June 2020

GRANTING TRACEABILITY OF ASSEMBLIES BY ENSURING VISUAL ACCESSIBILITY OF ASSEMBLY PARTS LABELS THROUGH A VIRTUAL VISION SYSTEM IMPLEMENTED AT BUILD PREPARATION STAGE

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Granting traceability of assemblies by ensuring visual accessibility of assembly part labels through a virtual vision system implemented at build preparation stage

Abstract

The ability to produce already assembled parts is a remarkable advantage of additive manufacturing technology over traditional manufacturing. We define an assembly as a collection of parts that are physically linked and share a common functional goal. Traceability of produced assemblies/parts is a must for some key manufacturing verticals such as automotive, aerospace and medical. Meaning that all parts must have proper and reliable identification system, thus enabling production and quality management systems. Traceability of assemblies using part labels is challenging due to several factors. For instance, some assembly part labels may not be visually accessible, thus blocking automated/manual quality inspection or categorizations in later stages of the manufacturing line. Here, we propose an inspection mechanism composed of virtual vision system to validate that an assembly labelling had been correctly located prior production. Additionally, once the inspection on the virtual model finished, produced information about the label and the labelling location can be communicated to automated quality inspection machine vision systems, located at the end of the 3DP digital manufacturing workflow, to check that physical assembly is consistent with the digital one. The method proposes alternatives in case identified labels does not satisfy traceability criteria and notifies users accordingly. Since the mechanism is implemented in the build preparation stage allows customers to save time and resources by avoiding the production of non-operative produced parts.

Introduction

Part traceability is a key feature for the manufacturing industry and specially for highly regulated sectors like automotive, medical and aerospace verticals. At the same time, the ability to produce already assembled parts (*assemblies*) is a key differentiator feature of the additive manufacturing technology. Traceability of assemblies is equivalent to the traceability of its composing parts, meaning that for each part of the assembly there will exist a traceability system at place, e.g., a label in its surface. There are multiple factors that can lead to practical inoperancies in the labelling of an assembly. Such factors are reinforced by the fact that assembly perspective is lost in current additive manufacturing digital workflows and parts are labelled individually without taking further consideration on the restrictions from composing assembly. Such approach results in the loosing of assembly traceability.

The labelling of assemblies is challenging according to a series of different situations that may affect how parts are labelled and where labels are located. If parts are not properly labelled, engraved vs extruded can led to later functional issues or if labels are not visually accessible assembly traceability cannot be granted by quality management manufacturing systems, once in the production line.

Here we propose a method to grant the traceability of assemblies by ensuring proper labelling of each composing part: the existence and visual accessibility of each part label. Enabling users to perform checks in the print preparation stage will enable consistency of the traceability system for a given assembly and save time and efforts to the user from producing parts that later in the manufacturing process would let to discard produced parts.

