# (STMS) Standard Texture Metrology Simulation for General CNC Machining Processes

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**Abstract:** *This research will develop a simplified surfaces roughness measurement system STMSto be used in subtractive CAM processes.This STMS system will involve a solid modeling approach to measure tolerances through CAD comparison procedures, plus the addition of real texture profiles for metrology purposes. The CAD comparison will be performed between the input CAD model (part to be machined) and the output machined model after simulation. The addition of real textures will report levels of surfaces' roughnessbased on standards. To do so, the STMS system will access standard texture databases from an organism of standardization (ex. ISO or ASME).The parameters taken form those databases will be translated in texture profiles and applied as general texture patterns to the output model. After those procedures, the outcomes of the system will be a report about tolerances and roughness of the machined model's surface, and a realistic textured model useful for virtual mockups, visual inspections as well as design intent checking.*

**Palabras clave:** Machining simulation; Metrology; Virtual Mock-up; Rendering; CAD/CAM

## Project Description and Goals

The accurate roughness estimation has become increasingly important in the instrument, computing, data storage, automotive and biomedical industries (Jesuthanama, Kumanana and Asokana, 2005). Surface texture is a key consideration affecting the function and reliability of engineering components. However, roughness estimation for CNC simulation in architecture and other related fields is fairly infrequent. One of the main reasons is that current systems of metrology are highly complex, demand anenormous amount of time and require expensive and specific hardware.

Each intelligent technique requires computational properties, suitable for some specific problems and not for others. For example, gettingmolecular precision in the surface finishing is not necessary in the construction of a wood furniture assembly. On the contrary, cellphone's components must consider micro-tolerances in order to assembly themadequately. Incorporating a new roughness estimation system (STMS) easy to use; general purpose oriented; and thatdoes not require specific hardware; can substantially improve the efficiency of the general machining processes in the architecture field.

There are two main elements that determine surface roughness, basically described in two different scales. The roughness of the material in terms of molecular arrangement (material properties), and the geometry derived from manufacturing processes (shape and macro texture). The addition of both elements defines a specific surface roughness: geometry + material properties. The STMS system proposes a complement betweentwo different strategies of roughness measurementin two different scales, and produces a single model as a result.

In the new system,Surface Roughness shall be measured at geometrical level and at molecular level (surface roughness of the material itself.). The first measurement, which is done on the solid model geometry, will be comparing the distances between the model input and output obtainedfrom a Boolean subtraction during themachining simulation process. This comparison will show the tolerances between surfaces of input and output measuring the normals from the input model surface to theoutput model surface.The materials' micro-profiles will be accessed from databases of material textures, which are being developed by different organisms as ISO or ASME.

Outline of main goals the STMS System:

- General public oriented
- Significant spread of CAM processes accuracy (home CAM future)
- Oriented to easily available materials for machining (woods, plastics, etc.)
- Exchange with popular CAD and CAM systems

(Rhino CAD/CAM, Sketchup,AlphaCAM)

- Spread of Global Roughness Standards in the Architecture field (Interoperability, Standardization)
- Develop of hyper realistic models for being used in Virtual Mock-ups.

## Motivations

Due the fact that mechanical engineering has already developedexclusive high standard metrology systems; the development of a simpler model to use in low to medium complexity tasks would spread this practice in the architecture field.In the CAD world there are several successful experiences in this regard. Examples like Sketchup and Rhino are CAD applications that shifted from a very specific domaininto a general level accessible by anyone. Even more, some software developers have been even working on CAM platforms that can operate directly with Sketchup. The future of CAD software is being led to overcrowding. The increasing capability of new computers has allowed anyone to have access to sophisticated architectural and engineering applications. With this, the universalization of digital manufacturing systems is a matter of time. In the near future companies dedicated to the construction retailwill provide digital fabrication devices to connect personal computers in the comfort of home. In this inevitable scenario, software development that supportsthese new generations of devices is an excellent development opportunity.

Options for surface roughness measurement are essentially delimited by the precision required in the result(Petropolous, 2007). For example, surface roughness could be assessed by eye and touch, but this is not considered a measurement.Additionally, with the actual practices in construction, parts are machined through several individuals, departments, companies, and CAD/CAM systems. At the end of this iteration, it is hard to tell if the tool path to be machined accurately reflects the original design intent. Evaluation and assessment of measured roughness profiles must be performed in accordance with standards. Various Standards on Surface Roughness are currently being developed. In this regard we can name the ISO Roughness Standard effort as asignificant example.

