Potentials of Additive Manufacturing to Prevent Product Piracy

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Abstract

Infringements of intellectual and industrial properties rights in terms of imitations of products are continuously increasing. Massive economic and reputational damages are consequences for concerned companies. One solution to this problem can be the use of Additive Manufacturing (AM) technologies. This production technology enables complex designed products and specific product properties due to the use of different manufacturing processes and materials, which can help preventing product piracy safety measures of products can highly benefit from these capabilities, which have not been possible yet. The layer wise process allows, for example, to implement identifiable marks under the parts surface and to adjust mechanical properties in a certain way. The use of AM can strongly reduce the economic efficiency of plagiarism. This paper will present approaches to product piracy prevention by the use of AM focusing on the tagging of products, preventive measures as well as the interplay of these types.

Introduction

"Product piracy is the crime of the 21st century" was a statement of the president of the international chamber of commerce, Manfred Gentz. [AKL11] Even though the problem of counterfeiting is not new to originators of products as there were already imitations of oil lamps in the Roman Empire more than 2000 years ago [ChZi09], Gentz is absolutely right. Studies conducted by the Organization for Economic Co-operation and Development (OECD) in 2008 and by the German Engineering Association (VDMA) in 2012 reveal alarming figures across many branches. Beside the audio-visual and pharmaceutical sector, the automotive and electronics [OECD08] as well as the mechanical and plant engineering [VDMA12] industry are massively affected. Especially spare parts, components of machines and complete machines are plagiarized with an increasing high economical damage as shown in figure 1. The economical damage is not only loss of profit but also a high risk for employments. The loss of 7.9 billion € (Mrd.) just in the German mechanical and plant engineering industry equals ca. 37.000 employments. [VDMA12]

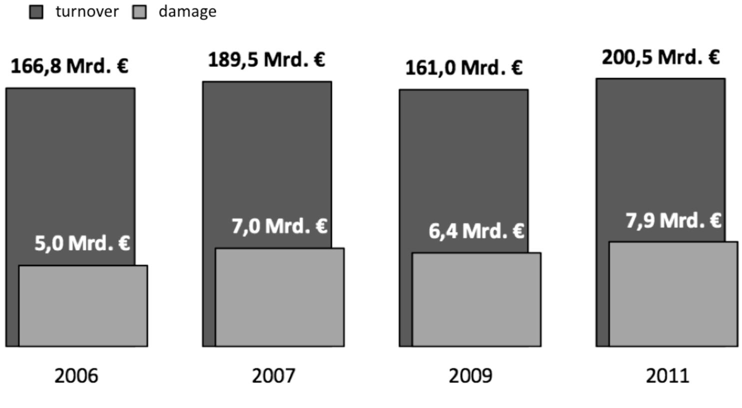

figure 1: Turnover and Damage by Product Piracy in Mechanical and Plant Engineering [VDMA12]

In the technology network “intelligent technical systems” OstWestfalenLippe (itsOWL) with 174 collaborating industry partners and research institutes the project “itsowl-3P – Prevent Product Piracy” is carried out. The main goal of this project is to strengthen the industry due to the development of new approaches in order to prevent product piracy and the consequences in terms of economical damage and the loss of employments. One approach to face the threats of counterfeits is to use Additive Manufacturing (AM). Especially the concerned branches have been identified in an expert survey as very promising to profit from the use of AM [EKW+12]. This paper will begin with the presentation of background in terms of types and impacts of product piracy, types of measures against product piracy and the potentials of AM in general and to extend the range of measures or to implement existing measures in a different and innovative way. So it is split up in three parts: Product piracy, AM and the approach to match the capabilities of AM with the needs to prevent product piracy.

Types and Impacts of Product Piracy

The case that a product is launched on the market and has similar or the same properties in terms of appearance and functionality as a product that is already on the market for some time does not imply automatically a violation of industrial property rights. Certainly this is not desired by the developer and manufacturer of the original product but it could be a legal imitation. An illegal imitation violates industrial property rights and is termed product piracy (see figure 2). Product piracy can further classified into counterfeits and plagiarisms. Counterfeits violate non technical industrial property rights for instance due to the forgery of a brand while plagiarisms infringe technical industrial property rights for instance by the use of the same technical concept of a function. [Koe12] Using this classification is not possible in some cases because of the violation of both, technical and non technical property rights, in one imitation. [Mei10] Besides product piracy contractual violation in terms of factory-overruns can bring imitations on the market. Actually these imitations are original products but manufactured and brought on the market without being licensed by the originator. [Fuc06] In all these considered cases imitations entail a high risk of damage for the originator. Damages can occur directly and indirectly. These classes of damage are displayed in figure 3 and will be discussed in the following.

