suppose that On-board equipment of CBTC (communication based train control system) is installed on operation all trains. When these trains are operation, send-receive through communication with adjoins train or wayside equipment that necessary various data are different in train safety running do. The train borne equipments of CBTC system is installed to all the trains running on the lines. When these equipments run along the track various data required for safe train operation will be transmitted by communications with other adjacent trains or wayside equipment. Each train borne equipment installed to the train can be known constantly the information such as the movement authority against of the leading train. Therefore, deceleration value to avoid the collision with the preceding train or acceleration value can be determined. Deceleration or acceleration like this shall be taken into account for avoiding collision with other trains including following train as well as that with proceeding train.

In this paper, Main contents consider comforts ability to position that safety is guaranteed, develop algorithm to do so that can run adaptively to running speed profile that train is established. Train borne equipments analyzes received information for this algorithm, must do train control of most suitable. Of course, must establish efficient train running plan for this. The most important thing in that establishes running plan is safety. But, it is important factor as well as passenger's comforts ability.

Explain about algorithm to decide movement authority in chapter 2 of this paper that see according to these contents. And show simulation for performance estimation of algorithm and the result that is developed in chapter 3. Finally, explain about conclusion in chapter 4.

2. MOVEMENT AUTHORITY SETTING ALGORITHM

Flow chart of general algorithm is like that Fig. 1.

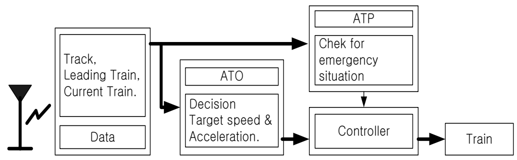

Fig. 1 Movement authority setting flow chart.

Chapter 2.1 introduce calculate method of acceleration profile, and chapter 2.2 described about the proper equation for setting MBS(Moving Block System) level according to flow chart Fig1. Finally chapter 2.3 presentation about Movement authority setting algorithm in base of contents ch.2.1 and ch.2.2.

2.1 Acceleration profile of Train.

The most important things are comfortable and safety of passengers at train running algorithm. So a train must set acceleration and deceleration that passengers don't feel a jerk. For this reason, if we have a target speed that we want to reach, a train should have such as following velocity profile.

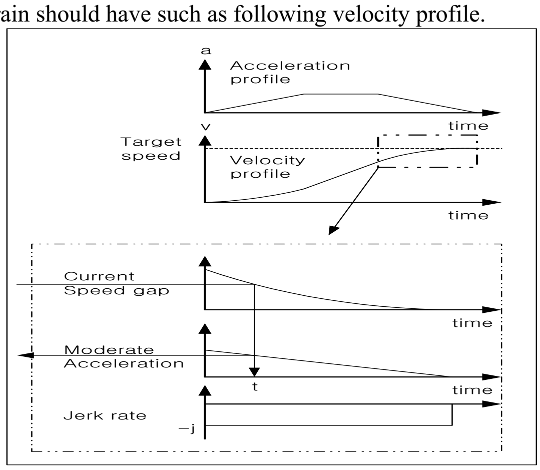

Fig. 2 Calculate acceleration from velocity gap.

$$jerk_{rate} = jerk \ (\ Constant\ value)$$

$$a = jerk \times t + c_1 \quad (1)$$

$$v = \frac{1}{2} jerk \times t^2 + c_1 t + c_2 \quad (2)$$

$$t = \frac{-c_1 \pm \sqrt{c_1^2 - 2jerk(c_2 - v)}}{jerk}$$

$$t = \left. \frac{-c_1 + \sqrt{c_1^2 + 2jerk(v_{abs} - c_2)}}{jerk} \right|_{v_{abs} = |v|} \quad (3)$$

We evaluate the acceleration of train substituting time t into equation (1). The difference between target velocity and current velocity, v, is substituted into equation(3) to evaluate the new time t. Then, the acceleration is calculated using above t from equation (1). Because the order of train velocity equation is second-order related to time t, there can be the imaginary time t in the solution of the equation (1), when v > 0. Since, time t has to be always positive real number, we re-define v as follows.

v = -abs(v_err)

Using above evaluation process, we can estimate optimal train acceleration on real-time whenever the velocity difference between velocity profile and current train velocity is measured at time t. Then, the train operates to follow the optimal acceleration. In this case, train increase the velocity more and more to meet the target acceleration keeping the jerk of train under the predefined limits

2.2 Movement authority

Train receives periodically the current position of itself, the position of leading train, velocity limit of the current block which the train is running on, velocity limit of next block and the distance from current position of itself to next block.

