products, may need to be performed on the web material and/or on the individual pieces of the web material that will be or are already converted into a part to assure and/or certify compliance to these customer and/or regulatory requirements.

[0005] In a traditional web inspection system, a multi-camera inspection system may be used to image portions of a web extending across a cross-web dimension of the web being inspected. Each camera of the multi-camera inspection system is coupled to an individual image processor of a computing device, wherein only a fraction of the total available processor capability is actually being utilized to process the captured image data. These traditional arrangements may lend to wasted capacity of the image processors capacity, added expense, and lack of flexibility in the ability to configure the inspection system(s) for inspection of different types of webs and/or for different characteristics that are being measured or tested for with respect to the web undergoing the imaging process.

SUMMARY

[0006] The systems, devices, and methods described herein include arrangements for imaging of a manufactured web using a plurality of image capturing devices, (e.g., cameras), wherein the image data that that is captured by the plurality of image capturing devices is combined to form a "virtual camera data array" including image data from each of the plurality of image capturing devices spatially synchronized to the specific physical locations of the web where each image capturing device imaged the web. The virtual camera data array may be generated in some embodiments by a single image processor, or a number of image processors that is less than the number of the image capturing devices providing the image data used to form the virtual camera data array. This technique may provide more efficient use of the available processing capacity of the processor(s) use to process the image data, thus maximizing processor efficiency and reducing cost. Image data provided by the image capturing devices may include imaged portions of the web that overlap, and processing of the image data to generate the virtual camera data array may include processing to remove redundant (duplicate) data, and other processing procedures used to prepare the virtual camera data array for further analysis. The combining of the image data captured by a plurality of image capturing devices into a single virtual camera data array may simplify the analysis of the data, for example, used to detect defects in the web, and to determine one or more statuses associated with the imaged web. In addition, the use of a single virtual camera data array that is formed for the image data captured by a plurality of image capturing devices imaging a web, in some embodiments as the web is continuously advanced past the image capturing devices, allows for analysis of various aspect of the web, such as patterns associated with the web, that might otherwise be more difficult or impossible to analyze based on the individual image data provided by each image capturing device.

[0007] According to a first aspect of the present disclosure, there is provided a method for inspecting a web, the method including: imaging, by each of a plurality of image capturing devices, a plurality of imaging areas extending across a cross-web dimension of the web while the web is advanced along a down-web dimension of the web; generating, by the plurality of image capturing devices, image output signals comprising image data captured by each of the plurality of image capturing devices and corresponding respectively to each of the plurality of imaging areas extending across the cross-web dimension of the web; aligning, by processing circuitry, the image data corresponding to the plurality of imaging areas extending across the cross-web dimension of the web to generate virtual image data

corresponding to a virtual image area of the web that extends across the cross-web dimension of the web at a same down-web dimensional position of the web; combining, by the processing circuitry, the image data from the plurality of imaging areas to remove redundant data from the virtual image area and to generate a virtual camera array corresponding to image data captured from the plurality of imaging areas of the web; and pre-processing the virtual camera array by applying, by the processing circuitry, at least one of one-dimensional or two-dimensional filtering, ranked filtering, pass-through, contrast enhancement, and static flat-field correction to the virtual camera array; analyzing, by at least one inspection system, the virtual camera array to determine at least one inspection status for the web, at least in part by detecting, by the at least one inspection system, a pattern printed on the web, the pattern spanning at least two adjacent image areas of the image areas in the cross-web direction.

[0008] According to a second aspect of the present disclosure, there is provided a system for inspecting a web, the system including: a web inspection station configured to advance the web through a processing line along a down-web dimension of the web past an imaging station; a plurality of image capturing devices positioned at the web inspection station and configured to image a plurality of imaging areas extending in a cross-web dimension of the web while the web is advanced through the imaging station along the down-web dimension, and to generate image output signals comprising image data captured by each of the plurality of image capturing devices and corresponding respectively to each of the plurality of imaging areas extending across the cross-web dimension of the web; processing circuitry communicatively coupled to the plurality of image capturing devices, the processing circuitry being configured to: spatially synchronize the image data corresponding to the plurality of imaging areas extending across the cross-web dimension of the web to generate image data corresponding to a virtual image area of the web that extends across the cross-web dimension of the web at a same down-web dimensional position of the web, and combine the image data from the plurality of imaging areas to remove redundant data from the virtual image area and to generate a virtual camera array corresponding to image data captured from the plurality of imaging areas of the web; pre-process the virtual camera array by applying, by the processing circuitry, at least one of one-dimensional or two-dimensional filtering, ranked filtering, pass-through, contrast enhancement, and static flat-field correction to the virtual camera array; and at least one inspection system configured to analyze the virtual camera array to determine at least one inspection status for the web at least in part by detecting a pattern printed on the web, the pattern spanning at least two adjacent image areas of the image areas in the cross-web direction.

