Summary of My Research

3D Sketching plays an important role during the geometric designing process, especially in the earlier conceptual styling stage, the most synthetical, dominant and creative stage in the whole design process; Recently, the spline-based sketching activity is increasingly predominant in CAD/CAS, such a high degree of freedom adds more difficulties when creating and manipulating surfaces. Therefore, the effective mechanism to support quick illustration and intelligent manipulation of these sketches will boost the efficiency and thus enhance creativity for the free form shape designing.

My research addresses this issue through further improving the constraint-based modeling method, physically-based deformation technique and sketch-based interface to develop a more intelligent free form shape manipulation system for conceptual styling task.

It's well-known, the constraint-based surface modelling methods provide users more flexible shape control by using built-in logic to derive the shape of the model; however the major difficulty of those approaches is the constraint solving, which has to compute the values of degrees of freedom such that defined constraints are satisfied. Therefore, my work tries to optimize the constraints solving process by highlights the correlation between the curve, surface features and the geometric constraints; the modeling phase fully considers the designer's different drawing style, and a robust interpreter is presented to construct a B-spline surface along arbitrary sketched curves with respect to the user's design intention. Such a process addresses the issue of the traditional illustration for depicting 3D subjects, where the creation of 3D objects is usually preceded by a sequence of drawing steps through using few strokes. Besides these, I also contributed an effective algorithm which is able to automatically approximate the arbitrary hand drawing curve into Cubic B-spline based on an adaptive sampling mechanism; as a result these sequent approximated B-spline curves will serve to construct the surface models.

Since the stepwise refining is inevitable for the mental illustration during conceptual design phase, the effective manipulation technique of free form curve and surface is critical. Conventional geometric modeling software offers the designer shape interaction and manipulation through editing the associated control points, orders, knot vector and point clouds. Such modeling by indirect manipulation of algebraic and geometric parameters proves to be difficult and tedious, especially for novice designers. Researchers have instead explored direct ways through adding physical behavior to the traditional parametric surface patches. Those constraints, encoded as user-applied sculpting forces that modify the surface in predictable ways, impose the physical effects on the deformable models. However, to date, physically-based manipulation of B-spline represented shapes is not fully developed.

A novel method is proposed in my research aiming at offering the designer more efficient and direct parameter-independent surface control by combining the physically-based deformation technique and finite element method (FEM). For each resulting B-spline surface, a bar network is built from its control vertices. The algorithm presented is able to automatically extract geometric constraints from user-applied spline sculpting operation, and these "external forces", are adaptively imposed on the bar network, as a result the least possible adjustment to the control vertices is involved to obtain desired surface properties. During the implementation I further illustrated the surface properties by defining geometric constraints (point, tangency, curve and surface area so on). The influence of these constraints is well defined according to the global and local deformation by attaching an influence factor to each control vertex. In order to improve the flexibility, all the spline strokes are freely controlled by a dragger in 3D space, which will produce a sequence of dynamic deformations to facilitate the user to achieve the desired models.

This research work is implemented in a 3D virtual environment (C++ and OpenInventor), and it is also applied to a collaborative AR/MR designing system (Related with IMPROVE European project); where the modeling and modification process can be simultaneously controlled by different clients, based on an "OSGA" communicating platform. And the sketching input data may come from the common 2D mouse movement or 3D tracking data, like hand tracking.

Since the designers are more interested in how to obtain the aesthetic results instead caring about geometric details, I also further discuss the improvement from the lower geometric shape control to grammar-based higher shape manipulation during my PhD research (Related with AIM@SHAPE European project). Firstly a symbolic curve description by using the intrinsic curvature feature (Leyton system) is adopted to effectively classify the general 2D planar curves. Furthermore, I introduced the quantitative parameters to analyze the curve properties based on the curvature plot. Consequently a set of semantic-based shape operators according to different properties illustrated. Each operator, capsulated by group of geometric constraint, is well defined by fully considering the curvature variation (refer to the 6 Leyton process grammar). Designer thus can obtain the aesthetic curve control through these pre-defined constraints and a simple user-driven dragging process.

Future Research Plan

During the five-year more scientific research, I've extended my knowledge from geometric modeling, physically-based deformation technique and sketch understanding (STAT of HCI technique) to semantics–based shape handling; and I also possess a certain experience of getting involve in some European Projects. From my point of view, I would like to pursue the following topics as my possible future Postdoctoral research:

1. Bioinformatics： Considering the substantial application of geometric graphics technique and also my 2-year master image processing experience and more than 3-year 3D modeling PhD research, I would like to extend my knowledge into Biological field: such as image analysis and 3D reconstruction.
2. Geometric Modeling and Computer Vision: Based on my mathematic knowledge in geometric surface, I would also expand my research to discrete geometric processing and computer computing, such as mesh parameterization, surface remeshing. And I am personally interested in the shape retrieval research field.
3. Semantic Shape Handling
   Shape representation, shape modeling and shape retrieval.
   The use of a shape-grammar to define a set of interactive deformation operators of 2D curves has been investigated in my PhD research. In fact, about the concepts and tools defining higher levels of shape description/manipulation there are still variety of work to be done.