We can safely schedule the train movement from above informations.

1. Train has to be kept under the current block's velocity limit.
2. Train has to be decelerated to the next block's velocity limit.
3. If train is running on the yellow block of movement authority level of leading one, then the train has to be decelerated.

Considering the position of leading train, current train estimates the red zone which is never violated, yellow zone which is decelerating zone, and blue zone which is irrelevant to the leading one. Then, train operates properly according to the estimated zone.

In this paper, we used the model of safety braking model to set movement authority as follows.

Safety braking model defines the position which train never violates considering worst cases. In this model, the check points look like followings. Briefly speaking, they are measurement tolerance of train's position, over-run velocity above the block limit, measurement tolerance of train's velocity, response and delay time of the systems, maximum response time of emergency braking system regarding to over-acceleration, deceleration rate of braking system, gradient and curvature of line, and safety braking distance evaluated according to the track of database which operates in vehicle on the board. Supervisory brake distance, S_spv, are general-purpose requirements of brake distance to reach target position given by ATP(Automatic Train Protection system). In S_spv variables, there are maximum supervisory brake distance to evaluate minimum length of yellow block, S_spv.y, and minimum supervisory brake distance to evaluate the minimum length of red block, S_spv.r.

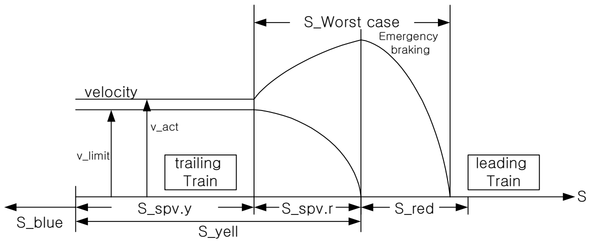

Fig. 3 Safety braking model

$$S_{spv\_y} = jerk_{in} + \frac{1}{2}\frac{v_{enter}^2 - v_{out}^2}{-a_{spv}} + jerk_{out} + v_{enter}T_{SB} \qquad (v_{enter} = v_{act})$$

$$S_{spv\_r} = \frac{1}{2}\frac{v_{enter}^2}{-a_{spv}} \qquad (v_{enter} = v_{limit})$$

$$jerk_{in} + jerk_{out} = \frac{1}{2}\frac{v_{enter} \times (-a_{spv})}{jerk_{rate}}$$

$$jerk_{rate} = max\ jerk$$

$$S_{yell} = S_{spv\_y} + S_{spv\_r}$$

2.3 Movement authority setting algorithm

In this paper, using the algorithm of movement authority level depicted in the paragraph 2.2, we present the effective algorithm of movement authority.

A. Case of track limit velocity.

Target velocity of train is set to track limit velocity to keep the train velocity under the track limit velocity. Acceleration of train to reach target velocity is evaluated using equations in the paragraph 2.1. Then, next track limit velocity and the distance to the next track is considered to check up violence of yellow zone of next track. When the violence is detected, the train is decelerated. In this process, we used following equation to re-calculate yellow zone of next track.

$$S_{yell\_track} = jerk_{in} + \frac{1}{2}\frac{v_{enter}^2 - v_{track\_limit.velocity}^2}{-a_{spv}} + jerk_{out} + v_{enter}T_{SB}$$

Red zone is not related to the concept of track limit velocity. When the train violates the next track's yellow zone, we calculated the difference between track limit velocity and train's current velocity, and then re-evaluate the some time using equation (3) in the paragraph 2.2. Optimal acceleration of train is evaluated from equation (1) of the paragraph 2.1 using this time t. Train is accelerated to the acceleration keeping the train's jerk under predefined limit.

