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(71) Applicant: **TWINE SOLUTIONS LTD.** [IL/IL]; Hatnufa 7 Kodak Building, Kiryat Arie, 4951025 Petah Tikva (IL).

(72) Inventors: **MOSHE, Alon**; Twine Solutions Ltd., Hatnufa 7 (Kodak Building), Kiryat Arie, 4951025 Petach Tiqva (IL). **MOSHE, Goor**; Twine Solutions Ltd., Hatnufa 7 (Kodak Building), Kiryat Arie, 4951025 Petach Tiqva (IL). **PERLMAN, Mirta Beatis**; Twine Solutions Ltd., Hatnufa 7 (Kodak Building), Kiryat Arie, 4951025 Petach Tiqva (IL). **PLITT, Victoria**; Twine Solutions Ltd., Hatnufa 7 Kodak Building, Kiryat Arie, 4951025 Petah Tikva (IL).

(74) Agent: **SHALEV, Asaf** et al.; S. J. INTELLECTUAL PROPERTY, 24 Hanagar St., 4527713 Hod Hasharon (IL).

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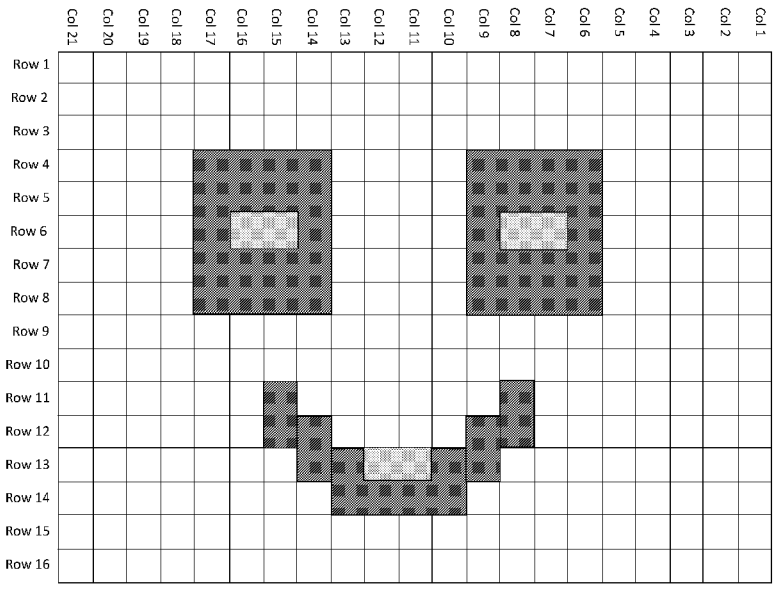

Fig. 1

(57) Abstract: A thread treatment scheme determination system comprising a processing circuitry configured to: obtain a multi-treatment pattern comprised of a plurality of pixels, each pixel being associated with a pixel thread length, and each pixel being associated with a respective pixel treatment; and determine, based on the multi-treatment pattern, a thread treatment scheme for automatically treating, by a digital thread treatment mechanism, one or more threads used for textile application in accordance with the multi- treatment pattern.

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A THREAD TREATMENT SCHEME DETERMINATION SYSTEM AND METHOD

TECHNICAL FIELD

The presently disclosed subject matter relates to a thread treatment scheme determination system and method.

BACKGROUND

Raw materials in the textile industry include un-treated threads, which are treated by thread manufacturers based on actual, or predicted, demand from the textile industry and textile manufacturers. For example, thread dyeing is performed by thread manufacturers based on an estimated and/or actual demand for various color threads (noting that threads can also be manufactured to have gradient colors which change along the length of a single thread).

The mere fact that the threads are treated based on demand estimations results in extreme waste of resources used to manufacture the threads, and in many cases also in waste of resources in the form of unconsumed threads (due to supply exceeding demand). The threads manufacturing process is far from being environmentally friendly, and consumes large volumes of fresh water, which then become polluting waste. This wastewater often contains toxic and reactive residues and chemicals that pose a hazard to the public.

Current manufacturing methods impose substantial limitations on the textile industry. For example, textile manufacturers suffer from a number of challenges due to current thread manufacturing methodologies, such as long lead time between order of a specific color to actually receiving it, large minimum order quantities limitations imposed by inefficient manufacturing process, being forced to sometimes compromise on specific colors due to a limited number of catalogue threads, etc.

Digital thread treatment systems, such as the ones disclosed in International Publication No. WO 2017/203524 and/or WO 2017/013651 (both of which incorporated herein by reference) by Twine Solutions Ltd., have been developed in order to address

these issues and enable on-demand thread treatment. Such systems enable applying different treatments for different portions of one or more continuous running threads.

However, such systems lack the capability to determine a thread treatment scheme based on a desired design pattern. There is thus a real need in the art for a new system and method for thread treatment scheme determination.

GENERAL DESCRIPTION

In accordance with a first aspect of the presently disclosed subject matter, there is provided a thread treatment scheme determination system comprising a processing circuitry configured to: obtain a multi-treatment pattern comprised of a plurality of pixels, each pixel being associated with a pixel thread length, and each pixel being associated with a respective pixel treatment; determine, based on the multi-treatment pattern, a thread treatment scheme for automatically treating, by a digital thread treatment mechanism, one or more threads used for textile application in accordance with the multi-treatment pattern, wherein: (a) the thread treatment scheme defines, for each thread, treatment portions, each of the treatment portions (i) is associated with a respective consecutive sequence of one or more of the pixels, wherein the respective consecutive sequence of the pixels are associated with identical pixel treatment, and (ii) having a corresponding calculated length, calculated based on the pixel thread lengths of the pixels comprising the respective consecutive sequence of the pixels, and (b) at least a first treatment portion of the treatment portions of a given thread of the threads, and a second treatment portion of the treatment portions of the given thread of the threads are treated differently.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the determination of the thread treatment scheme is also based on one or more of the following: (a) a thread weight of each of the threads, or (b) a thread type of each of the threads.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the determination of the thread treatment scheme is also based on a minimal treatment change length requirement, being a minimal length of the thread required for the digital thread treatment mechanism in order to complete a treatment change process for changing the treatment of the thread.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the thread treatment scheme enables producing a multi-treated textile having a reduced thickness or reduced weight than another textile having an identical appearance using non multi-treated threads.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the thread treatment scheme enables producing a multi-treated textile using a smaller amount of threads than another textile having an identical appearance using non multi-treated threads.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the treating includes applying one or more treatment materials selected from: dye material, coating material, dye effect material, conductive materials, magnetic material, biological active material, or chemical treatment-material.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the processing circuitry is further configured to determine threads application instructions for a thread applicator for applying treated threads, treated according to the thread treatment scheme, in order to produce textile in accordance with the multi-treatment pattern.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the multi-treatment pattern is a two-dimensional pattern or a three-dimensional pattern.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the pixel thread length depends on at least one of the following characteristics of one or more of the threads: thread width, thread production method, thread tenacity, or thread elasticity.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the textile application is one of: knitting, sewing, embroidery, or weaving.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the identical pixel treatment can be gradual along at least one of the treatment portions.

