Sketch drawing on infinite paper sheets

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***Abstract*— The process of drawing theoretically infinite drawings on infinite paper sheets is normal for many industries. Ordinary today used techniques exploited for relatively short drawings (size A0 or similar) are useless for this problem.**

The proposed paper presents a solution of a flatbed plotter for drawing long (theoretically infinite) drawings. The problems with paper shifting and rotation as well paper corrugation are solved using specific optical sensor and the appropriate software.

Keywords - optical head, flatbed plotter, optical shift correction.

I. INTRODUCTION

The presented work describes solutions and results obtained in the process of design and implementation of embedded controller of large-scale textile plotter. All presented here solutions were successfully implemented.

The plotters of this type draw drafts for hand-driven cloth cutting. The cutting table is from 10 to 50 meters and this limits the length of the draft. The paper if specific textile paper with plastic film back. Required draw accuracy is 0.05 mm (much lower than regular CNC controlled machines accuracy) which corresponds to the cutting accuracy. Several solutions are known for this type of plotters but the best one is to implement machine able to draw infinite draft without bi-directional paper movement. This is the class of flat-bed textile plotters.

The problem with infinite drawings comes from two main factors:

- The plotter draws the draft frame by frame and has to connect each line crossing frame boundary with accuracy better that the 50% of the drawing tool width.
- The source paper spool is not absolutely parallel to the receiving spool nor to the drawing plane. This results to the fact that the papers shift to the left or to the right on every frame change. Together with this shift, it also rotates. After several frames some corrugations appear.

All of these have to be controlled and corrected by the plotter software. To do this one of the best ways is to use optical sensing to measure all paper movements and corrugations. [1]

Here are presented ideas, solutions and implementations of such a machine.

The paper structure is as follows:

Part I – this introduction.

Part II – basic machine mechanics reflecting to the correction algorithms.

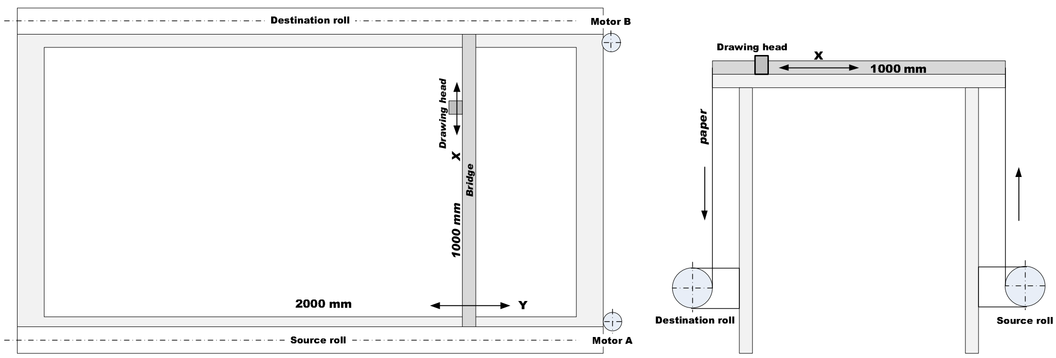
Part III – optical subsystem and markers detection.

Part IV – resulting solutions.

Conclusion.

II. BASIC MACHINE MECHANICS

The presented machine is a flatbed plotter with table size 2000 x 1000 mm working area and 2100 x 1100 mm mechanical size. The view is shown on Fig. 1.



a) Top view

b) Side view

Figure 1. Flatbed textile plotter

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The elements interesting here are the drawing head, which incorporates both pen mechanism, and the optical head designed to solve the problems discussed below. [2]

The sketch is long as much as the designer needs (more than 1000 mm). Virtually all lines are continuous, but practically they are drawn frame by frame as is shown on Fig. 2. Here F1 to F4 are sequence of frames. The line is drawn with 3 break points B1 to B3. Finally, after finishing we have a single line.

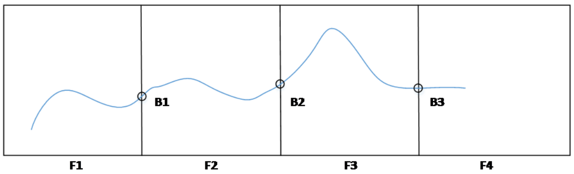

Figure 2. Sketch frames and line breaks

is usual. This needs second precise measuring of the frame end/beginning position.

