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Reverse Engineering - A Constant Challenge to Maintain Originality

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ABSTRACT
The originality of a design is directly proportional to the time taken to make it, but from the financial perspective this can cost the organisation a fortune, owing to the competition that it has to face in the live market. It is for this reason that many organisations tend to look for designs that are already available to be used as a reference so that they can build their design on those lines. What matters is the originality of the reverse-engineered design. It is indeed a challenge that shall be attempted to be presented through this paper. The paper shall introduce certain basic concepts like reverse engineering, originality of designs, customer specific mindset and shall thereafter elaborate certain factors that greatly affect reverse engineering, which include technical, commercial and practical aspects. The output of reverse engineering thus done maintaining originality shall be understood from the viewpoints of technical feasibility, commercial viability and manufacturability from the practical perspective. This paper shall stress upon the challenges that a designer needs to face while carrying out reverse engineering and the balance that needs to be maintained between cost, originality and optimum parameters. In addition to these topics, this paper shall also try to present certain risk and opportunity analyses so that a complete picture of the concept can be drawn. The paper shall conclude with the summary of challenges and the means to mitigate the same so as to ensure that a reverse-engineered product does not happen to be a replica of another design but becomes an optimised design by itself.

Introduction

1. The concept of Reverse Engineering

Everybody needs some or the other kind of inspiration in order to come up with certain outputs. It may be in any form but the need for a certain reference is inevitable when it comes to the world of engineering. Engineering by itself is a science of making lives easier by solving practical problems and when it comes to practical problems, there needs to be complete comprehension of the process parameters that are involved in the situation.

Reverse Engineering is an approach in which an existing solution is thoroughly studied and a better and optimised solution is suggested to the customer based on the given inputs. The very fact that the customer has given a readily available solution points out to the need for further development and optimization required in the same. Thus it is also a science of understanding the current requirements and present a design that can suit the requirements at a better offer price or with better offer parameters.

In the process of Reverse Engineering, most of the times there is very less amount of alteration done to the design as it has already been in practise and is to a certain extent proven by a certain process. All that is required is fine tuning that can enable better performance that can let the process give out better outputs than earlier. Somehow it is necessary to have this outcome-based thinking while working in the field of Reverse Engineering.

The need for a reference comes from an interesting example given as follows. Assume that a person has never seen a lion, either in the form of pictures or in the form of a model or in reality. Now if the task of describing a lion to the person is assigned to someone, it would be extremely difficult to build this perception of what a lion would actually look. One cannot use quantitative measures like the number of limbs or sense organs that a lion has as it would be highly confusing. At the same time one cannot get too qualitative in matters of strength and so on. What can be the best aid in this case is an image or model or an actual sighting of a lion and nothing else. References are this important in engineering as well. One can easily imagine a hexagon headed metric bolt but when it come to the concept of a Knuckle joint, a drawing or a model would definitely be required to enhance the understanding.

Thus having understood the importance the references in Reverse Engineering, it is necessary that the component that needs to undergo this process of reverse engineering is thoroughly understood. Reverse Engineering is not only a process of replicating the dimensions of a given reference sample, but it is a process of re-designing the component such that it suits the mating component and tries to provide a better quality of performance as compared to the very sample received. This itself leads to a concept called originality of design, which shall be considered in the next section.

2. Originality of a Design

There is a well known saying which purports to say that a design that cannot earn profits is a mere piece of art. Thus what is required from a design is the ability to generate revenues than costs. But in the sense this control of costs

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can in fact cost the organisation quite an amount as original designs are not at all that easy to make or even acquire. Originality is thus more or less a gift and only the gifted designers can bring out original designs.

In the ancient engineering times, there was no social media or advancement in communication systems, due to which, every engineer had to rely on first principles and generate designs that would be sustainable and efficient, so that they would stand the test of time. In the present day scenario, most of the designs are readily available on free sites for costless download and the same has rendered a sense of inability to think and generate new ideas. This is all because of the readily available material and references, which would have not been the case in event there would have been no references available. It is, at most of the times, the availability of resources that curtails growth as the scarcity of resources makes the individual either look for them or generate them.

Design is basically defined as a solution to an existing situation, which when unattended leads to certain problems. This solution may be in any form - animate like a product or inanimate like a service. What matters is the originality with which a designer can develop the solution. It is quite natural that there may be situations wherein certain references can be taken but more or less a pilot designer needs to be an inventor rather than merely being a developer. This narrows down to the need for originality of a design wherein the existing process parameters are aptly understood and the solution(s) in the required form(s) is delivered to the satisfaction of the customer.