[0009] According to a third aspect of the present disclosure, there is provided a method for inspecting a web including a printed pattern on the web, the method including: imaging, by each of a plurality of image capturing devices, a plurality of imaging areas extending across a cross-web dimension of the web and along an imaging row in a down-web dimension while the web is advanced in a processing line along a down-web dimension of the web; generating, by the plurality of image capturing devices, image output signals comprising image data captured by each of the plurality of image capturing devices and corresponding to each of the plurality of imaging areas extending across the cross-web dimension of the web extending along the imaging rows for each of the image capturing devices; aligning, by processing circuitry, the image data corresponding to the plurality of imaging areas that align with one another extending across the cross-web dimension to generate image data corresponding to a virtual image area of the web that extends across the cross-web dimension of the web at a same down-web dimensional position of the web and that aligns the image data corresponding to the printed pattern of the web in a

same relative position as the printed pattern on the web; pre-processing the virtual camera array by applying, by the processing circuitry, at least one of one-dimensional or two-dimensional filtering, ranked filtering, pass-through, contrast enhancement, and static flat-field correction to the virtual camera array; combining, the processing circuitry, the image data from the plurality of imaging areas to remove redundant data from the virtual image area and to generate a virtual camera array corresponding to image data captured from the plurality of imaging areas of the web; and analyzing, by at least one inspection system, the virtual camera array to determine at least one inspection status for the printed pattern included with the web, at least in part by detecting, by the at least one inspection system, a pattern printed on the web, the pattern spanning at least two adjacent image areas of the image areas in the cross-web direction.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. 1 is a functional block diagram illustrating an overview of a system for manufacturing a web product, and for imaging and inspecting the web product in accordance with one or more exemplary implementations and techniques described in this disclosure.

[0011] FIG. 2 is a functional block diagram illustrating additional details of the system of FIG. 1 in accordance with one or more exemplary implementations and techniques described in this disclosure.

[0012] FIG. 3 is a conceptual diagram illustrative of an arrangement of image capturing devices and associated imaging areas for inspection of a web in accordance with one or more exemplary implementations and techniques described in this disclosure.

[0013] FIG. 4 is a conceptual diagram illustrative of another arrangement of image capturing devices and associated imaging areas for inspection of a web in accordance with one or more exemplary implementations and techniques described in this disclosure.

[0014] FIG. 5 is a conceptual diagram illustrative of an arrangement of image capturing devices for imaging a web that includes a pattern in accordance with one or more exemplary implementations and techniques described in this disclosure.

[0015] FIG. 6 is a conceptual diagram illustrative of an arrangement of image capturing devices for imaging a web that includes a pattern in accordance with one or more exemplary implementations and techniques described in this disclosure.

[0016] FIG. 7 is a conceptual diagram illustrative of a system for inspecting a web in accordance with one or more exemplary implementations and techniques described in this disclosure.

[0017] FIG. 8 is a flowchart illustrating an exemplary method in accordance with various techniques described in this disclosure.

[0018] FIG. 9 is a flowchart illustrating another exemplary method in accordance with various techniques described in this disclosure.

[0019] The drawings and the description provided herein illustrate and describe various embodiments of the inventive methods, devices, and systems of the present disclosure. The methods, devices, and systems of the present disclosure are not limited to the specific embodiments as illustrated and described herein, and other embodiments and variations of the methods, devices, and systems of the present disclosure, as would be understood by one of ordinary skill in the art, are contemplated as being within the scope of the present application.

CLAIMS:

1. A method for inspecting a web, the method comprising:

imaging, by each of a plurality of image capturing devices, a plurality of imaging areas extending across a cross-web dimension of the web while the web is advanced along a down-web dimension of the web;

generating, by the plurality of image capturing devices, image output signals comprising image data captured by each of the plurality of image capturing devices and corresponding respectively to each of the plurality of imaging areas extending across the cross-web dimension of the web;

aligning, by processing circuitry, the image data corresponding to the plurality of imaging areas extending across the cross-web dimension of the web to generate virtual image data corresponding to a virtual image area of the web that extends across the cross-web dimension of the web at a same down-web dimensional position of the web;

combining, by the processing circuitry, the image data from the plurality of imaging areas to remove redundant data from the virtual image area and to generate a virtual camera array corresponding to image data captured from the plurality of imaging areas of the web; and

pre-processing the virtual camera array by applying, by the processing circuitry, at least one of one-dimensional or two-dimensional filtering, ranked filtering, pass-through, contrast enhancement, and static flat-field correction to the virtual camera array;

analyzing, by at least one inspection system, the virtual camera array to determine at least one inspection status for the web, at least in part by detecting, by the at least one inspection system, a pattern printed on the web, the pattern spanning at least two adjacent image areas of the image areas in the cross-web direction.

2. The method of claim 1, wherein at least a subset of the imaging areas is aligned along the cross-web dimension of the web, and wherein each of the subset of imaging areas overlaps with at least one other imaging area of the subset of imaging areas along the cross-web dimension of the web.

3. The method of any preceding claim, wherein at least a subset of the imaging areas form a staggered pattern extending along the down-web dimension of the web, and wherein no imaging area of the subset of imaging areas overlaps with any other imaging area of the subset of imaging areas along the cross-web dimension of the web, the method further comprising aligning, by the processing circuitry, the image data the subset of the imaging areas in the down-web dimension to generate the virtual image data corresponding to the virtual image area of the web.