- The source and the destination rolls are not parallel. Of course, their mechanical axes are parallel with very high precision but spool mounting has the nature to move from the ideal axe. The real mounting results to the following shifts (Fig. 3). There is an angle between the mechanical axe and the spool axe. This leads to paper shift and frame distortion. When paper rewinds frame by frame the shift l and the angle α increases. As a result, the sketch frame has to be shifted and rotated to be connected correctly to the previous frame. This shift and rotation have to be measured.
- If the shift l becomes too big the flatness of the paper becomes broken and a single fold appears. The problem is shown on Fig. 4. The fold makes all drawing process impossible. In this case, the drawing process has to be stopped and some mechanical fit has to be done manually. The fold appearance discovering is extremely complicated but very important. This is the third case to be solved.

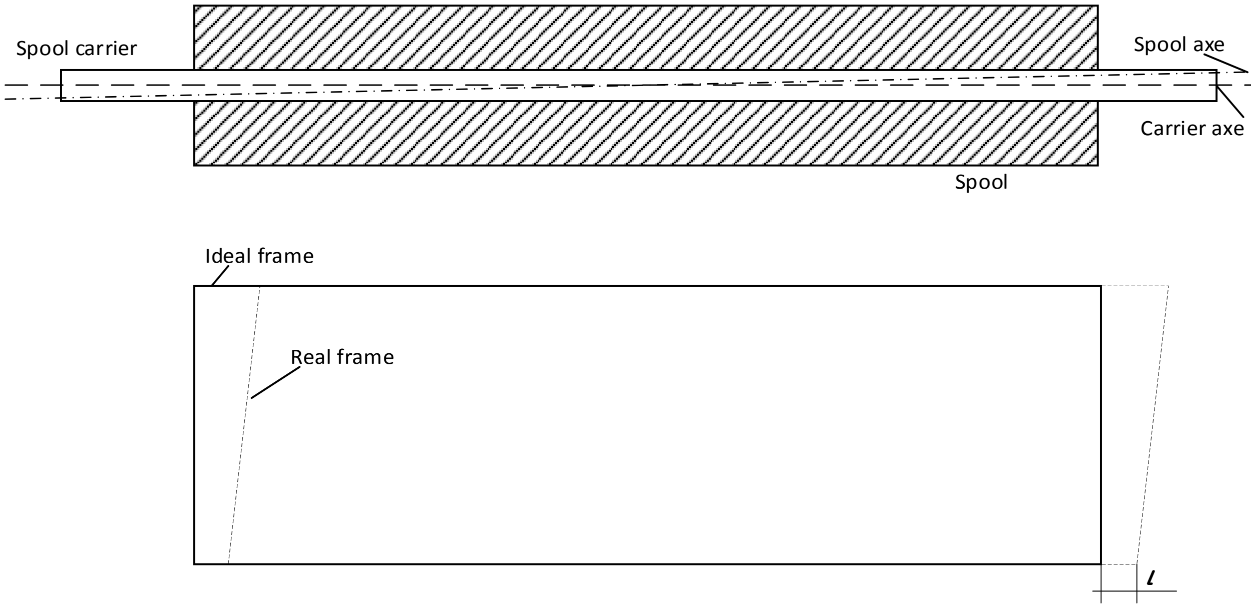

Figure 3. Paper and frame shifts

Mechanically the machine rewinds the ready frame on the destination roll after finishing frame draw. The next paper frame is ready for drawing. This is the ideal situation. [3]

There are several problems making ideal situation impossible. They are:

- We have to know the exact position of the left and right border of the paper. The papers are of different widths and their mounting on the source and destination rolls has no limiter, so the exact basic position and width are unknown at the beginning of a new sketch drawing.
- Theoretically, the paper is flexible but not elastic and does not have any linear stretch. Practically it is not true. The machine has a sensor measuring paper movement. It has position regulator to rewind the exact length of paper. Unfortunately, it is impossible to stop the end of the previous frame exactly at the position of the new one. A discrepancy of up to 5 mm

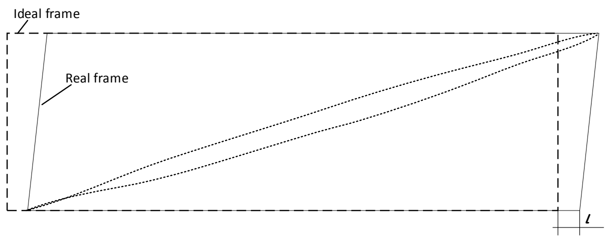

Figure 4. Frame shift and paper fold

These shifts, rotations and eventually fold appearance cannot be measured (and found) using ordinary sensors. They need some more advanced sensing. The solution was to implement and use an optical sensing component.