The most deterring factor when it comes to originality of a design is plagiarism. To a certain extent being inspired by an existing design, making your design like it and responsibly acknowledging the reference sources would be excellent but the idea of plagiarism destroys the very idea of acknowledging the original sources and leads the designer to present plagiarised ideas and concepts as their own. This factor is highly lucrative and easy going as there are very fewer efforts required but it affects the very foundation of a designer's free thinking and their ability to produce something of their own.

The field of reverse engineering naturally gives a very narrow bandwidth for originality as the basic requirement is that the component or service needs to be a 'look alike' of something else. However there is a narrow yet possible bandwidth wherein certain modifications, no matter how meagre they may be, can be done for the enhancement of the overall product performance. The aim of all this is to ultimately ensure that the end user is at a profit with the reverse-engineered component that should preferably have a sumptuous touch of originality.

3. The customer specific mindset

When it comes to the engineering domain, there are certain things that can be predicted while a few that cannot be. Among those that can be predicted, one can definitely predict the feasibility of the undertaking or the estimated cost of the project while the outputs of special process always remain beyond any kind of predictions. However what can be predicted with certainty is the unpredictable mindset of customers. It is a science by itself and needs deep understanding of the market trends of the past.

There are a certain needs and expectations of customers. Needs refer to the basic requirements that the customer demand in the product and expectations refer to something that is not otherwise documented but is supposed to be included in the output. The need may be a set of designs but expectations may be that all the designs need to be submitted at a time and that too before the deadline. The customer thus controls a huge portion of the design and associated forecasting with regards to the business plan of the organisation. In a way, it is the customers who control businesses when it comes to the longing for growth.

With regards to the present trend, one can easily judge that gone are the days when there used to be a rush for customer satisfaction wherein mere delivery of quality goods or services on time would ensure satisfied customers. For that matter, even the days of customer delight, in which lucrative offers could keep the customers gelled have gone away and in a paradigm shift, there have been ideas of customer obsession that have started to emerge in the market, according to which, during any new product development, a customer would explicitly look for your organisation to deliver the solution. It is this requirement of customer obsession that can be fulfilled to a huge extent by means of reverse engineering.

There is an important factor that needs to be understood when it comes to customer obsession by means of reverse engineering. This factor is nothing but the mindset of certain customers in which they expect an exact replica of the component to be made. This has got its own limitations. Firstly, it may not be completely feasible to gauge the complete technical specifications and manufacturing processes that have been used to make the reference sample. Secondly it would certainly be an ethically incorrect thing to replicate a design that has been already done by someone. Thus it is essential for the designer to tread the edge of a razor, maintaining balance between the customer expectations and a moral need to maintain utmost originality, which depends on several factors that affect reverse-engineering, which shall be elaborated in the following section.

4. Factors affecting Reverse Engineering

Reverse Engineering can be said to have its major dependence upon three aspects viz. technical, commercial and practical. These happen to be the key areas where one can conceptualize the predominance of the affecting factors. For any reverse engineered component, it is essential that these factors are duly considered before arriving at the final form of the solution so that there is a sustainable business contribution and at the same time certain value addition is done to the product by striving towards development of an original design. These factors shall be elaborated in the following sub-sections.

4.1 Technical Factors affecting Reverse Engineering

While carrying out the process of reverse engineering, the first aspect that needs to be considered is the technical factors. If a design is not technically sound, it always bears the risk of premature failure either during installation or operation. There are a certain key factors that need to be considered while carrying out the process of reverse engineering, as have been briefly explained as follows.

4.1.1 Skill of the Engineer

Reverse Engineering is a process of trying to recreate a design, but with certain value addition done to it. Skill plays a very important role in adding value to the product. There are some engineers who can re-create any design with modifications done empirically. However this comes as a skill with great experience and dedication put in. Highly skilled engineers may not require a plethora of references as with limited material the product can be conceptualised and re-created. However if the experience and skill is meagre, there can be instances wherein the engineer may just replicate

the design by means of tracing the drawings or so. It is important that either way, plagiarism is kept at bay and the design has certain originality by itself.

4.1.2 Essential Process Parameters

There are several process parameters that go into the making of any product. There are several videos on the internet that depict the methodology of manufacturing several products. However, there are certain sections in the videos in which the complete process is kept hidden from the viewers on account of certain trade secrets and propriety formulae that may even be in the form of patents. This is where the skill of the engineer comes into picture as they need to know the probable process required for the design as these process parameters are mandatory, omitting which, there can be deviations from the desired results.

4.1.3 Plagiarism

As explained in an earlier section related to the originality of design, plagiarism can seem to be an easy way to achieve great results in short time but it is as dangerous as metal cutting with a cutting tool that has a built-up edge developed due to improper process parameters. This therefore makes it imperative that short-cuts need to be avoided at all costs so that the design generated by means of reverse-engineering qualifies to be called original. Undertaking the path of plagiarism, there is nothing but a constant threat of impromptu changes in the design, which may not have been tracked by the engineer, thereby making a product referring the wrong reference itself.