In accordance with a second aspect of the presently disclosed subject matter, there is provided a thread treatment scheme determination method comprising: obtaining, by a processing circuitry, a multi-treatment pattern comprised of a plurality of pixels, each

pixel being associated with a pixel thread length, and each pixel being associated with a respective pixel treatment; determining, by the processing circuitry, based on the multi-treatment pattern, a thread treatment scheme for automatically treating, by a digital thread treatment mechanism, one or more threads used for textile application in accordance with the multi-treatment pattern, wherein: (a) the thread treatment scheme defines, for each thread, treatment portions, each of the treatment portions (i) is associated with a respective consecutive sequence of one or more of the pixels, wherein the respective consecutive sequence of the pixels are associated with identical pixel treatment, and (ii) having a corresponding calculated length, calculated based on the pixel thread lengths of the pixels comprising the respective consecutive sequence of the pixels, and (b) at least a first treatment portion of the treatment portions of a given thread of the threads, and a second treatment portion of the treatment portions of the given thread of the threads are treated differently.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the determination of the thread treatment scheme is also based on one or more of the following: (a) a thread weight of each of the threads, or (b) a thread type of each of the threads.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the determination of the thread treatment scheme is also based on a minimal treatment change length requirement, being a minimal length of the thread required for the digital thread treatment mechanism in order to complete a treatment change process for changing the treatment of the thread.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the thread treatment scheme enables producing a multi-treated textile having a reduced thickness or reduced weight than another textile having an identical appearance using non multi-treated threads.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the thread treatment scheme enables producing a multi-treated textile using a smaller amount of threads than another textile having an identical appearance using non multi-treated threads.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the treating includes applying one or more treatment materials selected from: dye

material, coating material, dye effect material, conductive materials, magnetic material, biological active material, or chemical treatment-material.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the method further comprises determining threads application instructions for a thread applicator for applying treated threads, treated according to the thread treatment scheme, in order to produce textile in accordance with the multi-treatment pattern.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the multi-treatment pattern is a two-dimensional pattern or a three-dimensional pattern.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the pixel thread length depends on at least one of the following characteristics of one or more of the threads: thread width, thread production method, thread tenacity, or thread elasticity.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the textile application is one of: knitting, sewing, embroidery, or weaving.

In one embodiment of the presently disclosed subject matter and/or embodiments thereof, the identical pixel treatment can be gradual along at least one of the treatment portions.

In accordance with a third aspect of the presently disclosed subject matter, there is provided a non-transitory computer readable storage medium having computer readable program code embodied therewith, the computer readable program code, executable by at least one processing circuitry to perform a thread treatment scheme determination method, the thread treatment scheme determination method comprising: obtaining, by a processing circuitry, a multi-treatment pattern comprised of a plurality of pixels, each pixel being associated with a pixel thread length, and each pixel being associated with a respective pixel treatment; determining, by the processing circuitry, based on the multi-treatment pattern, a thread treatment scheme for automatically treating, by a digital thread treatment mechanism, one or more threads used for textile application in accordance with the multi-treatment pattern, wherein: (a) the thread treatment scheme defines, for each thread, treatment portions, each of the treatment portions (i) is associated with a respective consecutive sequence of one or more of the pixels, wherein the respective consecutive sequence of the pixels are associated with identical pixel treatment, and (ii) having a

corresponding calculated length, calculated based on the pixel thread lengths of the pixels comprising the respective consecutive sequence of the pixels, and (b) at least a first treatment portion of the treatment portions of a given thread of the threads, and a second treatment portion of the treatment portions of the given thread of the threads are treated differently.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the presently disclosed subject matter and to see how it may be carried out in practice, the subject matter will now be described, by way of non-limiting examples only, with reference to the accompanying drawings, in which:

Fig. 1 is an illustration of a multi-treatment pattern, in accordance with the presently disclosed subject matter

Fig. 2 is a block diagram schematically illustrating one example of a thread treatment scheme determination system, in accordance with the presently disclosed subject matter;

Fig. 3 is a flowchart illustrating one example of a sequence of operations carried out for thread treatment scheme determination, in accordance with the presently disclosed subject matter; and

Figs. 4a and 4b are schematic illustrations of exemplary design patterns and associated advantages of using multi-treated threads treated in accordance with a thread treatment scheme determined by thread treatment scheme determination system for manufacturing same, in accordance with the presently disclosed subject matter.

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the presently disclosed subject matter. However, it will be understood by those skilled in the art that the presently disclosed subject matter may be practiced without these specific details. In other instances, well-known methods, procedures, and components have not been described in detail so as not to obscure the presently disclosed subject matter.

In the drawings and descriptions set forth, identical reference numerals indicate those components that are common to different embodiments or configurations.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "obtaining", "determining", "analyzing", "providing" or the like, include action and/or processes of a computer that manipulate and/or transform data into other data, said data represented as physical quantities, e.g. such as electronic quantities, and/or said data representing the physical objects. The terms “computer”, “processor”, “processing circuitry” and “controller” should be expansively construed to cover any kind of electronic device with data processing capabilities, including, by way of non-limiting example, a personal desktop/laptop computer, a server, a computing system, a communication device, a smartphone, a tablet computer, a smart television, a processor (e.g. digital signal processor (DSP), a microcontroller, a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), etc.), a group of multiple physical machines sharing performance of various tasks, virtual servers co-residing on a single physical machine, any other electronic computing device, and/or any combination thereof.

The operations in accordance with the teachings herein may be performed by a computer specially constructed for the desired purposes or by a general-purpose computer specially configured for the desired purpose by a computer program stored in a non-transitory computer readable storage medium. The term "non-transitory" is used herein to exclude transitory, propagating signals, but to otherwise include any volatile or non-volatile computer memory technology suitable to the application.

As used herein, the phrase "for example," "such as", "for instance" and variants thereof describe non-limiting embodiments of the presently disclosed subject matter. Reference in the specification to "one case", "some cases", "other cases" or variants thereof means that a particular feature, structure or characteristic described in connection with the embodiment(s) is included in at least one embodiment of the presently disclosed subject matter. Thus, the appearance of the phrase "one case", "some cases", "other cases" or variants thereof does not necessarily refer to the same embodiment(s).

It is appreciated that, unless specifically stated otherwise, certain features of the presently disclosed subject matter, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the presently disclosed subject matter, which are, for

brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination.

In embodiments of the presently disclosed subject matter, fewer, more and/or different stages than those shown in **Fig. 3** may be executed. In embodiments of the presently disclosed subject matter one or more groups of stages illustrated in **Fig. 3** may be executed simultaneously. **Fig. 2** illustrates a general schematic of the system architecture in accordance with an embodiment of the presently disclosed subject matter. Each module in **Fig. 2** can be made up of any combination of software, hardware and/or firmware that performs the functions as defined and explained herein. The modules in **Fig. 2** may be centralized in one location or dispersed over more than one location, as detailed herein. In other embodiments of the presently disclosed subject matter, the system may comprise fewer, more, and/or different modules than those shown in **Fig. 2**.

Any reference in the specification to a method should be applied mutatis mutandis to a system capable of executing the method and should be applied mutatis mutandis to a non-transitory computer readable medium that stores instructions that once executed by a computer result in the execution of the method.

Any reference in the specification to a system should be applied mutatis mutandis to a method that may be executed by the system and should be applied mutatis mutandis to a non-transitory computer readable medium that stores instructions that may be executed by the system.