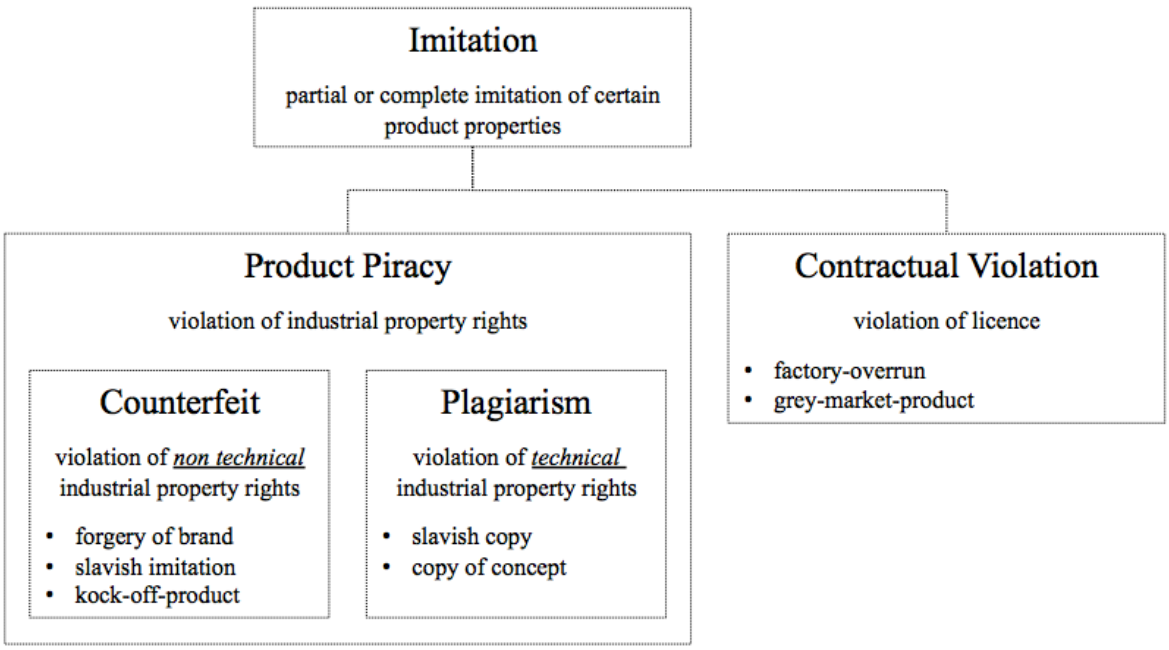

figure 2: Classification of Types of Imitations cf. [Koe12]

class	damage
direct	*loss of profits* • costs for product liability, customer complaints and service • reduced turnover volume and loss of market share • costs for product protection measures
indirect	*loss of today's markets* • collapses in prices • loss of image
	loss of tomorrow's markets • loss of know-how • loss of key markets

figure 3: Classes of Damages in Consequence of Product Piracy cf. [Koe12, Seite 21]