B. Case of leading Train velocity.

Target velocity of train under consideration is set to leading train velocity. Leading train's velocity is measured and calculated by displacement of itself. In algorithm of estimating optimal acceleration described previous paragraph, we set the acceleration to make the difference of velocities be zero. However, keeping distance between current rain and leading train has to be determined considering leading train's velocity and trailing train's deceleration capability. It difference from case of track limit velocity. This keeping distance has to include the sufficient buffering zone which is related to train's length. Therefore, yellow zone has to be redefined in this case as follow. In this paper, it is called the case of leading train velocity.

$$S_{yell\_car} = S_{spv\_y1} + S_{running\ area} + S_{spv\_y2} + S_{spv\_r}$$

$$S_{running\ area} = \frac{S_{spv\_y}}{2} + Train\_Length$$

$$S_{spv\_y1} = S_{spv\_y2} = \frac{S_{spv\_r}}{2}$$

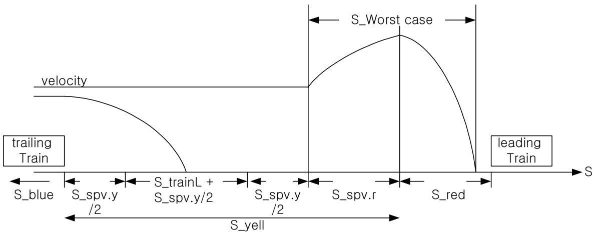

Fig. 4 New MBS level setting

When train violates S_{yell_car} zone and is given by appropriate operations, it is expected that velocity difference come to be zero in the $S_{running\ area}$ zone. When leading train is decelerating, trailing train goes beyond $S_{running\ area}$ zone and into S_{spv_y2} zone at least to be $v_{err} \geq 0$.

In this case of $v_{err} \geq 0$, the train is designed to be always deaccelerated, since the train runs on S_{spv_r} zone.

C. Block diagram of total system

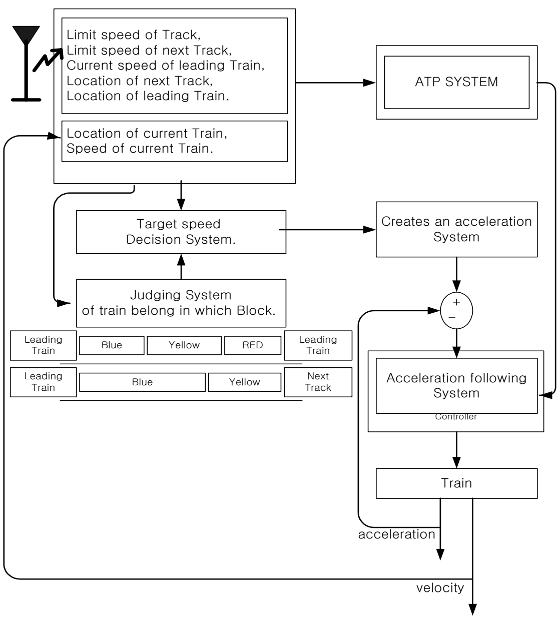

Fig. 5 Train movement algorithm Block diagram by MBS

We first receiving Data (limit speed of track, leading train position, and etc). Second step is decision target speed by the Target speed decision System and Judging System of train belong in which block.. Next step calculate acceleration. Finally, the controller will be accelerate or decelerate, until reach at the calculated acceleration value.

3. SIMULATION

To prove the efficiency of proposed algorithm, we used the Matlab ver6.5 for simulation, the result is follow.

3.1. Train modeling

We construct simulation train model as follow just consider point mass.