III. OPTICAL SUBSYSTEM AND MARKERS DETECTION

The optical subsystem has to be able to measure paper shifts and rotation and to enable fold appearance finding. These tasks are impossible if the optics sees only the paper field. Every new frame is blank and unmeasurable. The paper boundaries coordinates are measurable if: a) the optical head can move to them and b) the optical subsystem can recognize that boundaries. The very first impulse to mount some kind camera is not productive. The drawing plot is glass (reflecting) and the distance between the lenses and the paper is 10 mm. These generate problems for optical recognition. Paper boundaries do not provide information about frame’s end exact position. In conclusion – we have to measure both X and Y frame movements and coordinates to be able to calculate coordinates corrections.

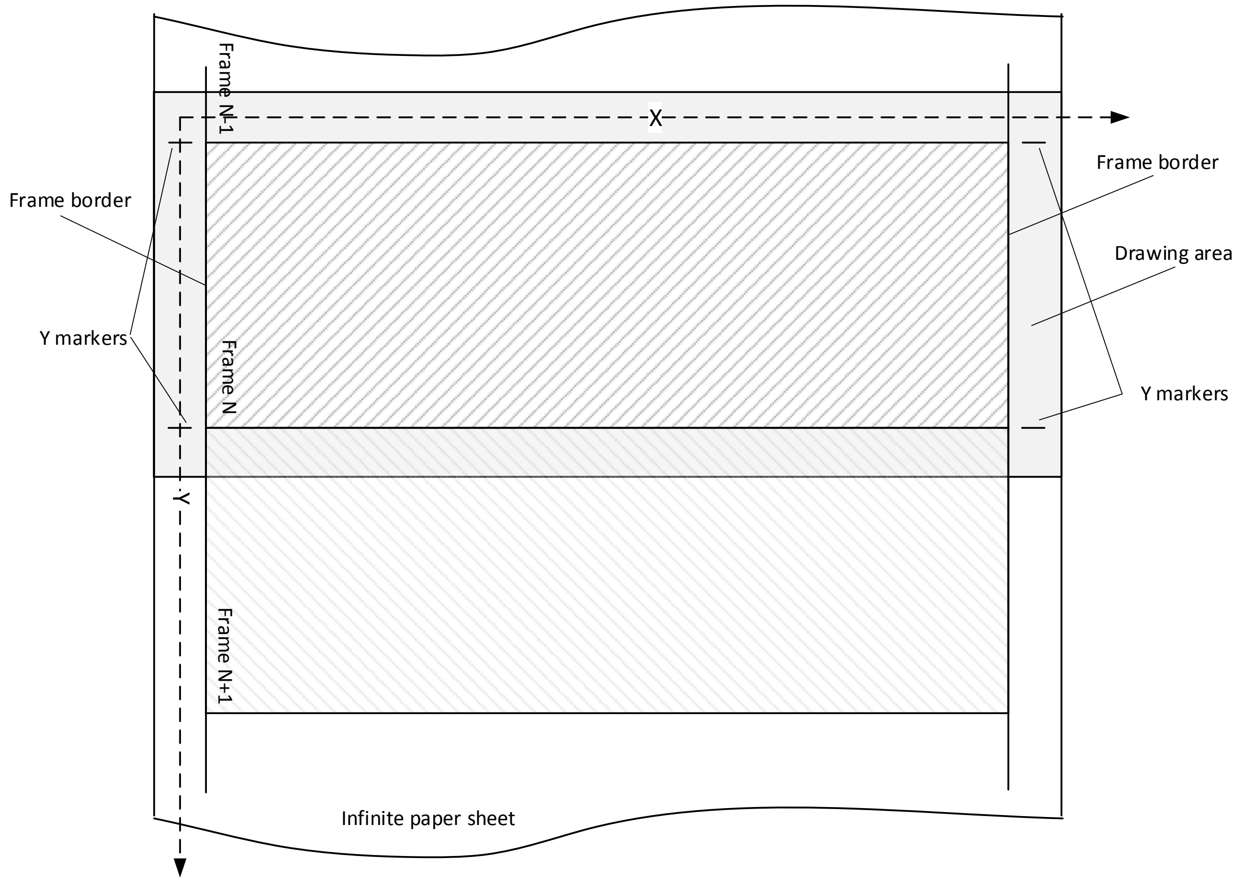

Figure 5. The coordination system and reference lines

The idea is to draw referential lines in the drawing area. These lines are shown on Fig. 5. There are two types of referential lines: frame boundaries, marking X_1 and X_2 frame field boundaries and “Y markers”. The “Y markers” are used to mark Y_1 and Y_2 frame field boundaries - the virtual beginning and end of the frame. The “Y markers” are drawn outside the frame zone.

For finding referential lines and their coordinates was designed an optical head consisting of two white light LED sources and light intensity detector. This detector detects the difference between empty field and a field with a line drawn on it. The detector has very small working area. It finds the line only if it is in a circular area with diameter D=0.6 mm. The diameter is selected according to the fact that drawing pencil draws line 0.5 mm thick. [4]