Direct damages for genuine manufacturers result in loss of profits due to product liabilities and customer complaints. These problems occur when a counterfeit has been purchased and the customer claims in a case of damage and wants the original manufacturer to compensate. Thus on the one hand costs arise for this compensation of damage or on the other hand costs for the proof of the products authenticity are caused. This situation becomes more critical if persons are injured or other equipment is damaged and consequential losses as a result of defects occur. [AK10] Furthermore losses of profits arise directly by means of reduced sales for the benefit of imitators. Protection measures can be implemented in the original products to counteract but this will result in additional costs as well. [AKL11][Koe12]
Indirect and thus more sustainable damages are caused by the loss of today’s markets in terms of collapsing prices for the original products and particularly in terms of reputational damages. In the process of reengineering and producing cribbed products imitators build up their own knowledge so that the unique selling point of the originator will be lost. As a consequence tomorrow’s market shares are under threat. [Fuc06][AKL11]
The occurrence of product piracy in the form of counterfeits holds not only risks and for the manufacturer of original products but also for the customers especially if low quality imitates are purchased. Thus one criterion to classify counterfeits is the quality while the most important criterion for the original manufacturer consists in the degree of deception. The correlation of these criteria and the impacts on the risks for customers and originators can be divided into four sections that are shown in figure 4. Counterfeits that can be allocated to section 1 are the most dangerous ones. There is a high degree of deception and a low product quality thus the customer is possibly endangered sanitary and the originator earns the customers claims as mentioned before. Products in section 2 cause high economical damage for the original manufacturer as these products are purchased unknowingly because of the high quality and the high degree of deception. Therefore there is nearly no risk of personal injuries and consequential damages but a better price-performance-ratio for customers will result in fewer sales of the original products. Products placed in section 3 involve less danger for the originator because of the less degree of deception. The main risk in this case is that the customers don’t attach great importance to a brand or the originality of the product but a more interested in the functionality that is fulfilled by the counterfeit as well. Thus the same consequences as for section 2 products can be mentioned. But the advantage for the originator is that the customers decide for their selves if they buy a counterfeit or an original. Section 4 comprises products that are obviously imitations and in most cases very cheap in comparison to the originals. Risks in terms of sanitary dangers are given for customers due to the low quality depending on the products functionality. But as the customer knows about this the only danger for original manufacturers consists in loss of exclusivity. [Mei10][Koe12]

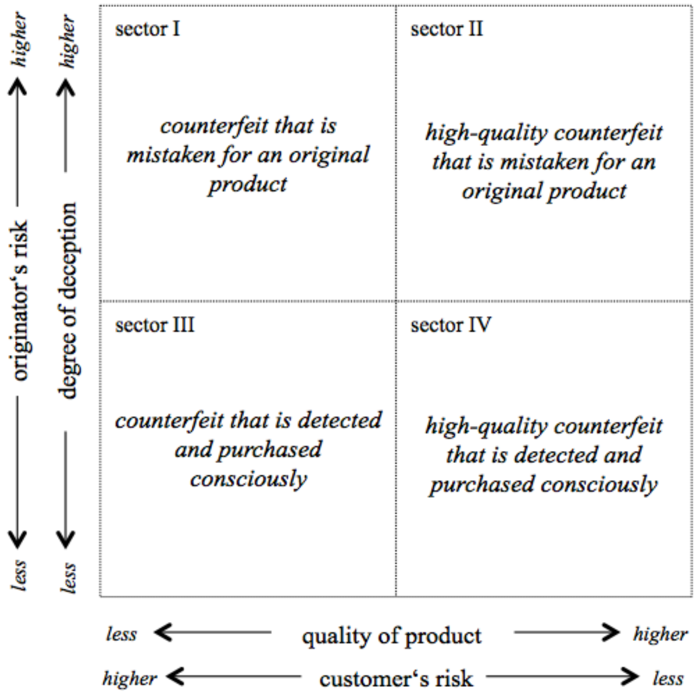

figure 4: Types of Appearance of Product Piracy cf. [Mei10][Koe12]

What kind of measures will help to prevent the production of counterfeits with regard to the four sections? Measures that make it more difficult to copy because of a complex design or incomprehensible functionalities are useful to prevent counterfeits in section 1 and 2. A good visible and hardly forgeable brand or label will help in these cases as well so that the originality is more obvious for the customer. Goods in sections 3 and 4 are fewer protectable by means of marking. The customer purchases knowingly the counterfeit. Therefore the only thing that will help is a preventive measure as described for sector 1 and 2.