4.1.4 Accuracy of conversion

One of the most common aspects of reverse-engineering is the conversion of given samples into three dimensional models and corresponding drawings. Converting any animate object into a conceptualised model in a software include its own limitations like human errors of measurement that may override the instruments, however accurate the instruments may be. Thus it is both - the person and process that needs to be in place while carrying out the process of reverse-engineering so that the process of conceptualisation and re-generation of the features is as accurate as possible.

4.1.5 Effectiveness of Reverse-Engineered Part

In the technical domain, there is a very important aspect called the through-put of the process which is greatly governed by the effectiveness of the process. It is important that the skills are put into comprehension of the required process parameters of the product such that there remains a greater component of originality in the design along with optimal accuracy of the conversion of the sample component into a reverse-engineered one.

4.2 Commercial Factors affecting Reverse Engineering

Having understood the technical factors, it is essential that one then turns towards the commercial factors. This is in consonance with the fact that any design that is technically sound needs to be commercially profitable and feasible as well. A design that would be non-profitable would not be accepted by even the most technically sound client. Thus it is most of the times that cost precedes the quality as it is an external factor that is largely viewed by customers. Although this is a comparison known as ‘apple to apple’, it is necessary that the reverse-engineered design also becomes sound on the commercial front, the factors affecting which, have been briefly explained as follows.

4.2.1 Investment with the risk of failure

Any undertaking requires a capital for investment and when it comes to investment, there is always a risk involved in the same. However thorough the market study might have been, there always exist surprise elements that can pop in an unexpected time and deter the chances of success of the process. While carrying out the process of reverse-engineering, it is a mandatory requirement that certain basic equipment for metrological activities is maintained. However investing in such assets needs to come with a sound plan for the recovery of the investments.

4.2.2 Return on Net Assets (RNA) for Tools and Assets

The concept of RNA is as essential as the concept of the profitability ratios. In reality there can be profits only when the returns on the net assets crosses the breakeven point, without which there would only be investments and debits that can lead to a situation where the process of making a new product would actually be profitable than carry out the process of reverse-engineering. Thus it is essential that sound planning is put in sincerely so that there is complete surety of crossing the break-even point.

4.2.3 Profitability

The process of reverse engineering can be said to an expensive one as it involves investment in measuring equipment, sample making and the phase of trials. There is no surety that the process would be successful or not. All these aspects affect the profitability of the process and indirectly the profitability of the company as well.

4.2.4 Cost effectiveness of the Process

There is minor hair line of variation between the concept of profitability and cost effectiveness. While profitability aims at determining the profits earned with reference to the investment, cost effectiveness ensures that whatever investment is done, there are positive returns for every header thus undertaken. This may sound non-intuitive to a certain extent but is an essential factor as profitability is much of a performance parameter whereas cost effectiveness aims at reducing the unnecessary expenses so that there are prospective profits in the time to come so that the overall process attains sound practicality.

4.3 Practical Factors affecting Reverse Engineering

The technical and commercial factors affecting reversing engineering have been briefly explained till this point. However these domains are mostly looked into until the order is received. Once the order is received, it is essential that the same can be converted into the product, for which certain practical factors need to be considered, which have been briefly explained as follows.

4.3.1 Resources and Equipment for measurements

There is no end to the technical specifications of equipment that might be essential to carry out reverse engineering. There may be components that may be made once in a blue moon but may require high-end equipment for its generation and on the other hand there may be components that may be made with a greater frequency and may not require paraphernalia of devices. Thus it is essential that one gets hold of systematic forecasting of orders so as to invest in the right areas so that there are viable returns on the same.

4.3.2 Manufacturing Setup

Every reverse-engineered part may be conceptualised and re-generated under a single roof but it is not necessary that it can be manufactured in the same organisation as well. This is because there may be certain process or practical variables that may not be in the practical limits of the organisation and this calls for the concept of out-sourcing. This out-sourcing can be of two kinds; firstly for equipment and secondly for skill. Either ways, there is a certain considerable loss of control over the parameters that can cost the success of the product as well.

4.3.3 Sample batch size

Every experiment has a result. Depending upon the desired outputs, the results may be favourable or unfavourable but it is for certain that a process does have definite results. A process without an outcome is said to be incomplete and is yet under control. Similarly in the process of reverse engineering, there is a need to check the re-designed part such that it comes out as per the desired outcome. For this there should be a certain size of the batch i.e., the number of replicas that need to be manufactured as there needs to be a practical sample size in order to ascertain the success. However, this comes with a bound uncertainty about the size of the batch as it is certainly unknown as to when the component would come out as a confirming component.