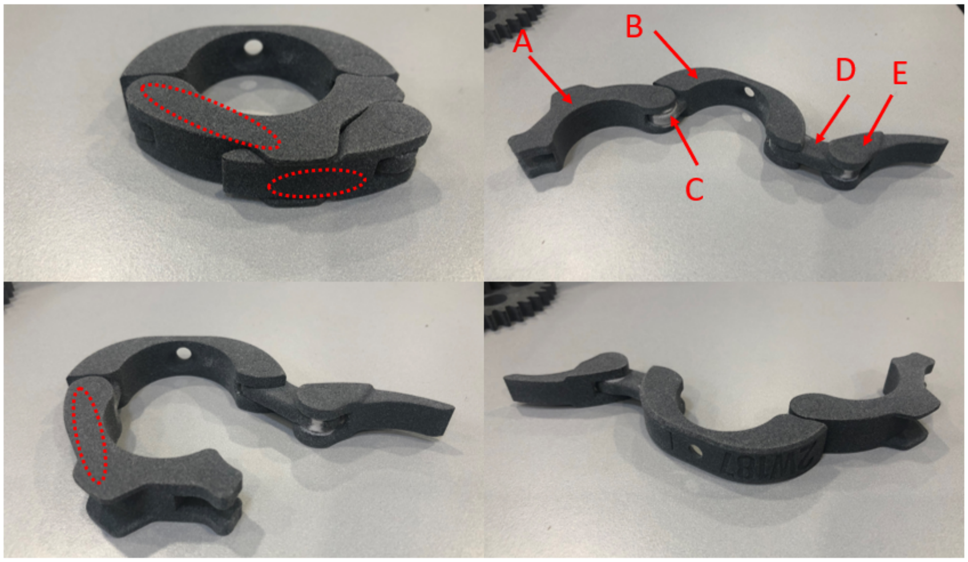

Figure 1. An assembly, its composing parts and relative positions. Note that assembly shown is composed of five different parts labelled as A, B, C, D and E. Label location is not obvious according to its functional movements. Red ellipses highlight suitable labeling locations.

Figure 2. Example of a complex assembly with several inner moving parts working according to a gear manually powered.

Method

Figure 3 describes Additive Manufacturing main stages and where the proposed method takes place. The method actuates in the build preparation stage and will produce the following information:

1. Verification of the existence of assembly part labels.
2. Location of assembly part labels.

3. Visual suitability of assembly labels.
4. Consistency of assembly labels regarding to content and form.

Such information can be used later in final quality inspection stages performed by automated machine vision systems.

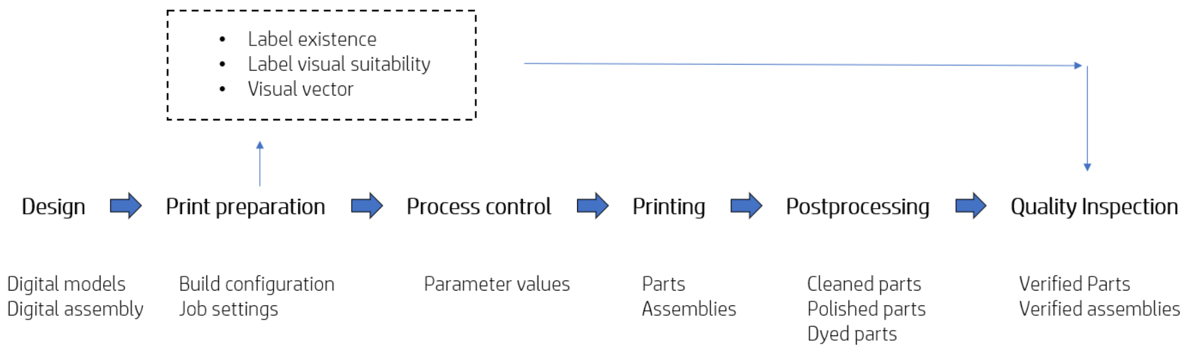

Figure 3. 3DP manufacturing workflow. Assembly labels will undergo several processes from their creation in the Design or Print Preparation stage, through Printing and Postprocessing to the final stage.

First step: checking existence and getting label information for each part

For each single assembly part, we run the following algorithm:

1. Label location in the digital model. Virtual Multi-camera approach depicted in Figure 4. Digital model is isolated from the assembly and a set of images are taken from different perspectives in the virtual space. Camera locations are defined on the surface of the minimal sphere that contains the bounding box of the digital model (i.e. Bounding Sphere) and the radius of such sphere can be set at several values. Images are then processed to isolate image regions candidates for hosting labels.
2. Label extraction via OCR Analysis. All images from previous steps are processed using Optical Character Recognition techniques [1] to extract the characters of the composing the label.
3. Aggregation. All label information produced in previous step is aggregated into a single label.
4. Label location recording. The average of camera location is taken for all images that produced label information and weighted according to contribution. Such information is recorded as spherical coordinates altogether with coordinates origin defined as the translation between assembly and digital model centers of mass.

The outcome is a table where each row corresponds to a part and details label existence, it's location and content. See following Table 1 as an example with paradigmatic cases specified.

Part ID	Label existence	Label location	Label Content
Part 1	Yes	$Origin_1\ , (r_1 \quad \theta_1 \quad \varphi_1)$	*Text 1*
Part 2	Yes	$Origin_2\ , (r_2 \quad \theta_2 \quad \varphi_2)$	*Text 2*
Part 3	Yes	$Origin_3\ , (r_3 \quad \theta_3 \quad \varphi_3)$	*OCR not succeeded*
Part 4	No	-	-
...	...	...	...