Types of Measures against Product Piracy

As mentioned before producing imitations is not an illegal act as long as there are no property rights for the original product registered but the registration of property rights is not enough to prevent counterfeiting. It is a necessary step in order to have legal means to react but the reaction has to be based on traceable measures implemented in the products. Consequential a comprehensive protection concept can only be achieved by a combination of legal measures, measures to identify the authenticity of product and preventive measures. These kinds of measures should be supported by an open communication strategy so that the involved stakeholders in terms of staff members in the development and manufacturing processes, suppliers and customers get sensitized. A major challenge is to coordinate and aggregate the correct measures depending on the product. Therefore a continuous control of effectiveness has to be conducted to adjust the holistic protection concept if necessary. The Plan-Do-Check-Act cycle that was originated for quality control processes can be applied. [PlZi12]

As it was stated out before there are different types or levels of measures noticed in the literature: Legal, strategic, product-related, process-related, it-based, communicative and identifying measures. [Kok12a][VDMA12] The following examples will clarify what kinds of concrete measures belong to the considered levels. The decision if legal measures are the right way to protect a new product should be one of the first steps in the development process. The benefit has already been described. Legally there is no justification to react on a detected counterfeit if there are no property rights registered for the original. Three options for a

registration are available: Technical protection in terms of patents; protection of creativeness in form of registered designs; protection of label. But to do so it is necessary to reveal the products functionality and design. So on the one hand legal protection is achieved but on the other hand potential imitators get the know-how to copy. Therefore it is a trade-off between advantages and disadvantages if keeping the product details secret results in a higher degree of protection. [Lor12] Strategic measures should be applied in a high level of general business strategy as there can be a combination of product and service or a deep vertical range of manufacturing. Product related measures have to be considered during the development of each product to achieve a piracy robust measure. For instance hidden functionalities in a black box design or the integration of several functions in one part are measures that can be allocated in this level. The goal that has to be reached is that imitators and competitors cannot understand the functionalities of the product in detail. It is possible to use it and the main purpose is fulfilled but it will be not comprehensible. Process related measures support the traceability of original products in the whole product lifecycle. It starts with monitoring of the raw material, passes the production process with monitoring of production parameters and logistic steps and ends with revoking or disposal of products. The use of IT can support these activities during the whole process chain by means of data monitoring and storing. A lot of processes for instance the data exchange between machines and product designers are based on IT-systems and this is exactly the step where specific IT-based measures can be applied. In times of cyber crimes and spying of industries the encryption of documents and CAD data is an important step to protect the knowledge of companies. IT-based controlling of the manufacturing machines and processes allows ensuring that products are produced in the right batch-size at a defined date so that non licensed manufacturing can be prevented. [PlZi12]
A lot of measures that are very important to check the authenticity of products can be found in the identifying level. Marking the products or parts will allow customers or authorized persons to clarify if the product is an original one or a counterfeit. In this area it can be distinguished between visible and invisible marks that are implementable for different stakeholders. For a verification done by a customer a visible measure is more applicable but invisible measure are essential for verifying the products originality in case of customer complaints and product liability. The effort for implementing such measures into a product and for the proof of it goes wide apart. Visible ones can be seen with bare eye and for the proof of invisible marks some equipment like ultrasonic or RFID reader may be necessary. [Fuc06][Kok12b]
One aspect that will be in the focus of research during the project itsowl-3P is the relation between marking or identifying measures and their impact on a preventive protection. At first sight marking, particularly invisible marks, provide a non-preventive protection but a reactive protection. The possibility to identify a product in cases of complaints helps to avoid costs caused by product liability. This seems to be the main purpose but looking at bank notes shows that visible as well as invisible marks have a preventive effect as well if they are difficult to forge and supported with communicative measures. Everyone is informed that there are more marks than visible at first sight and that these marks can be proofed easily. Thus there is a correlation between different types of measures that shall be assessed during the research activities. Another focus is laid on the development of new technical measures that become possible due to the use of innovative AM. In the study of VDMA [VDMA12] more than 400 companies have been questioned. While 76% of the participants specified the registration of property right just 28% stated out to use technical copy protections. The major part of these technical measures is implemented as marks or tags and just 24% used specific design measures. 23% claimed that currently available measures are not suitable for their specific problem. Therefore the projects approach is to use AM to widen the range of technical and especially design measures to prevent product piracy or at least to render counterfeiting uneconomically.