## Related Work and Technical Concepts

Textures have been generally classified into two major types, structural and statistical. Structural textures are those composed by repetitions of some basic texture primitive, such as directional lines, with a deterministic rule of displacement. This type of texture arises in machined surfaces. Statistical textures cannot be described by primitives and displacement rules (Tsai and Wu, 1998). The spatial distribution of gray levels in such textured image is rather stochastic. Sandpaper and leather, for instance, fall in this category.

Benardos and Vosniakos (2003) studied several methodologies that are implemented for the surface roughness's prediction in CNC procedures. The different methods are based on machining theory (Boothroyd, 1988; Baek et al., 2001), experimental investigation (Ghani and Choudhury, 2002; Beggan, 1999), design of experiments (Davim, 2001; Chouhury and El-Baradie, 1997) and smart techniques. The academic approach is based on agreements and idealisms which are responsible for mistakes and restrictions. The present trend among researchers in the field of manufacturing, favoring intelligent techniques is due to the enhanced computing power( Jesuthanama, Kumanana and Asokana, 2007).

A parameter-reduced approach could be an appropriate strategy for developing a simpler system of roughness prediction.

A large number of standards in surface textures have been developed by: the International Organization for Standardization (ISO); the American Society of Mechanical Engineering (ASME); the National Institute of Standards and Technology (NIST), and other Organizations. Each of them uses its own parameters and techniques to produce their databases. Most of these systems use peer-reviewed analysis, tools surface texture, and specimen database for parameter their evaluation and for algorithm verification

Texture injects realism into rendering, transforming dull synthetic scenes into digital replicas of reality (Dana, 2000). A texture mapping system during the actual machining process simulation would be useful to check the appearance of the piece without the expense of real materials and time in its construction

## Scale of surface Roughness

In order to simulate a surface topography, it is necessary to identify separatelyRoughness, Waviness, and Form (Shape). This work considers the concept of mixing different approaches about surface metrology achieving a simpler roughness measurement system. The new mixed modelanalyzed will include the following parts:

**Roughness measurement:** The information about parameters of material's profiles (in a micro scale) will be obtained from textures data basis. With this information the general texture will be constructed using the BTF approach (explained in the next section).

**Waviness measurement:** Is understood as the result of Boolean subtraction operations between the tool and the stock during simulation process. This parameter does not depend on the material texture and will beapplied in the simulation process by means of the BDRF function (explained in the next section).

Form: Will be obtained directly from the CAD input model.

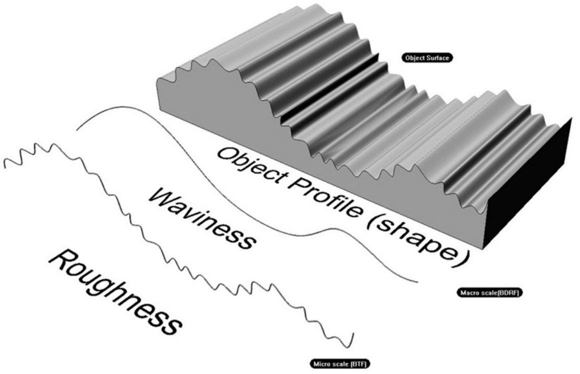

*Fig. 1 Scales for Surface Roughness (author)*

## BDRF Bidirectional reflectance distribution function

BRDF is a four-dimensional function that defines how light is reflected at an opaque surface. The BDRF is commonly used for representing geometric reflectance of elements in a scene. According with its characteristics of accuracy in the reflectance direction, BDRF is suitable for representing the global light of an object rather than its micro texture. The BRDF is a fundamental radiometric concept, and accordingly is used in computer graphics for photorealistic rendering of synthetic scenes, as well as in computer vision for many inverse problems, such as object recognition.

## BTF

Just as the BRDF describes the coarse-scale appearance of a rough surface, the BTF (bidirectional texture function) is useful for describing the fine-scale appearance of a rough surface (Dana,1996). BTFs precisely represent reflectance variation at a fine (meso-) scale as a lighting function and viewing direction. Real-world textures ascend from both spatially-varying surface reflectance, understood as the form of an object, and meso-structure that represents the micro material's profile.