Any reference in the specification to a non-transitory computer readable medium should be applied mutatis mutandis to a system capable of executing the instructions stored in the non-transitory computer readable medium and should be applied mutatis mutandis to method that may be executed by a computer that reads the instructions stored in the non-transitory computer readable medium.

Bearing this in mind, attention is drawn to **Fig. 1**, which is an illustration of a multi-treatment pattern, in accordance with the presently disclosed subject matter.

The multi-treatment pattern shown in Fig. 1 is a simplified, exemplary, multi-treatment pattern based on which a thread treatment scheme needs to be established to enable thread applicators (being textile manufacturing machinery that is configured to take part in the textile manufacturing process) to manufacture multi-treated textile. The exemplary multi-treatment pattern is comprised of a plurality of pixels, starting at (row 1, column 1) and ending at (row 16, column 21). Each of the pixels is associated with a

pixel thread length (a length of a thread required to represent the pixel in actual manufactured multi-treated textile), and each pixel is associated with a respective pixel treatment, a thread is required to undergo in order to be usable for manufacturing multi-treated textile based on the multi-treatment pattern. It is to be noted that various types of treatments can be performed, such as applying one or more treatment materials onto the threat, selected from: dye material, coating material, dye effect material, conductive materials, magnetic material, biological active material, chemical treatment-material, etc.

The treatment in the illustrated example is dyeing with various colors. As can be appreciated, some of the pixels in the multi-treatment pattern are white, some are dark grey, and some are light grey. It is to be noted that in case the raw thread color matches one of the colors of the multi-treatment pattern, in those portions where the multi-treatment pattern is in the color of the thread - the thread does not have to be treated (for example, if the thread is white - there is no need to dye that portion thereof, it should remain white).

In the illustrated example, the first 68 consecutive pixels are white pixels (the first three rows, and the first five columns in the fourth row). Accordingly, the thread treatment scheme can define dyeing a portion having a length of 68 times x (x being the pixel thread length of a single pixel) of the thread in white (optionally unless the raw thread is white, in which case dyeing white can be redundant). The next four consecutive pixels are dark grey (the third row, between the sixth and nineth column). Accordingly, the thread treatment scheme can define dyeing a subsequent portion having a length of 4 times x of the thread in dark grey. The next four consecutive pixels are white again (the third row, between the tenth and thirteenth column). Accordingly, the thread treatment scheme can define dyeing a subsequent portion having a length of 4 times x of the thread in white (optionally unless the raw thread is white, in which case dyeing white can be redundant). The next four consecutive pixels are dark grey (the third row, between the fourteenth and seventeenth column). Accordingly, the thread treatment scheme can define dyeing a subsequent portion having a length of 4 times x of the thread in dark grey. The next nine consecutive pixels are white again (starting at the third row, eighteenth column, until the fourth row, fifth column). Accordingly, the thread treatment scheme can define dyeing a subsequent portion having a length of 9 times x of the thread in white (optionally unless the raw thread is white, in which case dyeing white can be redundant). The next single pixel (fourth row, sixth column) is dark grey. Accordingly, the thread treatment scheme

can define dyeing a subsequent portion having a length of x of the thread in dark grey. The next two consecutive pixels (fourth row, seventh to eighth columns) are light grey. Accordingly, the thread treatment scheme can define dyeing a subsequent portion having a length of 2 times x of the thread in light grey, and so on.

It is to be noted that in order for such thread treatment scheme to be designed for a continuous running thread to be used for manufacturing multi-treated textile in accordance with the multi-treatment pattern, a digital thread treatment mechanism used to actually treat the thread has to be capable of operating in the required resolutions, especially in transitioning between treatments for consecutive portions. This means that such a digital thread treatment mechanism has to be able to treat one or more pixels with a first treatment, and then instantaneously treat one or more immediately subsequent pixels (immediately subsequent to the pixels treated with the first treatment) with a second treatment, while each treatment has to provide the required result in accordance with the multi-treatment pattern. Looking at the illustrated example, the digital thread treatment mechanism has to be able to dye the first portion (having a length of 68 times x) in white, and immediately thereafter, dye second portion (having a length of 4 times x) in dark grey, and so on.

It is to be noted that in some cases (although not necessarily so) it may be challenging for some digital thread treatment mechanisms to make instantaneous transitions between thread treatment types, as some digital thread treatment mechanisms require time to complete a transition from a first treatment to a second treatment, other than the first treatment. Looking at the illustrated example, such digital thread treatment mechanisms cannot change dyeing colors instantaneously, as color treatment changing might require a certain thread length for completion. It is impossible for such digital thread treatment mechanisms to dye the first portion (having a length of 68 times x) of a given thread in white, and immediately thereafter, dye a second portion (having a length of 4 times x) of the same given thread in dark grey. In such digital thread treatment mechanisms, there is a minimal treatment change length requirement, being a minimal length of thread required for completing a change of treatment of the thread. Such minimal treatment change length requirement can be determined based on a time required to complete a transition between treatments, and the travel speed of the treated thread during the treatment process.

Accordingly, when using digital a thread treatment mechanism that is uncapable of making an instantaneous transition between thread treatment types, it is impossible to treat a continuous running thread to be used for manufacturing multi-treated textile in accordance with the multi-treatment pattern and provide the required treatment result in each portion in accordance with the multi-treatment pattern. In such cases, more than one thread has to be treated and used to manufacture the multi-treated textile in accordance with the multi-treatment pattern, and the thread treatment scheme has to define how to treat each thread.

Irrespectively of the ability of a digital thread treatment mechanism to make instantaneous transitions between thread treatment types, it is to be noted that in many cases in order to produce a multi-treated textile in accordance with the multi-treatment pattern, the digital thread treatment mechanism is required to make use of a plurality of threads in view of various considerations. Some exemplary considerations include maintaining a tension of the threads, adhering to stretching limitations of the threads, etc. Additional considerations that may be taken into account are related to the thread applicators, that are unable to determine and maintain a specific and exact length of thread to be used for manufacturing each segment of the manufactured textile, due to limitations such as the tension of the fabric, the needle tension, spool winding tension etc.

It is important to note that even when using more than one thread, conventional thread applicators that use single color threads usually require more threads than thread applicators that use threads treated in accordance with the multi-treatment pattern. Looking at the illustrated example, three different colors are used: white, light gray and dark grey. Using single color threads in the textile manufacturing process would require three different threads for manufacturing the illustrated pattern – a white thread, a light gray thread and a dark grey thread. To the contrary, even when digital thread treatment mechanisms that are uncapable of making an instantaneous transition between thread treatment types, use multi-treated threads (being threads having at least two different portions that are treated differently by a digital thread treatment mechanism as further detailed herein), the multi-treated textile manufacturing process would require only two treated threads for manufacturing the illustrated pattern. This is true in the illustrated example when the length of thread required to complete a change from white color to dark grey color is shorter than, or equal to, the length of light gray thread in between the white threat and the dark grey thread.