Potentials of Additive Manufacturing in general

The technology of AM has been developed further during the last years so that mechanical properties of parts produced with AM and in cases of metal parts with a specific post processing like heat treatments became comparable with traditionally manufactured parts. [TRL+12] In various industries the usage of these technologies shifts from rapid prototyping to AM. Various materials are available for an additive production: From ABS plastics to metals as nickel super alloys. In the project itsowl-3P three different AM processes, Fused Deposition Modeling (FDM), Laser Sintering (LS) and Selective Laser Melting (SLM), will be considered. All of them produce parts on basis of sliced part information layer-by-layer. While the FDM process builds up the parts by melting a thermoplastic extrusion material, the LS and SLM use a combination of powder material and laser that is melting the powder based on the geometry of each layer. LS uses plastics and SLM metals.
Comparing AM with traditional manufacturing processes the major advantages consists in nearly unlimited capabilities in the design of products. By using AM there is no correlation between complexity and manufacturing costs as the parts are build up layer wise without the need of any tooling and so without any costs for tooling. This benefit can be summarized as "complexity-for-free" [HDD06]. Due to this fact most of the design rules that have to be considered to produce tools for traditional manufacturing or to get the whole product assembled don't have to be applied in design for AM. For designers it becomes possible to develop products driven by functionality and fewer by design rules. Thus several parts traditionally manufactured with the need of assembling can be replaced by one AM part that fulfills the same functionality in one part. The advantages and costs saving potential are obvious. Individualized products are easily producible just on basis of a CAD file and some data preparation work. Thus product variants can be realized without the economical requirement to produce thousands of products caused by costs for tooling that have to be split up on a high batch volume. The development of new products is speeded up and changes on existing products can be realized quickly just by changing the design in a products CAD file. [Zaeh06] [HHD06]
In figure 5 the major benefits of using AM are summarized. The point "safety against product piracy" can partly be achieved by one of the already known advantages. The correlation between the advantages and what kind of protection can be achieved by combining more than one benefit will be evaluated during the project itsowl-3P. In most cases one benefit implies one or more others so that additional values are definitively reached by using AM. The fields of application concerning the prevention of product piracy will be discussed in the following.

flexible production	integration of functions	freedom of design
less assembly	less time-to-market	individualization
fast deployment of changes	no production tools necessary	*safety against product piracy*

figure 5: Benefits of Additive Manufacturing [LJM+12][Zaeh06][HDD06][GRS10]

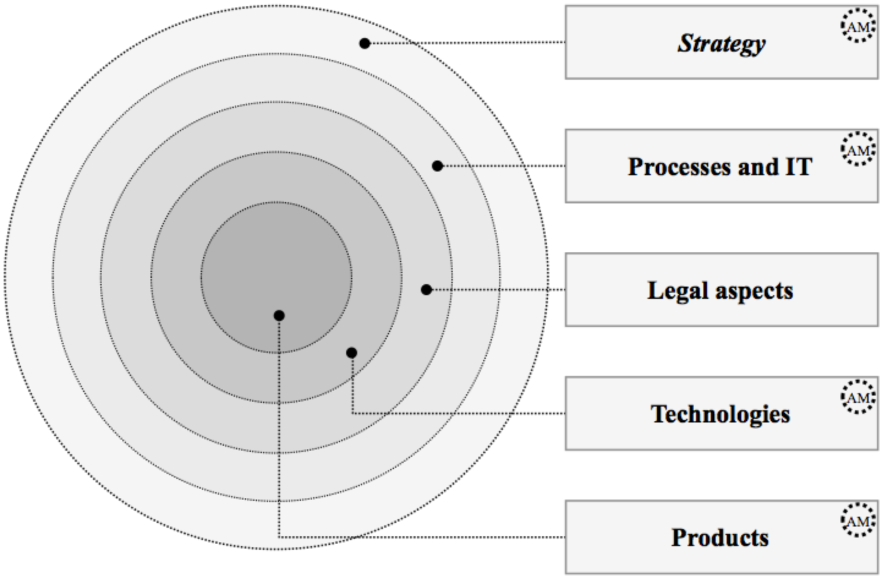

figure 6: Levels of Intervention with AM

As mentioned above a promising and sustainable protection of products should be based on the combination of various measures in different levels. Figure 6 shows the interplay of measures in five levels that have consolidated out of the different types of measures. Communicative measures are not displayed as there is a need of communication and sensitization for each product and company. The levels in which AM can contribute with specific measures to the protection of products against product piracy are marked with an encircled AM in figure 6:

Strategic level

In this level AM can influence decisions to the subject of partner selection for producing and distributing a product. The strategic use of AM allows a relocation of production to produce just where the parts or products are needed. The production process is highly automated for the most part. Therefore producing in countries with high personal costs becomes profitable. The gap between production in low-income countries and manufacturing in industrial countries is minor compared to traditional manufacturing with a higher degree of manual processing.
Furthermore AM can shift the make-or-buy decision towards the make in terms of producing the product or key components representing the essential knowledge. Thus just the company itself possesses the 3D data and important parameters for producing these components. The threat of becoming a victim of contractual violations is consequently lower.