4.3.4 Lead Time

A very important practical parameter in the process of reverse engineering is the lead time. The time taken to make a completely original design is the longest whereas the process of plagiarism is of the shortest duration. Although both are not feasible according to the limitations of the process of reverse engineering, it is necessary that the process considers an approach of originality with adequate references such that there remains proper scope for optimisation of the lead time and in turn the success of the outcome as well.

4.3.5 Flexibility and co-operation of the Tool maker

Sample batch size is an excessively tricky aspect wherein there needs to be a proper vigil on the conformance of the components. In most of the cases, there is the aim of 'first time right' that is achieved but there may be some instances wherein certain modification in the tools and process may be required. This is highly dependent on the co-operation of the Tool maker as well. It is true that it is only the foundry industry where modifications in the moulds are comparatively the easiest but there may be situations wherein other tools that are mostly metallic may also require modifications. It is utmost important in such scenarios that tool makers extend their complete co-operation towards modifications, that may be minor and less frequent yet essential.

5. Output of Reverse Engineering

Having understood the inputs and the very process of reverse engineering from a perspective of maintaining originality throughout, the outputs are worth consideration for a complete comprehension of the concept. It is well known that outcome of a process greatly depends upon the process itself and in case of reverse-engineering too, the output can be conceptualised based on the technical, commercial and practical factors that play a vital role in the success of the process. The outcome can thus be understood from the standpoints of technical feasibility, commercial viability and practical manufacturability, briefly explained as follows.

5.1 Technical feasibility

Any process needs to be technically feasible in order to ensure its success. This is the primary step towards having a plan towards a desirable outcome. It is necessary that all the technicalities that are considered during the process happen to be feasible, that is say, it is necessary that the very outcome can be at least conceptualised as a virtual model. If this basic aspect is not feasible, it cannot be a wise decision to undertake the process in the first place. When it comes to the component of originality, it may seem to be difficult in the nascent stages but with the development of skills, it can assure the engineer of success.

5.2 Commercial viability

A technically feasible solution further qualifies to stand the test of commercial viability. This is basically a measure of the ability of the product to succeed in the market, which is dependent upon the amount of optimisation of process and design that has gone into the product. A plagiarised product may seem to be profitable in the beginning but would certainly start to backfire in the long run. A novel design may seem to be totally non-viable due to its high cost but can prove to be most profitable in the long run if kept updated. Reverse-engineered components need to strike a balance between these as they need to click in the market and at the same time ensure returns to the organisation.

5.3 Practical manufacturability

Interchangeability has greatly paved way to designers think of the concept of 'design for manufacturability'. With this, every technically feasible and commercially viable design also needs to be practical with regards to the manufacturability. It should be such that it can be manufactured in-house and only if required, it shall be sub-contracted. This is possible only in case of original designs because plagiarised designs would have certain process parameters that might have not been completely understood by the engineer.

6. Risk and Opportunity analysis

Like every other process, the process of reverse engineering also involves a certain risk and there are certain limitations the Engineer to a state of make or buy decisions, wherein one needs to take a call on whether the component should be produced in-house or out-sourced completely. The prime risk factors involve human errors, equipment failures, errors in measuring instruments, lack of skill and competence to carry out the processes or reverse-engineering and so on. There are certain limitations as well. Some of them include lack of complete availability of resources and skills to come up with an exact replica, need to out-source certain processes, constant follow-up with several interested parties that can drain out the energy out of the engineer and so on.

It is true that wherever there is a risk, there is certainly an opportunity for improvement and a chance for design optimisation. Having understood the risks and limitations, one can definitely look towards opportunities like upgradation of skills, equipment and several other aspects like in-house manufacturing capabilities and the ideas of development of a strong internal design database that can prove to be essential to develop new components in the future.

7. The challenge to maintain originality

Having comprehended several aspects that govern the inputs, process and output of reverse engineering, one can arrive at a stage wherein it can be said that maintaining originality is a challenge but it is certainly not something impossible indeed. Challenges like this need to be faced with proper skills and material equipment such that reverse-engineering can be elevated from the notion of a merely plagiarised design to a design which has thoughtful technical optimisations such that there are prospects for growth of business through the same.

There may be times when it may seem to be impossible but perseverant efforts and a sound planning can ensure there is no room for any kind of unnecessary errors that can curtail the success of the overall process.

Conclusion

Thus it can be concluded that the process of reverse engineering has been understood from the view-points of

technical feasibility, commercial viability and practical manufacturability along with the various factors affecting the process with a perspective of maintaining originality of design throughout that can enable the organisation to have least influence of other designs on the design under consideration and thus there can be sound commercial benefits to the organisation as well. Although there are certain risks and limitations in the process, there are opportunities as well, which can be utilized to optimise the design such that the overall process yields the desirable outcome as required by the designer and the organisation.

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