To explain this, let's look at the illustrated example once again. As indicated above, the first 68 consecutive pixels are white pixels (the first three rows, and the first five columns in the fourth row). Accordingly, the thread treatment scheme can define dyeing a portion, of a first thread, having a length of 68 times x (x being the pixel thread length of a single pixel) of the thread in white (optionally unless the raw thread is white, in which case dyeing white can be redundant). The next four consecutive pixels are dark grey (the third row, between the sixth and nineth column). Accordingly, the thread treatment scheme can define dyeing a portion, of a second thread, having a length of 4 times x of the thread in dark grey. The next four consecutive pixels are white again (the third row, between the tenth and thirteenth column). Accordingly, the thread treatment scheme can define dyeing a subsequent portion of the first thread having a length of 4 times x of the thread in white (optionally unless the raw thread is white, in which case dyeing white can be redundant). The next four consecutive pixels are dark grey (the third row, between the fourteenth and seventeenth column). Accordingly, the thread treatment scheme can define dyeing a subsequent portion of the second thread having a length of 4 times x of the thread in dark grey. The next nine consecutive pixels are white again (starting at the third row, eighteenth column, until the fourth row, fifth column). Accordingly, the thread treatment scheme can define dyeing a subsequent portion of the first thread having a length of 9 times x of the thread in white (optionally unless the raw thread is white, in which case dyeing white can be redundant). The next single pixel (fourth row, sixth column) is dark grey. Accordingly, the thread treatment scheme can define dyeing a subsequent portion of the second thread having a length of x of the thread in dark grey. The next two consecutive pixels (fourth row, seventh to eighth columns) are light grey. Accordingly, the thread treatment scheme can define dyeing a subsequent portion of the first thread having a length of 2 times x of the thread in light grey. This can be accomplished if the minimal treatment change length is up to a single pixel (as only a single pixel of dark grey (sixth row, sixth column) exists between the white pixel at the sixth row, fifth column and the light gray pixel at the sixth row, seventh column), which is the minimal treatment change length required to complete the transition from the white color to the light gray color in the illustrated example. Accordingly, after finishing the coloring the first thread in white, a transition is made to color the first thread in light gray. The transition requires a minimal treatment change length of one pixel, following which the first thread is colored in light gray as required. As the minimal treatment change length

in the example above is up to a length represented by one pixel, all transitions in the illustrated example can be made while using only two threads. It is to be noted however, that if the minimal treatment change length was longer than a length represented by a single pixel (e.g., had it been a length represented by two pixels) of the multi-treatment pattern, the transition between white pixels (starting at the third row, eighteenth column, until the fourth row, fifth column) to the dark grey pixel (in the fourth row, sixth column), and then to the light grey pixels (in the fourth row, seventh to eighth columns) could not have been made using only two threads. This is true in view of the fact that the thread that is treated in white color cannot complete a transition to light grey in a length of thread that represents a single pixel of the other thread that is treated in dark grey color (as the minimal treatment change length which requires more than a single pixel). Therefore, in this example (where the minimal treatment change length is longer than a length represented by a single pixel of the multi-treatment pattern) three threads are required.

Having described the example shown in Fig. 1, attention is now drawn to **Fig. 2** - a block diagram schematically illustrating one example of a thread treatment scheme determination system, in accordance with the presently disclosed subject matter.

Thread treatment scheme determination system 200 can comprise a network interface 220 (e.g. a network card, a WiFi client, a LiFi client, 3G/4G client, or any other component), enabling thread treatment scheme determination system 200 to communicate over a network with external systems, e.g. for obtaining multi-treatment patterns, for providing thread treatment schemes (e.g. to be used by a digital thread treatment mechanism), for providing threads application instructions (e.g. to be used by a thread applicator for applying treated threads, treated according to the thread treatment scheme, in order to produce multi-treated textile in accordance with the multi-treatment pattern), etc.

Thread treatment scheme determination system 200 can further comprise, or be otherwise associated with, a data repository 210 (e.g., a database, a storage system, a memory including Read Only Memory – ROM, Random Access Memory – RAM, or any other type of memory, etc.) configured to store data, optionally including, inter alia, multi-treatment patterns, etc. Data repository 210 can be further configured to enable retrieval and/or update and/or deletion of the stored data. It is to be noted that in some cases, data repository 210 can be distributed, while the thread treatment scheme determination system 200 has access to the information stored thereon, e.g. via a wired or wireless

network to which thread treatment scheme determination system 200 is able to connect (e.g. utilizing its network interface 220).

Thread treatment scheme determination system 200 further comprises a processing circuitry 230. Processing circuitry 230 can be one or more processing units (e.g. central processing units), microprocessors, microcontrollers (e.g. microcontroller units (MCUs)) or any other computing devices or modules, including multiple and/or parallel and/or distributed processing units, which are adapted to independently or cooperatively process data for controlling relevant thread treatment scheme determination system 200 resources and for enabling operations related to thread treatment scheme determination system's 200 resources.

Processing circuitry 230 comprises a thread treatment scheme determination module 240, configured to determine thread treatment schemes, as further detailed herein, inter alia with reference to Fig. 3.

Turning to **Fig. 3**, there is shown a flowchart illustrating one example of a sequence of operations carried out for thread treatment scheme determination, in accordance with the presently disclosed subject matter.

In accordance with the presently disclosed subject matter, thread treatment scheme determination system 200 can be configured to perform a thread treatment scheme determination process 300, e.g., using thread treatment scheme determination module 240. For this purpose, thread treatment scheme determination system 200 is configured to obtain multi-treatment pattern comprised of a plurality of pixels, each pixel being associated with a pixel thread length, and each pixel being associated with a respective pixel treatment (**block 310**).

The pixel thread length is an actual length of thread which the pixel represents, and it can be predetermined and configurable. In some case, the pixel thread length can depend on at least one of the following characteristics of one or more of the threads: thread weight, thread production method, thread tenacity, thread elasticity, thread material, thread texturizing method, thread geometry, thread linear density, thread twist (which can be measured in Twist per Inch (TPI)), number of plies forming the thread, threat lubricant used, elasticity of a fabric on which the threads are applied, mechanical features of the thread applicator/s, etc.

The pixel treatment with which each pixel is associated can vary between different pixels, and it can be comprised of applying one or more treatment materials selected from:

dye material (optionally selected from a plurality of dye materials having different colors), coating material (optionally selected from a plurality of coating materials having different properties), dye effect material (optionally selected from a plurality of dye effect materials having different effects), conductive materials (optionally selected from a plurality of conductive materials having different conduction properties), magnetic material (optionally selected from a plurality of magnetic materials having different magnetic properties), biological active material (optionally selected from a plurality of biological active materials having different biological properties), or chemical treatment-material (optionally selected from a plurality of chemical treatment materials having different chemical properties). It is to be noted that these are non-limiting examples and other types of treatment are contemplated as well.

The obtained multi-treatment pattern can be a two-dimensional pattern or a three-dimensional pattern.

Thread treatment scheme determination system 200 is further configured to determine, based on the multi-treatment pattern, a thread treatment scheme for automatically treating, by a digital thread treatment mechanism, one or more threads used for textile application (e.g., knitting, sewing, embroidery, or weaving) in accordance with the multi-treatment pattern (**block 320**).

in some cases, as part of the determination of the thread treatment scheme the number of threads to be used in the textile manufacturing process is automatically determined, while in other cases, the number of threads to be used in the textile manufacturing process is manually input to the thread treatment scheme determination system 200, e.g. by an operator thereof, and the thread treatment scheme is determined with the input number of threads as a constraint (noting that in some cases the constraint may lead to inability of the treatment scheme determination system 200 to generate a feasible thread treatment scheme, and in such cases an error message can be provided to the operator).