Level of processes and IT

The improvement of innovation speed that can be achieved by using AM due to the capability of producing just on basis of the 3D product data is the main contribution of AM in this level. The innovative manufacturing process and the shortened process chain compared to traditional manufacturing allow variations, individualizations and redesigns of products without the need of any tooling. Thus the barrier to renew a products design is very low and the products duration on market will become shorter in the future. In some industry sectors the innovation speed is already very high. Increasing the innovation speed to a level that is so

high that an imitator can indeed copy a product but when the first imitations are produced the original product is no longer up-to-date may help enormously that the sales figures are no longer threatened by imitations. With this the time-to-market of new developments can be shortened as well. If some iterations in the development of a new product are necessary traditional manufacturing is very slow. In each iteration step or for each change of design new tooling is needed that has to be produced before the new product version can be manufactured. Using AM a change of design can be put into practice directly just by sending the file to the production machine and setting up the correct parameters.
An additional protection aspect is given by the splitting of necessary information for the manufacturing process. As mentioned above the 3D CAD data are the most important data for the production. All product information can be store in this file. It includes the geometric information as well as material specifications. But is this enough to manufacture the product? It is not. Parameters for setting up the machine are needed as well. Laser focus, laser intensity, exposing speed, the correct layer thickness etc. are necessary to achieve the desired result and product quality. So the required data are split up into two documents as it is in the "lock and key" principle. Without the right parameters it will be possible to manufacture the product on basis of the CAD data but it will take some iterations to achieve the real quality if at all. Thus there is no economical use of imitating with the "key".

Level of legal aspects

This level has not been marked in figure 6 because there is no direct contribution to a legal protection of products by the use of AM. Measures as the registration of property rights and trademarks can be allocated here. Concerning the traceability and enforcement of property rights AM may contribute indirectly due to innovative ways of tagging a product but these measures itself are described in the product level.

Technologic level

Using AM improves indirectly the safety against product piracy due to the needed knowledge about this innovative technology. In a real world with an increasing demand for high quality products it is not as easy as it is often presented in the media to "print" a product. Naturally this depends strongly on the requirements and expectations that a product has to satisfy. But thinking about industrial applications in plant engineering or the automotive and aerospace industry the requirements on products in terms of mechanical strengths in spite of lightweight designs, tolerances and surface qualities etc. are very high. To match these needs a deep knowledge about the AM technology is necessary and currently not widespread. Furthermore the investment costs for AM machines cannot be neglected although a whole process chain for traditional manufacturing is far more expensive but more available. So using AM raises the barrier for potential imitators in two ways. The manufacturing process has to be mastered to produce suitable imitations and simultaneously the economical barrier is raised.

Product level:

The product itself and its design are in the center of the protection concept as it is shown in figure 6. Using AM extends the design freedom so that internal structures can be implemented in parts. This allows innovative tagging of parts with invisible marks that have been impossible to manufacture traditionally. Examples for invisible marks can be internal structures representing a code that is identifiable by ultrasonic or due to use measurement of transmitted light trough the parts surface. Such a coding can be used to identify the product in

case of customer complaints to avert product liability but can also be the key to the functionality of the product if implemented as “lock and key” principle in two related parts.
Furthermore a design that is more adapted to the functionality of the product including the integration of several parts or functions into one part. This may result in a more complex product geometry that is more difficult to copy because a scanning process will not capable to capture to whole structure. Implementing certain characteristics into the product that are necessary to fulfill the desired function will complicate to understand the functionality. For example moving the center of mass of a product due to the implementation of different densities or internal structures can be essential for a parts functioning or may help to establish the authenticity. A reengineering and measurement of these characteristics will be hard for someone else than the developer and so the degree of protection is increased. These measures can be categorized as blackbox design so that something particular is implemented that is not comprehensible.
Further improvements of a products protection can be achieved by means of its individualization. AM allows producing more or less unique product compared to handcrafted. Just thinking about an it-based function that randomizes the design of a parts surface. Each product would be different and copies produced traditionally can just be one as the other to be of economical interest. Manufacturing product in a batch size of one will become economical. And this may be a measure to prevent to mistake an imitation for a real product. Unfortunately ways to improve the safety against product piracy on this level are nearly endless in consequence of the freedom of design. Thus this section will never be completely described but to abstract the main functions into concrete measures realizable by AM will be focus of the project itsowl-3P and further described in the next section.

