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Applications

Controlling the Speed of a Coding Line Conveyor Using Fuzzy Logic

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Abstract: *This paper presents performance improvement of a Coding Line Conveyer system (CLC), which is a key component of the automated parcels sorting complexes PP2000 used in logistics centers of Swiss Post. Normally, CLC operates with constant speed. The rules based on a fuzzy logic are applied to adapt the speed of CLC transportation belts. The rules take into account how parcels' parameters as size, surface quality, i.e. number of address regions, type of the address, number of barcodes, series of equal or similar parcels influence the parcels' processing time. As a result the processing capacity of PP2000 is increased. The approach proposed can be applied to similar parcels', letters' or baggages' sorting systems.*

Key words: *Fuzzy logic, control systems, parcels processing, sorting systems.*

Introduction

Automated sorting complexes, integrated in Swiss POST logistics centers, use a Coding Line Conveyors (CLC) system to transport the parcels and an Automated Coding System (ACS) for optical character recognition (OCR) of the parcels' address. The CLC controls the input, scanning and output belts (Figs. 1 and 2) to transport the parcels. When moving on the scanning belt the parcel's surface is scanned by the barcode and OCR readers of ACS. Parcel's address information is used to control CLC belts with commands for starting, stopping or driving them with constant speed. An essential subsystem of ACS is the Interface and Control Manager (ICM) [1].


Fig. 1. CLC input and scanning belts


Fig. 2. CLC output belt

The ICM ensures fine parcels' sorting controlling the internal ACS communications, as well as these ones to the external (PP2000) systems, including CLC. The ICM is developed on the base of Communicating Sequential Processes theory [4] and is fully parallel. It explores the Windows multithreading [6, 7, 8]. Parallel with the parcels processing activities the ICM exchanges information (messages) with the external systems and also collects statistical data for all sorted parcels. The subject of the current paper is to explore the statistical relations between parcel processing time and parcel's parameters, such as dimensions, surface and address type, number of barcodes, etc. Analyzing these dependencies, some fuzzy rules to command CLC speed more efficiently were defined and applied. New speed change commands were integrated in CLC (based on a Siemens controller) and in the protocol between ICM and CLC.

Parcels' parameters subject to statistical explorations

Each parcel has an unique 18 digits barcode (Identcode), as given on the left side of Figs. 3 and 4 and some additional barcodes (see on the right of Fig. 3). The IdentCode (IC) is synchronized with the parcel address data (ZIP code, City, Street and number) provided by the OCR and is used to direct the parcel to the final destination tray after leaving the CLC belts. All other PP2000 conveyers use barcode readers in order to sort the parcels. Barcode readers match the ICs sent to them by the ICM.

There are some requirements regarding the address labels defined by the Post. If they are observed by the customer, the parcel address can be found more quickly. For example, if the label is like the ones, shown on Fig. 3 or Fig. 4, then the OCR algorithm can find easily the parcel barcode and address.

Unfortunately, the rules above mentioned are valid only for the big post customers, such as e-Pay companies, telecoms sending directory books to the end clients, etc., but not for the usual, local customers. Normally, the parcel's label looks like as shown in Figs. 5 and 6 and it is frequently handwritten.

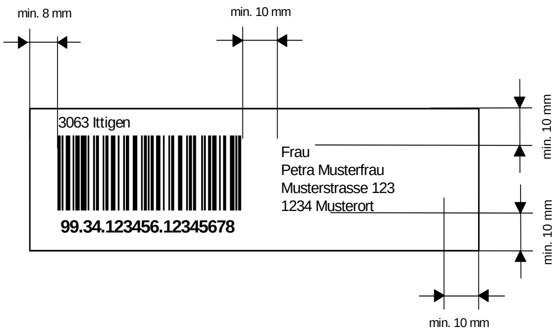

Fig. 3. Address label Type 1

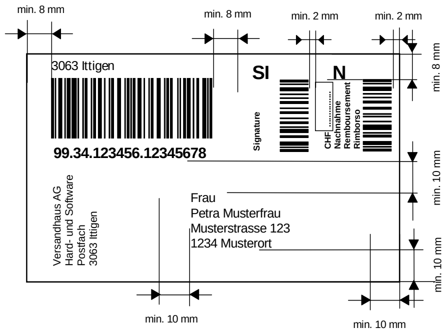

Fig. 4. Address label Type 2

The time for finding the address regions (shown on Fig. 5) and the right receiver address from the scanned parcel surface depends on the parcel size, quality of the parcel cover, availability of additional barcodes or their missing. In some cases, because of the inappropriate parcel cover or orientation (address not on the upper side), finding the correct address automatically is impossible, so human help is needed (Video Coding when the correct address region is selected by an operator and returned to OCR or Manual Coding when the operator inserts the address manually and puts the parcel again on the CLC input belt).