The thread treatment scheme defines, for each thread, treatment portions. Each of the treatment portions is associated with a respective consecutive sequence of one or more of the pixels of the multi-treatment pattern that are associated with identical pixel treatment. Looking at the illustration shown in Fig. 1, every series of consecutive pixels that is associated with the same color can be regarded of a treatment portion. For example, the first 68 consecutive pixels are white pixels (the first three rows, and the first five

columns in the fourth row) and are regarded as a treatment portion, in which the treatment is applying white dyeing material. The next four consecutive pixels are dark grey (the third row, between the sixth and nineth column), and are regarded as another treatment portion, in which the treatment is applying dark grey dyeing material. And so on.

Each treatment portion also has a corresponding calculated length, calculated by multiplying the pixel thread length by the number of pixels comprising the treatment portion. Looking at the illustration shown in Fig. 1, the first treatment portion comprises 68 consecutive pixels white pixels (the first three rows, and the first five columns in the fourth row) and its length is calculated by multiplying 68 by X, where X is the pixel thread length. The second treatment portion comprises the subsequent four consecutive dark grey pixels (the third row, between the sixth and nineth column), and its length is calculated by multiplying 4 by X, where X is the pixel thread length. And so on.

It is to be noted that at least a first treatment portion of the treatment portions of a given thread (of the one or more threads used for multi-treated textile application in accordance with the multi-treatment pattern), and a second treatment portion of the treatment portions of the same given thread are treated differently. This means that at least one thread of the one or more threads used for multi-treated textile application is a multi-treated thread, having at least two portions that are treated differently (e.g., colored in different colors or different color gradients).

In some cases, the determination of the thread treatment scheme is also based on a thread weight of each of the threads and/or a thread type of each of the threads. It is to be noted in this respect that in some cases, it may be desirable to use threads of different weight and/or type for producing a multi-treated textile in accordance with the multi-treatment pattern, and in such cases, the multi-treatment pattern can further define, for each pixel, what type of thread to use and/or what is the required thread weight. It is to be noted that in some cases the pixel thread length may also vary between pixels based on the type of thread and/or the weight of the thread associated with each pixel. It is to be noted that this may pose additional constraints in the determination of the thread treatment scheme.

In some cases, for example when the digital thread treatment mechanisms cannot change treatment types (e.g., dyeing colors) instantaneously, the determination of the thread treatment scheme is also based on a minimal treatment change length requirement. The minimal treatment change length requirement is a minimal length of the thread

required for the thread treatment mechanism in order to complete a treatment change process for changing the treatment of the thread from a first treatment in a given portion thereof to a second treatment, other than the first treatment, in an immediately subsequent portion thereof, immediately subsequent to the given portion. The minimal treatment change length requirement can be pre-determined or calculated based on various parameters, such as one of the following characteristics of one or more of the threads: thread width, thread production method, thread tenacity, thread elasticity, thread material, thread texturizing method, thread geometry, thread linear density, thread twist (which can be measured in Twist per Inch (TPI)), number of plies forming the thread, threat lubricant used, etc.

It is to be noted that the thread treatment scheme in accordance with the presently disclosed subject matter enables producing a multi-treated textile having a reduced thickness or reduced weight than another textile having an identical appearance using non multi-treated threads (being threads that are not treated by a digital thread treatment mechanism as detailed herein). In addition, the thread treatment scheme in accordance with the presently disclosed subject matter enables producing a multi-treated textile using a smaller number of threads than another textile having an identical appearance using non multi-treated threads.

It has been indicated herein that each of the treatment portions is associated with a respective consecutive sequence of one or more of the pixels of the multi-treatment pattern that are associated with identical pixel treatment. It is to be noted that the identical pixel treatment can be digitally controlled so that the treatment is made in a gradual manner along at least one of the treatment portions, such as coloring the portion with color gradients (gradually blending from one color to another, or between colors of the same tone (from light blue to navy blue), colors of two different tones (from blue to yellow), or even between more than two colors (from blue to purple to red to orange)). The use of the digital thread treatment mechanism enables digitally controlling the treatment so as to enable calculating and controlling a gradient length and/or a gradient appearance, and/ or gradient transition speed (the speed of change from color to color within the gradient), which is impossible in existing dyeing methods. It is to be noted that gradually changing properties of materials used for treating a consecutive sequence of a plurality of the pixels, such as gradually changing the color applied to the pixels of the sequence, is still regarded as identical pixel treatment for the purpose of this disclosure.

In some cases, thread treatment scheme determination system 200 is further configured to determine threads application instructions for a thread applicator for applying treated threads, treated according to the thread treatment scheme, in order to produce textile in accordance with the multi-treatment pattern (**block 330**). The thread treatment scheme is designed for a digital thread treatment mechanism to treat the thread/s required in order to generate multi-treated textile based on the multi-treatment pattern, however the thread applicator needs to have instructions for applying treated threads, treated in accordance with the thread treatment scheme, in order to produce multi-treated textile in accordance with the multi treatment pattern. This is especially true when the thread treatment scheme defines more than one thread to be used for producing multi-treated textile in accordance with the multi treatment pattern, and instructions for changing threads during the multi-treated textile production are required.

In some cases, the threads application instructions can define instructions for different thread feeds of the thread applicator (i.e., when to use each thread feed), where each thread feed is associated with a respective treated thread. Due to the fact that multi-treated threads are used by the thread applicator, less bobbins/spools/cones are needed in order to manufacture textile in accordance with the multi-treatment pattern (in comparison to thread applicators using non-treated threads).

It is to be noted, with reference to Fig. 3, that some of the blocks can be integrated into a consolidated block or can be broken down to a few blocks and/or other blocks may be added. It should be also noted that whilst the flow diagram is described also with reference to the system elements that realizes them, this is by no means binding, and the blocks can be performed by elements other than those described herein.

Attention is now drawn to **Figs. 4a and 4b**, showing schematic illustrations of exemplary design patterns and associated advantages of using multi-treated threads treated in accordance with a thread treatment scheme determined by thread treatment scheme determination system for manufacturing same, in accordance with the presently disclosed subject matter.

In the design pattern shown in Fig. 4a, there are shown four groups of closed shapes, where the closed shapes in each group are dyed with an identical color that varies between the groups (first color 405 for the first group, second color 410 for the second group, third color 415 for the third group and fourth color 420 for the fourth group). Each of the closed shapes in each group has a black contour, and the background color of the

closed shapes is identical in the entire design. In order to produce textile (e.g., by knitting) using conventional non-treated threads, 6 different threads (e.g., yarns) would have been required. One for the background color, one for the black contour, and one for each color of the four colors of the closed shapes. To the contrary, using the presently disclosed subject matter, only three threads (e.g., yarns) would suffice in order to produce textile in accordance with the design pattern shown in the figure.

In the design pattern shown in Fig. 4b, there are multiple color segments 450. In order to produce textile (e.g., by knitting) using conventional non-treated threads, a different thread would have been required for each of the color segment 450. To the contrary, using the presently disclosed subject matter, a single continuous running thread (e.g., yarn) would suffice in order to produce textile in accordance with the design pattern shown in the figure.

It is to be understood that the presently disclosed subject matter is not limited in its application to the details set forth in the description contained herein or illustrated in the drawings. The presently disclosed subject matter is capable of other embodiments and of being practiced and carried out in various ways. Hence, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting. As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for designing other structures, methods, and systems for carrying out the several purposes of the present presently disclosed subject matter.