The schematics of the optical subsystem is shown on Fig. 6. The two LED sources are orthogonal to each other and the projection of their illuminated areas is like a square. This area has illumination enough bigger that the surrounding areas

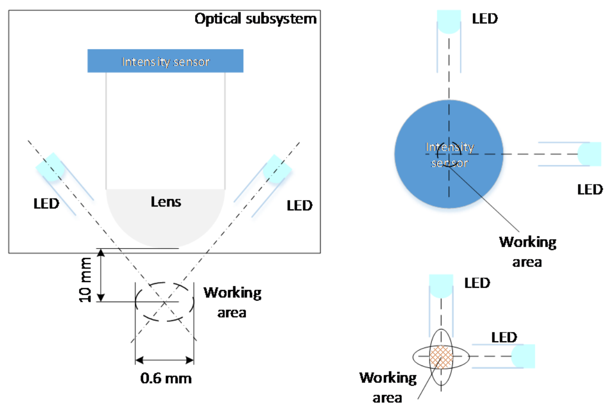

Figure 6. Optical subsystem

to detect line passing through it.

One of the main technical problems was to react exactly when the line passes through optical detector’s working area. The problem comes from the fact that the plotter control system has sampling period of 2 ms. The maximum machine speed is $V_{Xmax} = V_{Ymax} = 10$ m/s. This is 20 mm/sample. This is much more that 0.6 mm working area. As a result, if the machine head is moving with the maximum speed, it is impossible to find the referential lines. The calculated sensing speed is V=0.3 m/s. This results to the fact that the passing over the line cannot be omitted and an only one message for line finding will be generated. The next problem comes from time discretisation and the relative moment of line detection. We have the following general situations, shown on Fig. 7.

If we have the condition 7a), the coordinates of the line detected are the coordinates of the head; if we have the condition 7b), the line is detected twice in the time of tact *k*, and once in tact *k*+1, so its coordinates are those in tact *k*; in case of 7c), we have the opposite situation – the line is detected once in tact *k*, and twice in tact *k*+1, so its coordinates are those in tact *k*+1. This type of sensor reading is very complicated according the control software and needs special time diagram. This type of input event driver was especially designed for the optical subsystem. It worked only in the mode of coordinates detection and correction [5], [6].