## Approaches of roughness measurement

The first operation conducted on a material's surface, to obtain surface profile, is to separate the geometry of the texture of the material. Then, on the flat surface (ideally), develop tests to measure the profiles of the material. With this information it is possible to computationally recreate the material used in any simulated surface. In order to obtain the surface texture from real material there are different Approaches:-

## Electronic

With the purpose of measuring the surface texture, it is possible to use two types of electronic procedures: averaging (or velocity type) and profiling (or displacement type). Averaging or tracer-type instruments employ a stylus that is drawn across the surface to be measured. The vertical motion of the tracer is amplified electrically and is impressed on a recorder to draw the profile of the surface or is fed into an averaging meter to give a number representing the roughness value of the surface.

## Optical

Optical or area systems use optical methods for superficialcontrol. Equipment ranges from examination of the surface with simple microscopes or three-dimensional micro-topography to highly sophisticated techniques such as inferometry. Optical systems examinethe entire surface, not simply one line across it.

## STMS ModelApproach

The first Input of the STMS system will be a CAD model(model A)obtained from any software CAD that can export, as a suitable format for machining purposes (ex. Parasolid in AlphaCam). The next step shall be the machining setup. Here the CAM software will ask for general parameters of machining (speed, rate, offset, tool, etc.). After running the simulation of the tool path through CAM software, and checking the basic conditions of a well done machining operation, the STMS system will construct a new 3D model (model B) of the machined part. With this model B, the STMS system will generate a Boolean subtraction operation between the original cad model (A) and the model already machined (B). Afterward the STMS system will report the differences between models A and B by means of measuring the distance between their surfaces. This distance will be measured through normal lines from surface A towards surface B. The second important input is the material texture database. In order to create a new material texture, the first step is to obtain the texture profiles from the texture database; then, the STMS system will rebuild its texture by means of BTF algorithms. Later, the new material will be applied to the model B. The last surface roughness report will be obtained by the involvement of tolerances report and the material profiling report.

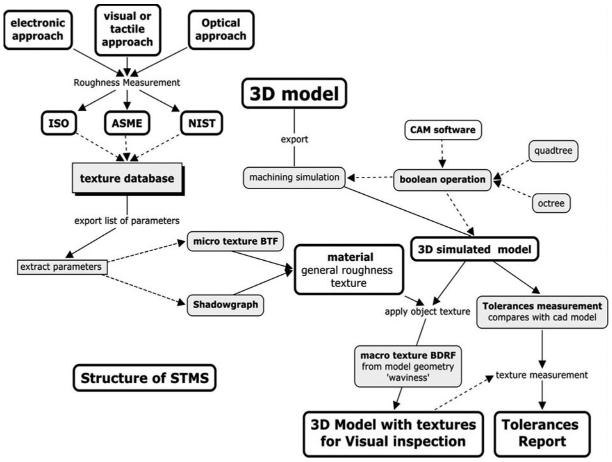

*Fig. 2 New model of machining simulation (author)*

## Intellectual Statement and Expected Results

Rather than just offers improvements in the intellectual point of view, this research proposes a system that will impact the entire ACE domain, including its practice and future prospective. Advances are proposed in computer graphics; CAD and CAM systems for architecture; engineering metrology; and databases for standardization.In the computer graphics domain the STMS will be pioneer in texture reconstruction for machining simulation using online databases. This function also proposes a novel and simplified approach to apply real textures to the virtual machined parts during the machining simulation process. This goal will be accomplished by means of simplifying the core algorithms and concatenating them in different stages of the texture reconstruction. New uses for CAD models are also proposed. Using them textured for further comparisons with the machined CAM model is an innovative experience. With this approach, relationship between CAD and CAM seem more fruitful than just being steps of a single process. Rather than this, interaction is in different levels, allowing designers to produce different instance and design intent checking. The metrology field will be also impacted. One of the ambitions of the present research is to spread this concept and practice to the most general level of manufacturing. The future of Home CAM is near; thus, systems of verification and quality control at the medium resolution standard are strongly required. Additionally, the development of texture repositories and databases for the STMSimplementation will require new protocols of accessibility by means of remote access on web platforms. With all these technical and intellectual changes, the actual state of the architectural production should be sensibly affected. Efficiency in the production process will reduce costs and construction time, and simplification of complex engineering system will allow performing roughness simulations using home computer hardware.

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