It will also be understood that the system according to the presently disclosed subject matter can be implemented, at least partly, as a suitably programmed computer. Likewise, the presently disclosed subject matter contemplates a computer program being readable by a computer for executing the disclosed methods. The presently disclosed subject matter further contemplates a machine-readable memory tangibly embodying a program of instructions executable by the machine for executing the disclosed methods.

CLAIMS:

1. A thread treatment scheme determination system comprising a processing circuitry configured to:

obtain a multi-treatment pattern comprised of a plurality of pixels, each pixel being associated with a pixel thread length, and each pixel being associated with a respective pixel treatment;

determine, based on the multi-treatment pattern, a thread treatment scheme for automatically treating, by a digital thread treatment mechanism, one or more threads used for textile application in accordance with the multi-treatment pattern, wherein:

(a) the thread treatment scheme defines, for each thread, treatment portions, each of the treatment portions (i) is associated with a respective consecutive sequence of one or more of the pixels, wherein the respective consecutive sequence of the pixels are associated with identical pixel treatment, and (ii) having a corresponding calculated length, calculated based on the pixel thread lengths of the pixels comprising the respective consecutive sequence of the pixels, and

(b) at least a first treatment portion of the treatment portions of a given thread of the threads, and a second treatment portion of the treatment portions of the given thread of the threads are treated differently.

2. The thread treatment scheme determination system of claim 1, wherein the determination of the thread treatment scheme is also based on one or more of the following: (a) a thread weight of each of the threads, or (b) a thread type of each of the threads.

3. The thread treatment scheme determination system of claim 1, wherein the determination of the thread treatment scheme is also based on a minimal treatment change length requirement, being a minimal length of the thread required for the digital thread treatment mechanism in order to complete a treatment change process for changing the treatment of the thread.

4. The thread treatment scheme determination system of claim 1, wherein the thread treatment scheme enables producing a multi-treated textile having a reduced thickness or

reduced weight than another textile having an identical appearance using non multi-treated threads.

5. The thread treatment scheme determination system of claim 1, wherein the thread treatment scheme enables producing a multi-treated textile using a smaller amount of threads than another textile having an identical appearance using non multi-treated threads.

6. The thread treatment scheme determination system of claim 1, wherein the treating includes applying one or more treatment materials selected from: dye material, coating material, dye effect material, conductive materials, magnetic material, biological active material, or chemical treatment-material.

7. The thread treatment scheme determination system of claim 1, wherein the processing circuitry is further configured to determine threads application instructions for a thread applicator for applying treated threads, treated according to the thread treatment scheme, in order to produce textile in accordance with the multi-treatment pattern.

8. The thread treatment scheme determination system of claim 1, wherein the multi-treatment pattern is a two-dimensional pattern or a three-dimensional pattern.

9. The thread treatment scheme determination system of claim 1, wherein the pixel thread length depends on at least one of the following characteristics of one or more of the threads: thread width, thread production method, thread tenacity, or thread elasticity.

10. The thread treatment scheme determination system of claim 1, wherein the textile application is one of: knitting, sewing, embroidery, or weaving.

11. The thread treatment scheme determination system of claim 1, wherein the identical pixel treatment can be gradual along at least one of the treatment portions.

12. A thread treatment scheme determination method comprising:

obtaining, by a processing circuitry, a multi-treatment pattern comprised of a plurality of pixels, each pixel being associated with a pixel thread length, and each pixel being associated with a respective pixel treatment;

determining, by the processing circuitry, based on the multi-treatment pattern, a thread treatment scheme for automatically treating, by a digital thread treatment mechanism, one or more threads used for textile application in accordance with the multi-treatment pattern, wherein:

(a) the thread treatment scheme defines, for each thread, treatment portions, each of the treatment portions (i) is associated with a respective consecutive sequence of one or more of the pixels, wherein the respective consecutive sequence of the pixels are associated with identical pixel treatment, and (ii) having a corresponding calculated length, calculated based on the pixel thread lengths of the pixels comprising the respective consecutive sequence of the pixels, and

(b) at least a first treatment portion of the treatment portions of a given thread of the threads, and a second treatment portion of the treatment portions of the given thread of the threads are treated differently.

13. The thread treatment scheme determination method of claim 12, wherein the determination of the thread treatment scheme is also based on one or more of the following: (a) a thread weight of each of the threads, or (b) a thread type of each of the threads.

14. The thread treatment scheme determination method of claim 12, wherein the determination of the thread treatment scheme is also based on a minimal treatment change length requirement, being a minimal length of the thread required for the digital thread treatment mechanism in order to complete a treatment change process for changing the treatment of the thread.

15. The thread treatment scheme determination method of claim 12, wherein the thread treatment scheme enables producing a multi-treated textile having a reduced thickness or reduced weight than another textile having an identical appearance using non multi-treated threads.

16. The thread treatment scheme determination method of claim 12, wherein the thread treatment scheme enables producing a multi-treated textile using a smaller amount of threads than another textile having an identical appearance using non multi-treated threads.

17. The thread treatment scheme determination method of claim 12, wherein the treating includes applying one or more treatment materials selected from: dye material, coating material, dye effect material, conductive materials, magnetic material, biological active material, or chemical treatment-material.

18. The thread treatment scheme determination method of claim 12, further comprising determining threads application instructions for a thread applicator for applying treated threads, treated according to the thread treatment scheme, in order to produce textile in accordance with the multi-treatment pattern.

19. The thread treatment scheme determination method of claim 12, wherein the multi-treatment pattern is a two-dimensional pattern or a three-dimensional pattern.

20. The thread treatment scheme determination method of claim 12, wherein the pixel thread length depends on at least one of the following characteristics of one or more of the threads: thread width, thread production method, thread tenacity, or thread elasticity.

21. The thread treatment scheme determination method of claim 12, wherein the textile application is one of: knitting, sewing, embroidery, or weaving.

22. The thread treatment scheme determination method of claim 12, wherein the identical pixel treatment can be gradual along at least one of the treatment portions.

23. A non-transitory computer readable storage medium having computer readable program code embodied therewith, the computer readable program code, executable by at least one processing circuitry to perform a thread treatment scheme determination method, the thread treatment scheme determination method comprising:

obtaining, by a processing circuitry, a multi-treatment pattern comprised of a plurality of pixels, each pixel being associated with a pixel thread length, and each pixel being associated with a respective pixel treatment;

determining, by the processing circuitry, based on the multi-treatment pattern, a thread treatment scheme for automatically treating, by a digital thread treatment mechanism, one or more threads used for textile application in accordance with the multi-treatment pattern, wherein:

(a) the thread treatment scheme defines, for each thread, treatment portions, each of the treatment portions (i) is associated with a respective consecutive sequence of one or more of the pixels, wherein the respective consecutive sequence of the pixels are associated with identical pixel treatment, and (ii) having a corresponding calculated length, calculated based on the pixel thread lengths of the pixels comprising the respective consecutive sequence of the pixels, and

(b) at least a first treatment portion of the treatment portions of a given thread of the threads, and a second treatment portion of the treatment portions of the given thread of the threads are treated differently.