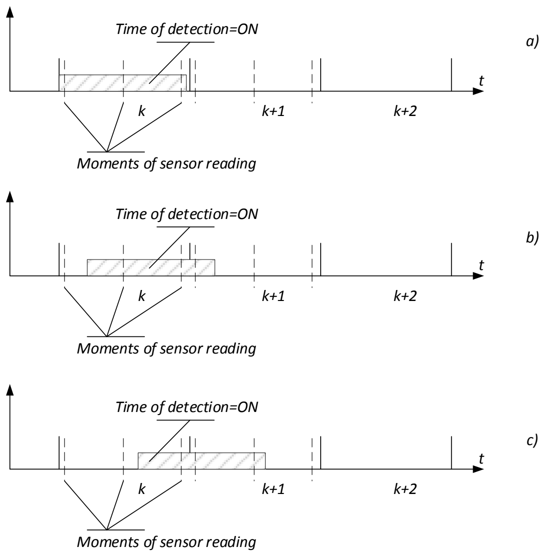

Figure 7. Time diagram of optical sensing

IV. RESULTING SOLUTIONS

The optical subsystem works on in the situation of frame change. In this case, the system LEDs are turned ON and referential lines finding begins. The X and Y coordinates are found separately. First is checked shift parallel the X axe. The machine head starting coordinates are (0, 0) mm according to the drawing coordination system – this is ~(-50, -50) relatively to the new frame boundaries. The head starts to move with the speed 0.3 m/s along the axe X to find the frame border drawn in the previous frame. When it is found its X_{borde1} coordinate is memorized. After that the head shifts to coordinates X = $X_{border2}$-50 mm and Y = 0 mm and starts to search the new $X_{border2}$ coordinate. After its finding the head returns to (0,0) position. The Y referential coordinates are found in two steps. First is found the left side Y referential line. Movement is alongside the Y axe. After finding Y_{left} coordinate it is memorized. After that the head is shifted to coordinates (0, $X_{border2}$+50) and again starts to move alongside the Y axe. After finding Y_{right} coordinate it is memorized. The head returns to the (0,0) position.

Than we look for fold appearance. The algorithm is very complicated but in general it lays on the following. If we have a fold the attempt to draw a line on the fold parallel to the fold ridge if we try to draw two lines with one and the same coordinates but starting from its opposite sides, the two lines will not overlap because the paper will shift a bit. The direction of the possible fold is found using $X_{border2}$ coordinates of the current and the previous frames. The sign of the difference determines the eventual fold orientation. After that is found an empty space in the future frame (no lines in a square 20x20 mm laying on the frame diagonal parallel to the fold) and the line is drawn in both directions. After that the optical detector moves over it and looks for discrepancy. If it is found the decision is that we have a fold and manual fit is needed. In the other case the work continues.

When there is no fold, the work continues with calculations of shifts and rotation. The X shift is calculated using the X_{borde1} coordinate. The Y shift is calculated using the Y_{left} coordinate. The rotation is calculated using the $Y_{left\ and}$ the Y_{right} coordinates. Here comes the next calculation problem. The rotation angle is very small – less than 0.002 rad. To avoid calculation mistakes all the mathematics is done with floating point quadro precision (10 bytes numbers). After calculation of the shift and rotation coefficients, the shift matrix is ready for calculation sketch lines' virtual coordinates to real ones. First are calculated the new boundary lines coordinates and the new Y referential lines coordinated. These lines are drawn and after that the system starts to draw the all frame.

V. CONCLUSION

The presented optical subsystem for position and orientation correction was implemented in a family of flatbed textile plotters. It was compared with the less-sophisticated position correction procedures running ordinary sensors. The result of implementation the presented technology is the fact that any kind of textile paper (various widths) positioned on "some" place in the drawing area was successfully used for sketches long from 1 m to 30 m. The discrepancy between lines was always less than 0.5 mm, e.g. lines connected to each other visually.

REFERENCES

[1] Hace, A. Jezernik, K. ; Curk, B. ; Terbuc, M. , Robust Motion Control of XY Table for Laser Cutting Machine, Industrial Electronics Society, 1998. IECON '98. Proceedings of the 24th Annual Conference of the IEEE, vol.2, pp. 1097 – 1102

[2] Emanuil Markov, Ivan Evg. Ivanov, Vesselin Gueorguiev, Program Generator Architecture, DESE 2011, Dubai, UAE, December 2011

[3] Gabriel A. Wainer , Discrete-Event Modeling and Simulation: a practitioner's approach. CRC Press, 2009.

[4] Nikolay Baldzhiev, Velizar Bodurski, V. Gueorguiev, I. E. Ivanov, Implementation of Objects Simulators and Validators using Program Generation Approach, DESE 2011, Dubai, UAE, December 2011.

[5] Nikolova K., I. Petrinska, S. Peneva, LED Artistic-Architectural Lighting In The City Of Sofia. Lux Junior 2013, 27. bis 29.9.13 Doernfeld, Germany, ISBN 978-3-927787.

[6] Nikolova K., B. Florian, N. Yaneva, P. Djanovska, I. Petrinska, D. Pavlov (Sofia): Spectral Correction of Photoelements for Measurement of Radiation in the Blue Light Spectrum, Lux Junior 2015, Doernfeld, Germany, September 25 to 27, 2015.