4. The method of any preceding claim, wherein the image output signals generated by the plurality of image capturing devices comprise raw video data.

5. The method of any preceding claim, wherein analyzing the virtual camera array with the at least one inspection system comprises:

determining, by the processing circuitry, a number of inspection systems to be used to process the image output signals; and

analyzing, by the processing circuitry, the virtual camera array using the determined number of inspection systems to determine the at least one inspection status for the web.

6. The method of any preceding claim, wherein the at least one inspection system comprises a single inspection system.

7. The method of any preceding claim, wherein the at least one inspection system comprises a number of inspection systems that is less than a number of image capturing devices included in the plurality of image capturing devices.

8. The method of any preceding claim, wherein the at least one inspection system utilized to analyze the virtual camera array comprises a number of inspection systems that is based at least in part on a resolution rate for imaging the plurality of imaging areas and a rate of movement of the web in the down-web dimension as the web is advanced.

9. A system for inspecting a web, the system comprising:

a web inspection station configured to advance the web through a processing line along a down-web dimension of the web past an imaging station;

a plurality of image capturing devices positioned at the web inspection station and configured to image a plurality of imaging areas extending in a cross-web dimension of the web while the web is advanced through the imaging station along the down-web dimension, and to generate image output signals comprising image data captured by each of the plurality of image capturing devices and corresponding respectively to each of the plurality of imaging areas extending across the cross-web dimension of the web;

processing circuitry communicatively coupled to the plurality of image capturing devices, the processing circuitry being configured to:

spatially synchronize the image data corresponding to the plurality of imaging areas extending across the cross-web dimension of the web to generate

image data corresponding to a virtual image area of the web that extends across the cross-web dimension of the web at a same down-web dimensional position of the web, and

combine the image data from the plurality of imaging areas to remove redundant data from the virtual image area and to generate a virtual camera array corresponding to image data captured from the plurality of imaging areas of the web;

pre-process the virtual camera array by applying, by the processing circuitry, at least one of one-dimensional or two-dimensional filtering, ranked filtering, pass-through, contrast enhancement, and static flat-field correction to the virtual camera array; and

at least one inspection system configured to analyze the virtual camera array to determine at least one inspection status for the web at least in part by detecting a pattern printed on the web, the pattern spanning at least two adjacent image areas of the image areas in the cross-web direction.

10. The system of claim 9, wherein at least a subset of the imaging areas is aligned along the cross-web dimension of the web, and wherein each of the subset of imaging areas overlaps with at least one other imaging area of the subset of imaging areas along the cross-web dimension of the web.

11. The system of claim 9, wherein at least a subset of the imaging areas form a staggered pattern extending along the down-web dimension of the web, and wherein no imaging area of the subset of imaging areas overlaps with any other imaging area of the subset of imaging areas along the cross-web dimension of the web, the processing circuitry being further configured to align the image data captured for the subset of the imaging areas in the down-web dimension to generate the virtual image data corresponding to the virtual image area of the web.

12. The system of any of claims 9 to 11, wherein at least one of the plurality of image capturing devices comprises either a line-scan camera or an area-scan camera.

13. The system of any of claims 9 to 12, wherein the at least one inspection system includes a number of inspection systems that is less than a number of image capturing devices included in the plurality of image capturing devices.

14. A method for inspecting a web including a printed pattern on the web, the method comprising:

imaging, by each of a plurality of image capturing devices, a plurality of imaging areas extending across a cross-web dimension of the web and along an imaging row in a down-web dimension while the web is advanced in a processing line along a down-web dimension of the web;

generating, by the plurality of image capturing devices, image output signals comprising image data captured by each of the plurality of image capturing devices and corresponding to each of the plurality of imaging areas extending across the cross-web dimension of the web extending along the imaging rows for each of the image capturing devices;

aligning, by processing circuitry, the image data corresponding to the plurality of imaging areas that align with one another extending across the cross-web dimension to generate image data corresponding to a virtual image area of the web that extends across the cross-web dimension of the web at a same down-web dimensional position of the web and that aligns the image data corresponding to the printed pattern of the web in a same relative position as the printed pattern on the web;

pre-processing the virtual camera array by applying, by the processing circuitry, at least one of one-dimensional or two-dimensional filtering, ranked filtering, pass-through, contrast enhancement, and static flat-field correction to the virtual camera array;

combining, the processing circuitry, the image data from the plurality of imaging areas to remove redundant data from the virtual image area and to generate a virtual camera array corresponding to image data captured from the plurality of imaging areas of the web; and

analyzing, by at least one inspection system, the virtual camera array to determine at least one inspection status for the printed pattern included with the web, at least in part by detecting, by the at least one inspection system, a pattern printed on the web, the pattern spanning at least two adjacent image areas of the image areas in the cross-web direction.

15. The method of claim 14, wherein the printed pattern comprises a plurality of outlines of shapes, each shape defining a perimeter for a part to be converted from the web.