Approach to be developed

The main goal that is focused in the project is to develop concrete measures that can be integrated in a parts design directly or supported by the use of AM. Therefore the potentials of AM and the possibilities described above will be translated in concrete measures and brought together in a catalog with various parameters. As a first step the three considered AM technologies in terms of FDM, LS and SLM will be analyzed concerning their specific possibilities to influence parameters of the machines as well as properties of materials that can be used in these manufacturing processes. By using certain design rules that have to be considered for each process it will be possible to mark the processes allowing the realization of a measure. Additionally the catalog will contain information about the costs that have to be considered for the implementation of a measure as well as the costs that will occur to proof the product concerning its authenticity. These costs will certainly arise only in the case that a tagging measure for a definitely identification of a part has been implemented. If possible another information could be the costs that are saved by using this measure by means of increasing the degree of protection and so of the reduction of possible imitations. This will be part of the project to check the potential of raising such information with general validity. In correlation with the costing information the effort of implementing and proofing the specific measure will be content of the catalog as well. In order to get an idea of the catalogs structure figure 7 shows a first draft. As shown in this figure, additional parameters of each measure will be used for assessing the protection level that can be achieved by application. A design example will help to get a first visualization.
If filled with various additively realizable measures the catalog will allow selecting one kind of protection or a combination of several for a product. An important step is the screening of potential parts that can benefit from AM in general. AM offers a wide range of potential but nevertheless an application is not mandatory useful for each kind of product.

	FDM	LS	SLM	Costs for Implementation	Costs for Proofing	Effort for Implementation	Effort for Proofing	Protection Level	Example	...
Measure A	X									
Measure B		X	X							
...										

figure 7: Structural Draft of Catalog of Measures

To screen parts or products that can benefit the restrictions of AM have to be considered in terms of producible dimensions and available materials. So the needs and requirements of a product have to be matched with the potentials and restrictions of AM.

Generally the screening process should split up in two iterations. In a first step threatened products should be identified. On the one hand these can be products that are currently on the market and are already confronted with problems in terms of product piracy. Furthermore products that are in the phase of development can be identified as potential as well if there are negative experiences with comparable products. This type is more promising as the catalog and its measures can directly be applied in the development to prevent future imitations. On the other hand potential parts can be part of the manufacturing process of products. This may be the case if products are produced traditionally but with a specific key component in the traditional manufacturing process. Such a key component represents the advantage in competition as well as the knowledge of a company deserving protection. Usually these components are needed in a small number of pieces and so the benefit of using AM, economically und protective, is likely. The second step of screening should contain the matching of requirements with technological restrictions as it was mentioned before. This step can be used as filter that let pass the parts with highest potential to benefit from the use of additive protection measures.

Conclusion and Outlook

The capabilities of AM offer a wide range of intervention possibilities on various levels of a products protection. Am can contribute to the degree of protection in a strategic way and particular due to the freedom of design and the necessary knowledge to master the manufacturing process. Once the catalog of measures has been filled the usefulness has be evaluated. Therefore the methodology for part screening is a very important step for the evaluation process. There will be parts to select that can benefit from the use of AM and specific additive protection measure on the one hand and parts for that the use of these technologies is useless on the other hand. For this reason the screening methodology will be essential for the successful application of AM for the protection of products or key components.

In the considered studies it was pointed out that there is a demand for further technological measure to counteract product piracy. The project itsowl-3P will analyze whether the described approach using AM on different levels is realizable and applicable by the industry. During the evaluation processes it has to be considered that AM is an evolving technology so that some restrictions that currently limit the applications and selection of potential parts will disappear in the future.

Finally the results of the project itsowl-3P will show if AM can contribute to counteract the crime of 21st century.

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