There are cases when OCR is not required because the receiver address (usually P.O. Box) is encrypted in the IC or in the additional codes. Then the parcel is sorted very quickly and OCR resources are for the next parcel.

The OCR is not required, also, when IC is missing, or if more than one ICs are found. Then the parcel's data can not be synchronized and the parcel is sent to Manual Coding.

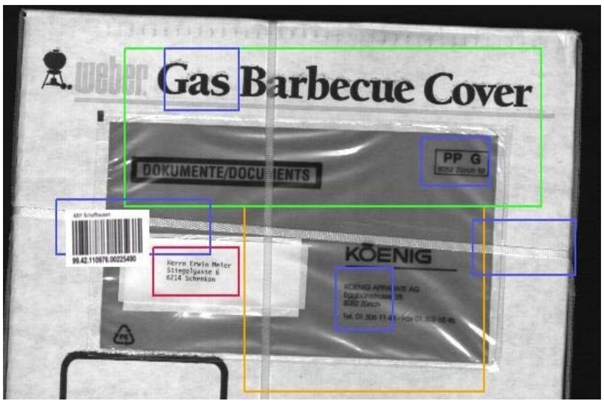

Fig. 5. Typical parcel surface

Fig. 6. Handwritten address

Statistical data collected by ICM

During its work ICM collects statistical data about the processed parcels and periodically stores it in log files. The information that is interesting for improving the CLC control is:

- parcel's decoding time;
- parcel's dimensions;
- time difference between two parcels;
- type of the address (printed or handwritten);
- parcels without IC;
- parcels with more than one IC.

A large number of tests with different number of parcels have been run. Series of 100, 500, 1000 and 2000 test parcels with printed, standard labels and totally unsorted parcels with non-standard surface and handwritten labels were used to find dependencies between parcels decoding time and parcels dimensions. Some of the statistical data are shown in Table 1. The first column of the table – proctime shows the processing time in ms; the second column presents the IC. The third column (adrtype) describes the type of the address label. Type "A" is a machine written one and type "M" is a manual written address. The last three columns in the table are related to the ZIP code (postcode) of the parcel and its dimensions.

The coefficient of correlation has been estimated to determine the significance of the relation between the parcel size and the processing time. The collected statistical information has been processed, using the application for data mining and statistical analysis – SPSS [10]. The data has been aggregated and the determination coefficient has been estimated. The results obtained have shown that many changes of the processing time are caused by changes in the parcel's size. The information retrieved from the OCR has pointed out that the parcels with standard labels are processed for a shorter time and on the opposite, with non-standard labels – much longer.

Forming the rules for speed changing

The evolution of the controllers led to the development of fuzzy expert control systems (FECS). Supervision and diagnostics have been the most successful applications implementing fuzzy reasoning strategies. The diagnostics tasks inform about the result the operator or a hierarchically upper entity (usually by triggering an alarm). The supervision blocks take actions depending on the state (step-point or control parameter change, direct action on some process elements, etc.). The two of them can be understood as a unique task with a main objective: to determine the state of the underlying process, in a mostly qualitative level. [2]

There are three steps to create a fuzzy controlled system:

- fuzzification – using membership functions to describe graphically a case;
- rule evaluation – application of fuzzy rules;
- defuzzification – obtaining the crisp or actual results.

Beforehand, inputs and outputs of the modeled system have been determined. It was already explained how the CLC work, as well as the information collected by the ICM and the relations between the above mentioned parameters. Considering these, the inputs of the model consist of the barcode existence, the type of label and the parcel size. The corresponding output parameter is the CLC scanning belt speed.

Table 1. SPSS view of mentioned statistical data collected by ICM

	proctime	identcod	adrtype	zipcode	length	width
1	390	990012009530177008	A	871200	325	240
2	437	990012009530612034	A	885200	302	236
3	568	990012009530614060	A	883400	313	243
4	462	990012009530614078	M	842400	214	227
5	234	990012120100002010	A	820700	288	240
6	406	990030180003044000	M	901000	272	166
7	859	990018200400004000	M	882000	362	294
8	218	990030650200005226	A	832000	481	376
9	546	990030980100024000	A	862000	252	482
10	765	990031230001038068	A	954200	266	168
11	578	990036050000009000	A	902800	308	231
12	687	990036060077044005	A	902800	340	233
13	203	990036070000065000	A	902800	415	316
14	671	990036120001006000	M	902800	313	231
15	921	990036120003056020	M	820000	451	313
16	328	990036120003056040	A	885200	604	456
17	718	990036140025604088	M	904200	252	220

The first step, fuzzification, is realized on the base of the data retrieved from the ICM. The different levels of the parcel size are defined by specifying the membership function (Fig. 7) for the fuzzy set. These levels are:

- small (parcel size < 2400 cm^2);
- average (1000 $cm^2 \leq$ parcel size $\leq$ 3800 cm^2);
- large (parcel size > 2400 cm^2).