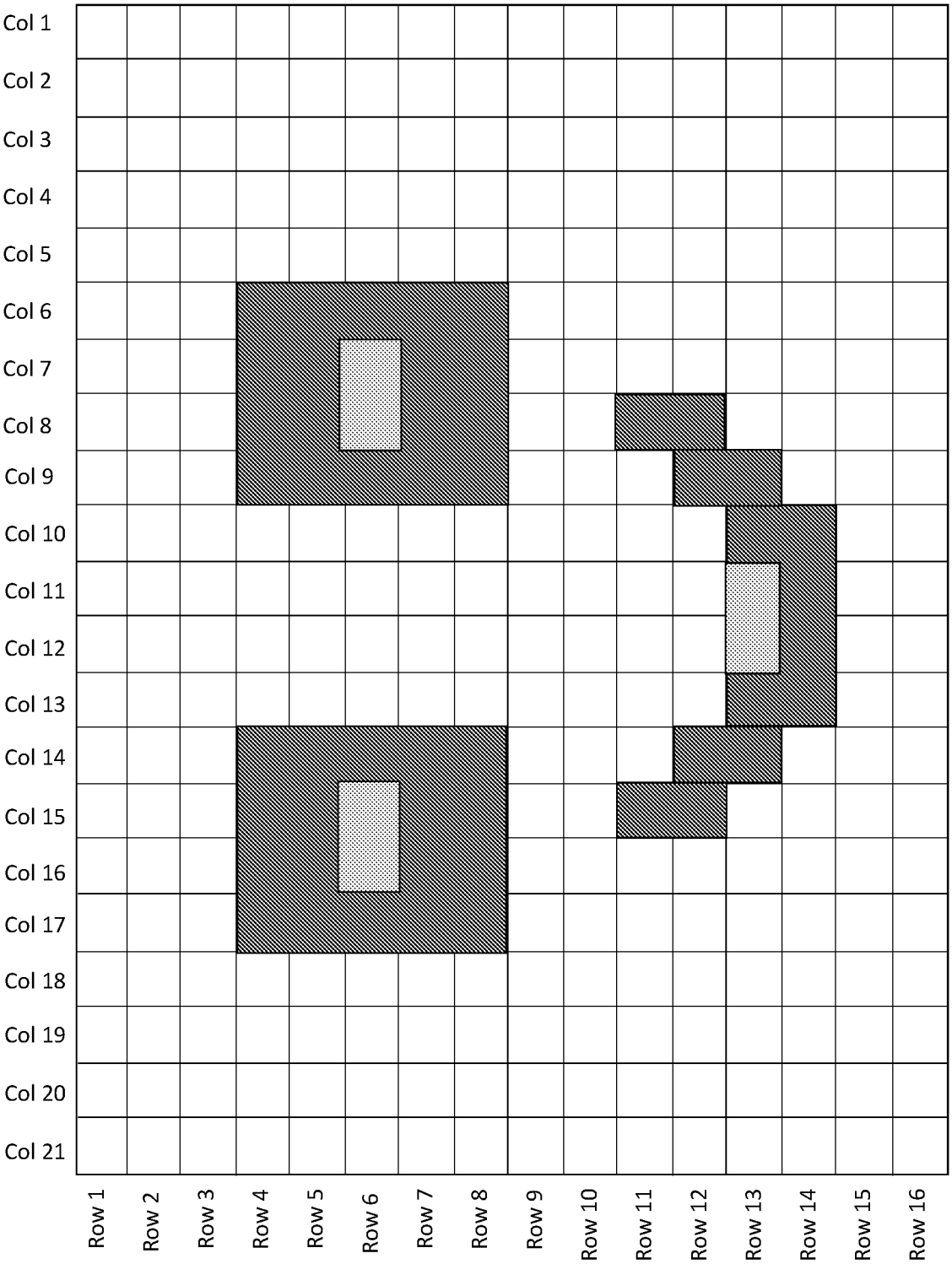
Col 1
Col 2
Col 3
Col 4
Col 5
Col 6
Col 7
Col 8
Col 9
Col 10
Col 11
Col 12
Col 13
Col 14
Col 15
Col 16
Col 17
Col 18
Col 19
Col 20
Col 21
Row 1
Row 2
Row 3
Row 4
Row 5
Row 6
Row 7
Row 8
Row 9
Row 10
Row 11
Row 12
Row 13
Row 14
Row 15
Row 16

Fig. 1

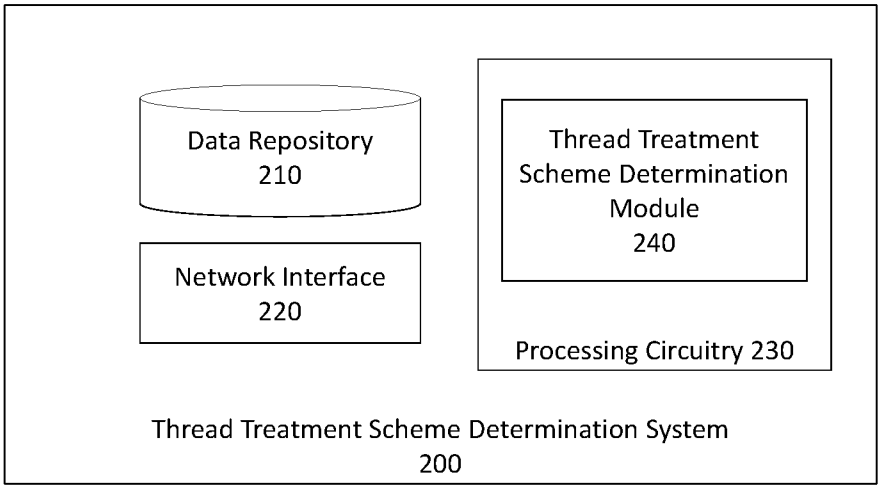
Data Repository
210
Network Interface
220
Thread Treatment Scheme Determination Module
240
Processing Circuitry 230
Thread Treatment Scheme Determination System
200

Fig. 2

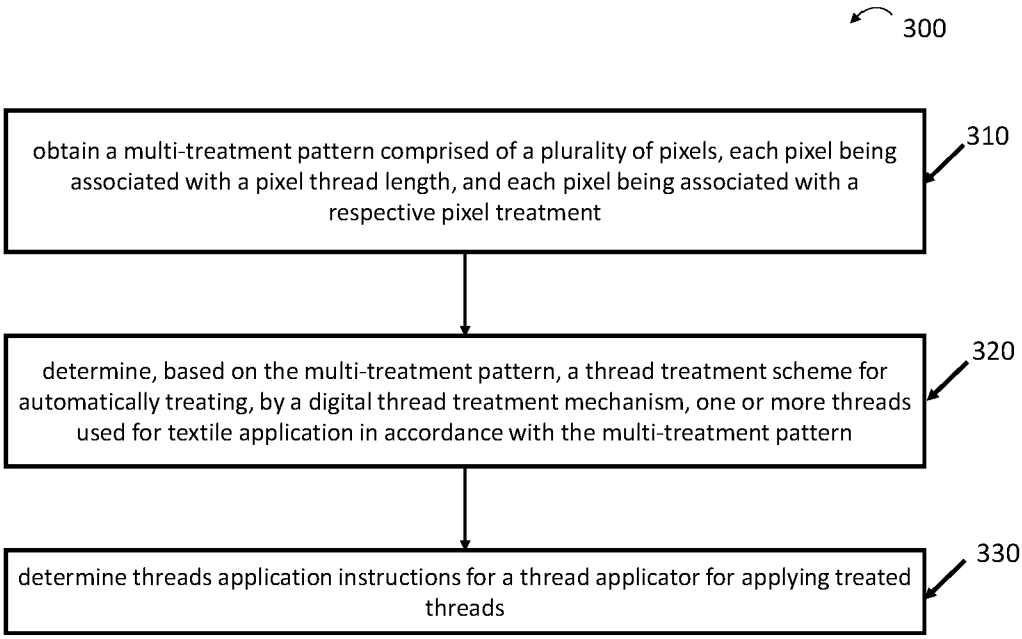
300
obtain a multi-treatment pattern comprised of a plurality of pixels, each pixel being associated with a pixel thread length, and each pixel being associated with a respective pixel treatment
310
determine, based on the multi-treatment pattern, a thread treatment scheme for automatically treating, by a digital thread treatment mechanism, one or more threads used for textile application in accordance with the multi-treatment pattern
320
determine threads application instructions for a thread applicator for applying treated threads
330