Part *n*		$Origin_1, (r_n \quad \theta_n \quad \varphi_n)$	*Text n*

Table 1. Outcome of the first step with paradigmatic cases introduced.

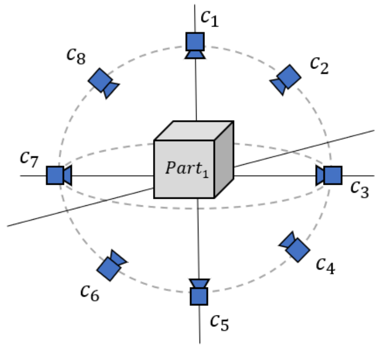

Figure 4. Virtual camera system. Note that only one meridian is shown for the sphere cameras located on sphere surface. Implementation is 3D and virtual cameras are equally distance sampled over all sphere 2D surface. Number of cameras depends on the sampling step which relates to the distance between camera and object.

Second step: assessing visual suitability of assembly labels

We assume that for given assembly and for each one of its composing parts the series of possible movements are detailed and represented by M_i for each *part i*:

$$M_i = \{(m_{i_1}, m_{i_2}, \dots, m_{i_N})\ where\ N\ is\ the\ total\ number\ of\ part\ i\ movements\}$$

Such elements m_i describing part movement can be a list of vectors describing translations and rotations according to some reference.

Then the list of all possible assembly positions is created:

Assembly positions
(A_1, B_1)
(A_1, B_2)
(A_2, B_1)
(A_2, B_2)

Table 2. Details all possible assembly positions according to the possible positions of its composing parts. Example for and assembly composed of two parts A and B and where each part has 2 possible movements.

For each one of the assemblies positions a procedure like the one detailed in previous section is performed. Using the virtual camera system, we look for the previously localized labels for each one of the composing parts. Then the outcome is a list detailing which labels are visible or not once the parts composing the assembly are joined. Thus table 1 is completed with one extra row indicating if label can be visually read.

Part ID	Label existence	Label location	Label Content	Label visually suitable
Part 1	Yes	$Origin_1, (r_1 \quad \theta_1 \quad \varphi_1)$	*Text 1*	Yes
Part 2	Yes	$Origin_2, (r_2 \quad \theta_2 \quad \varphi_2)$	*Text 2*	NO
Part 3	Yes	$Origin_3, (r_3 \quad \theta_3 \quad \varphi_3)$	*OCR not succeeded*	*NO*
Part 4	No	-	-	NO
…	…	…	…	
Part *n*		$Origin_1, (r_n \quad \theta_n \quad \varphi_n)$	*Text n*	*YES*

Figure 5. Illustrates and assembly that may have part labels not visually suitable since they remain out of sight once assembly is produced.

Third step: analyzing captured information: Consistency of assembly labels regarding to content and form

Finally, once all information had been gathered is analyzed holistically. Given and assembly with *n* number of composing parts, then *n* number of labels must exist, and the method can provide information about its overall consistency.

1. Check that all assembly parts had been labelled.
2. Check that part label is visually accessible in some assembly configuration.
3. Check that all assembly part labels are consistent, content and shape.

The user is communicated on the outcome of the analysis indicating the number of existing labels and its visual suitability.

Conclusions

Proposed method will grant assemblies are fully traceable in its composed parts. Customers will save resources (time, powder and money) by having an automated system to check assembly labelling is correct prior printing. If not, users will have the chance to go back to the design phase and modify digital models.

Introduced specification to detail part assembly labels can be communicated to other stages of the production line. For instance, when performing QA if labels must be visually accessible or even when doing unpacking in postprocessing station where indication of where labels are can be facilitated in a human friendly interface where 3D representations show point of view from where assembly part labels must be visually accessible.

References

[1] OCR methods. https://en.wikipedia.org/wiki/Optical_character_recognition

Disclosed by Jordi Roca, Sergio Gonzalez, Guiu Tio, HP Inc.