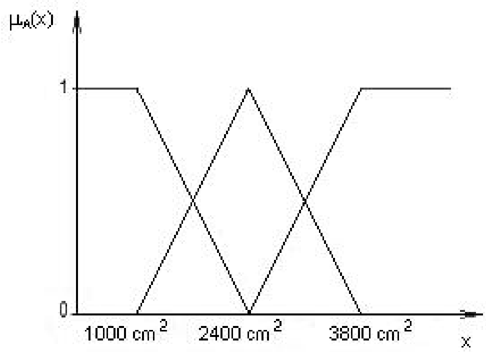

Fig. 7. Membership function for parcel size (*x*)

The label type has currently one value for each level: standard and non-standard. For the output, just like the label type, one value (singleton position) instead of a range of values is associated with each level. The levels of the output are:

- super high (0.8 m/s);
- high (0.7 m/s);
- average (0.6 m/s);
- low (0.5 m/s);
- very low (0.4 m/s).

The next step is to define the fuzzy rules. The rules are formulated using a series of if-then statements combined with AND/OR operators. In this particular case the rules are defined from a few statements:

- *IF the ICM has found IC and the parcel size is small and the address is standard THEN the speed is super high;*
- *IF the ICM has found IC and the parcel size is average and the address is standard THEN the speed is high;*
- *IF the ICM has found IC and the parcel size is large and the address is standard THEN the speed is average;*
- *IF the ICM has found IC and the parcel size is small and the address is non-standard THEN the speed is average;*
- *IF the ICM has found IC and the parcel size is average and the address is non-standard THEN the speed is low;*
- *IF the ICM has found IC and the parcel size is large and the address is non-standard THEN the speed is very low;*
- *IF the ICM has not found IC or found more than one ICs THEN the speed is super high.*

The rules are summarized in the table given below (Table 2).

Table 2. Set of rules

Type of label	Size of parcel		
	small	average	large
Standard	*Super high speed*	*High speed*	*Average speed*
Non-standard	*Average speed*	*Low speed*	*Very low speed*

The result of the Fuzzy Controller (FC) implementation is a fuzzy set of speed. In order to choose appropriate representative values for the final output (crisp values), defuzzification must be done. There are numerous defuzzification methods, but the most common one used is the center of gravity of the set [9]. The formula below converts the fuzzy set output to a real crisp value:

(F1) $$\text{Crisp Output} = \frac{\sum \text{Membership Degree} \times \text{Singelton Position}}{\text{Membership Degree}},$$

where:

- *Crisp Output* is the output;
- *Membership Degree* – the membership function $\mu_A(x)$ from Fig. 7;
- *Singelton Position* (0 or 1).

Introducing new commands to control CLC

The FC is implemented as an additional thread in ICM. To change the speed of CLC scanning belt, two new commands are introduced – M33 and M34 which increase and decrease the belt speed by 0.1 m/s. The commands are oriented to the behavior of Siemens-Dematic CLC [5] controller that was also preprogrammed. ICM and CLC are adapted to save information for the current belt speed in order to suppress the speeds over or under the high or low limits. In case there is no need to switch to different speed for the next parcel, CLC continues to operate with the current speed. This ensures high processing speed for the series of equal or similar parcels, which increases the total PP2000 performance.

After the implementation of FC series, tests with the same 100, 500, 1000 and 2000 parcels have been run. The calculations of the average processing times were compared with the ones obtained by the system before FC implementation. After the analysis it could be concluded that the new system improves the performance of this part of the line by 3-5%, depending on the series of the parcels.

The results are presented on Fig. 8. It can be seen that for series with more parcels, the processing time decreases, that can be explained with the bigger possibility for a sequence of parcels with equal dimensions and standard address labels.