Fig. 3

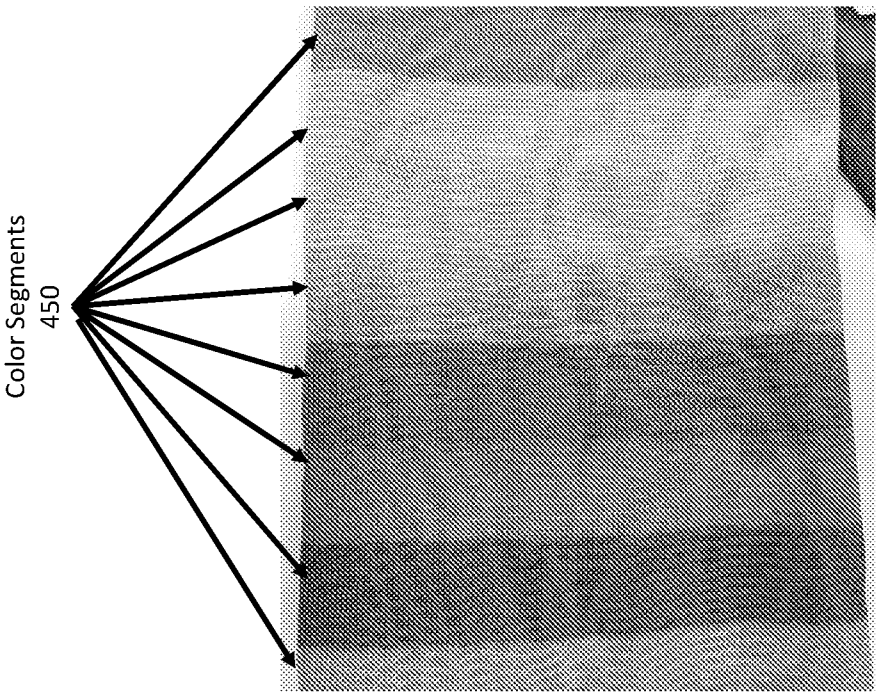
Color Segments
450

Fig. 4b

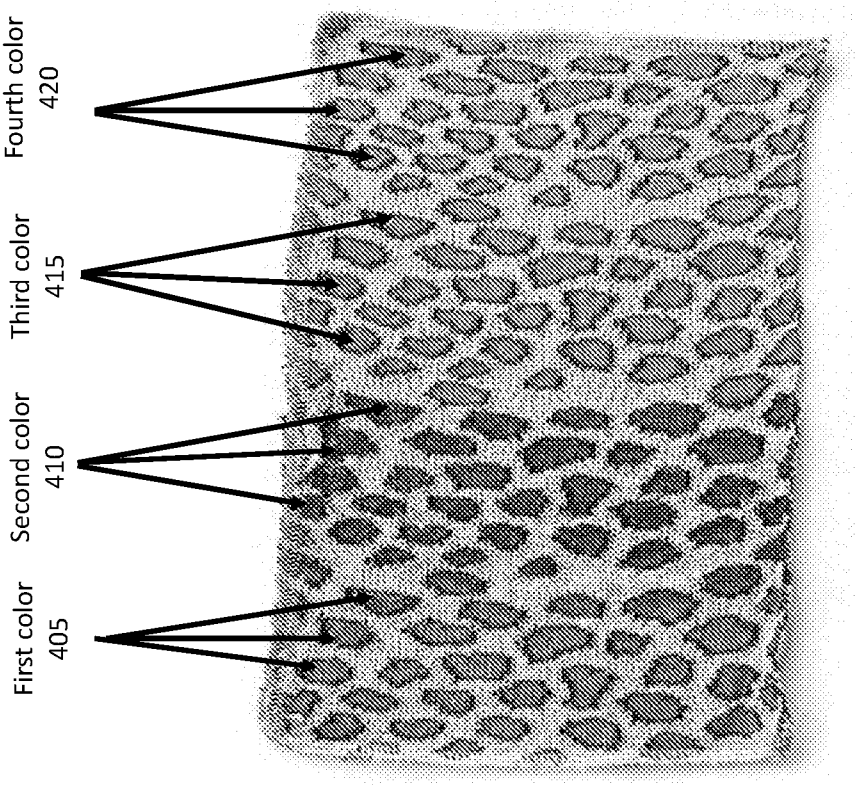
First color
405
Second color
410
Third color
415
Fourth color
420

Fig. 4a

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2022/050297

A. CLASSIFICATION OF SUBJECT MATTER
INV. D06B11/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D06B D05C D02G D05B D06Q D06P D04B B41J D03D G06F D03J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 166 141 A2 (HOFMANN KLAUS [DE]) 24 March 2010 (2010-03-24) cited in the application	1,6-8, 10,13, 17-19, 21,23
Y	paragraphs [0023], [0024], [0028], [0049], [0052], [0053]; figures 2,8	1,6-10, 12, 17-19, 21,23

X	JP 2008 289522 A (SEIKO EPSON CORP) 4 December 2008 (2008-12-04)	1,3, 6-10,12, 14, 17-19, 21,23
Y	paragraphs [0001], [0005], [0033], [0036] - [0042], [0045] - [0047]; claim 1; figures 1-3,6, 7(a), 7(b)	1,12,23

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[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 June 2022	13/06/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Uhlig, Robert

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2022/050297

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2002 294540 A (GIFU PREFECTURE; LAC KK) 9 October 2002 (2002-10-09) paragraphs [0004], [0009], [0010], [0017]; claims; figures 1,13	1-13, 15-23 1,12,23
X Y	JP 3 066937 B2 (CANON KK) 17 July 2000 (2000-07-17) paragraphs [0010], [0011], [0022], [0024], [0028], [0030]; claim 1; figure 5	1,2, 7-10,12, 13, 17-21,23 1,12,23
X	CH 697 623 B1 (TEXTILMA AG [CH]) 31 December 2008 (2008-12-31) paragraphs [0007], [0010], [0011]; claims 1,2; figure	1,6-10, 12, 17-19, 21,23
Y	JP S50 89683 A (.) 18 July 1975 (1975-07-18) the whole document	1,6-10, 12, 17-19, 21,23

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IL2022/050297

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