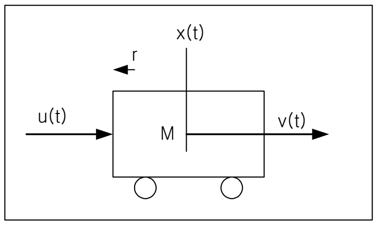

Fig. 6 Simple model of Train

Model equation :

$$\frac{dx(t)}{dt} = v(t)$$

$$\frac{dv(t)}{dt} = -rv(t) + \frac{1}{M}u(t)$$

$$(r : resistance,\ M : mass)$$

Convert to a discrete steady state form to computer simulation.

$$\dot{x} = \begin{bmatrix} 1 & \frac{1}{r}(1 - e^{-rT}) \\ 0 & e^{-rT} \end{bmatrix} x + \begin{bmatrix} \frac{1}{Mr^2}(e^{-rT} + rT - 1) \\ \frac{1}{Mr}(1 - e^{-rT}) \end{bmatrix} u$$

$$(T : sampling\ time)$$

3.2. Result of Simulation.

Now this Matlab ver6.5 simulink model is for prove MA setting algorithm. Blocks of Fig.7 are including Fig.5 block. But exclude ATP block from this simulation. Because of this system suppose ideal case.

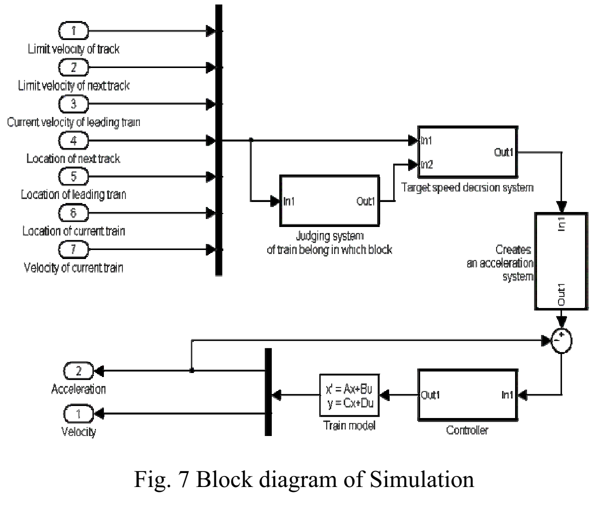

Fig. 7 Block diagram of Simulation

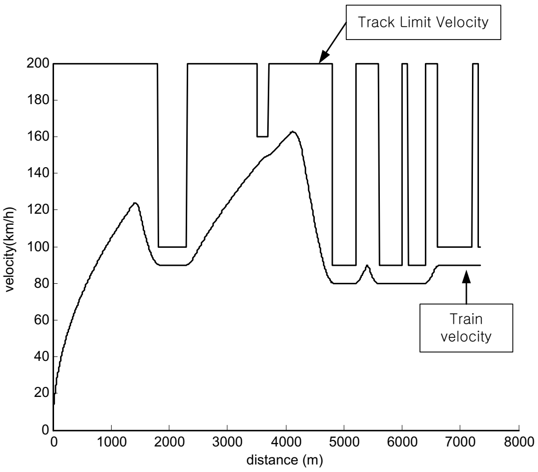

Fig. 8 Case of track limit velocity

At Fig.8 we confirm that trailing train velocity adjust track's limit velocity. And not overrun track limit velocity.

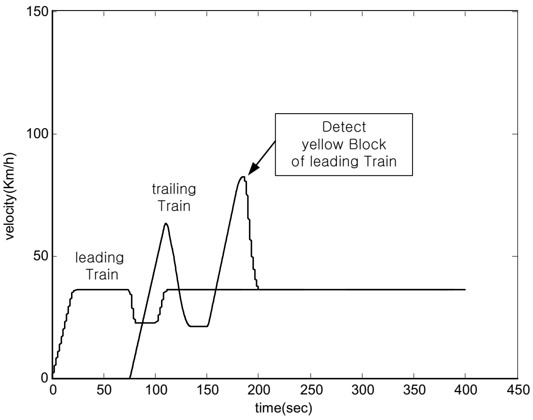

Fig. 9 Case of leading Train velocity.

At Fig. 9 max speed of leading train is 35 Km/h, trailing is 150 Km/h. Trailing train start time is 75sec after leading train. Detecting yellow block of leading train at 180sec and decelerate.

4. CONCLUSION

In this paper presentation an example control algorithm for movement authority train control system based on communications. This algorithm has the advantage of next. The optimum acceleration value calculates is easy using a simple equation. And that is real time algorithm using a velocity gap. So, we think that train movement efficient is increasing by actively reaction according to velocity gap.

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