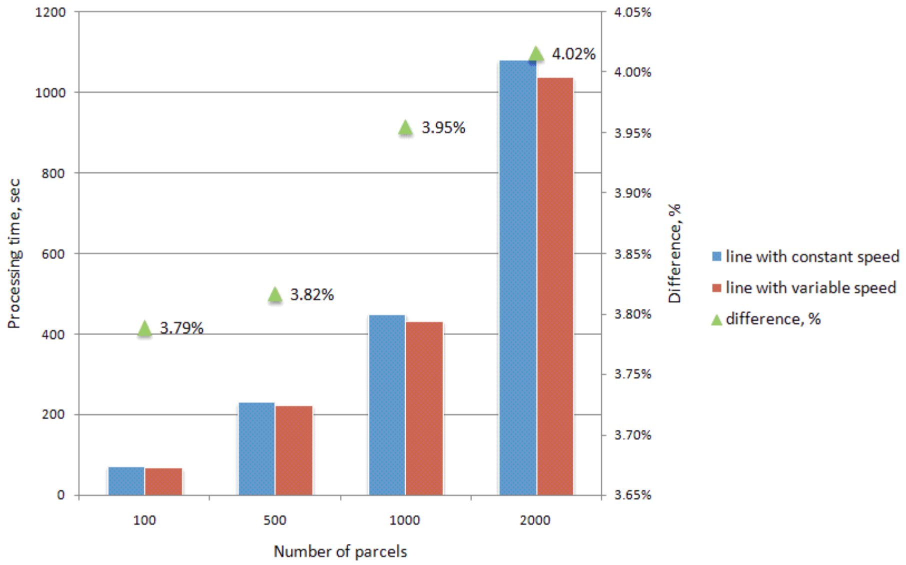

Fig. 8. Parcels' processing time for a line with constant and variable speed

The parameter that can be influenced by the belt speed change is the number of not synchronized parcels. This means that OCR provides the address data after ICM have sent the parcel to manual coding. In order to investigate this case, the results obtained from the test above mentioned, were analyzed in relation to the numbers of the not synchronized parcels. From the results given on Fig. 9, it can be concluded that the difference in the number of not synchronized parcels between constant or variable speed is less than 0.001. The difference is insignificant compared to the number of tens of thousands processed parcels.

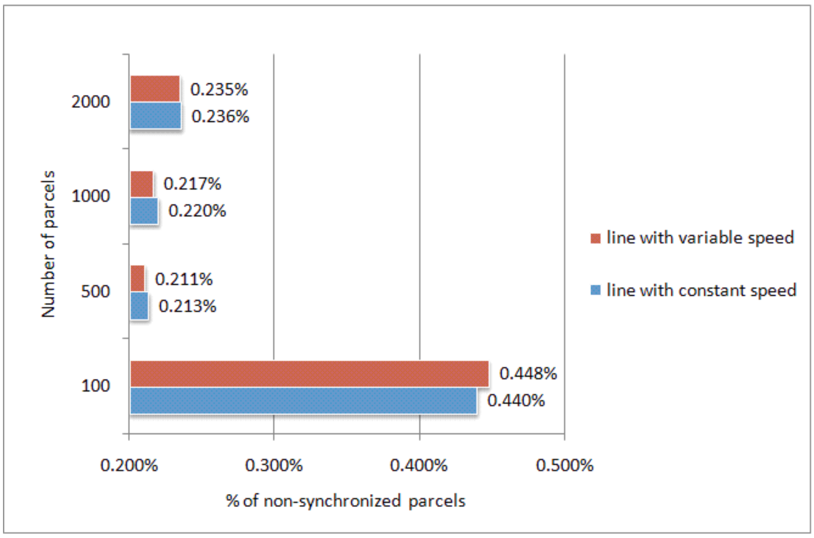

Fig. 9. Non-synchronized parcels for a line with constant and variable speed

Conclusions

The rule based controller proposed processes the parcels better than the current system that operates at a constant speed of 0.6 m/s. It increases the total performance of PP2000 sorting centers. The efficiency increases more than the mentioned 5% in cases, when large series of equal parcels are processed. This occurs frequently when GSM operators or national phone companies send phone books to hundred of thousands or millions of customers. The case is similar when big internet based trade companies deliver catalogues or ordered products to their customers.

The rule based approach presented for belts speed control can be applied in similar sorting systems as the ones for automated letters, baggage's or product processing.

The fuzzy controller is still in process of further developing. It is planned for its future improvement to create two membership functions linked to the parcel dimensions. The one is to correspond to the parcel width, the other – to its length. The outside look of the parcel will also be categorized. The processing time depends on the type of the packing used and can become longer with shiny, multicolored packing or one with patterns.

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