Title:
**3D Object Sculpting using NURBS surfaces and Leap Motion Controller**

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Introduction:
3D Sculpting (also known as Digital Sculpting) is the use of software which offers tools for shape modeling and manipulation of digital objects as if they were made of a real-life substance such as clay [3]. Designers and engineers often desire to touch the surface in a CAD system to model and modify its' shape. The user intuitively uses his hands to express the intended changes and manipulations [1].

In the past two decades, Human Computer Interaction (HCI), has been in great use to convey the idea of interpreting human gestures and intentions using a computer system. This work uses HCI with leap motion controller for shape modeling and modification of control points on NURBS and B-Spline surfaces to achieve the desired intended shape. This process aims to mimic the natural process of human CAD design.

While most of the 3D sculpting tools use mesh-based geometry, in which an object is represented by an interconnected surface mesh of polygons [7], our system implements the shape modeling, modifications and manipulations on NURBS surfaces, allowing the advantage of their representations [6]. The surfaces are deformed by the user, which can select an area of influence, in a flexible manner. Varying from one selected control point allowing local changes, to a group of control points emanating a broader area to be deformed.

For implementing HCI with 3D shape modeling we use the Leap Motion controller [2,4], which is a computer hardware sensor device that supports hand and finger motions as input. It comes in a form of a small USB peripheral device which is designed to be placed on a physical desktop [5] Using two monochromatic IR cameras and three infrared LEDs, the device observes a roughly hemispherical area, to a distance of about 1 meter. The LEDs generate pattern-less infra-red light and the cameras generate almost 300 frames per second of reflected data, which is then analyzed by the Leap software, which provides a 3D position data of the joints of both hands by comparing the 2D frames generated by the two cameras.

Main Idea:
The proposed CAD system is based on a developed algorithm which uses the Leap Motion output data, as it records hand movements. The algorithm analyzes these movements in order to provide the exact position of the hands in the 3D space in real time. Using the coordinates of the hands, the relevant control point are marked, thus allowing the user to change the position of the control point using a pre-determined hand gesture. This change results the NURBS/B-splines surface to adjust accordingly. Figure 1 depicts a flow chart of the developed CAD system.
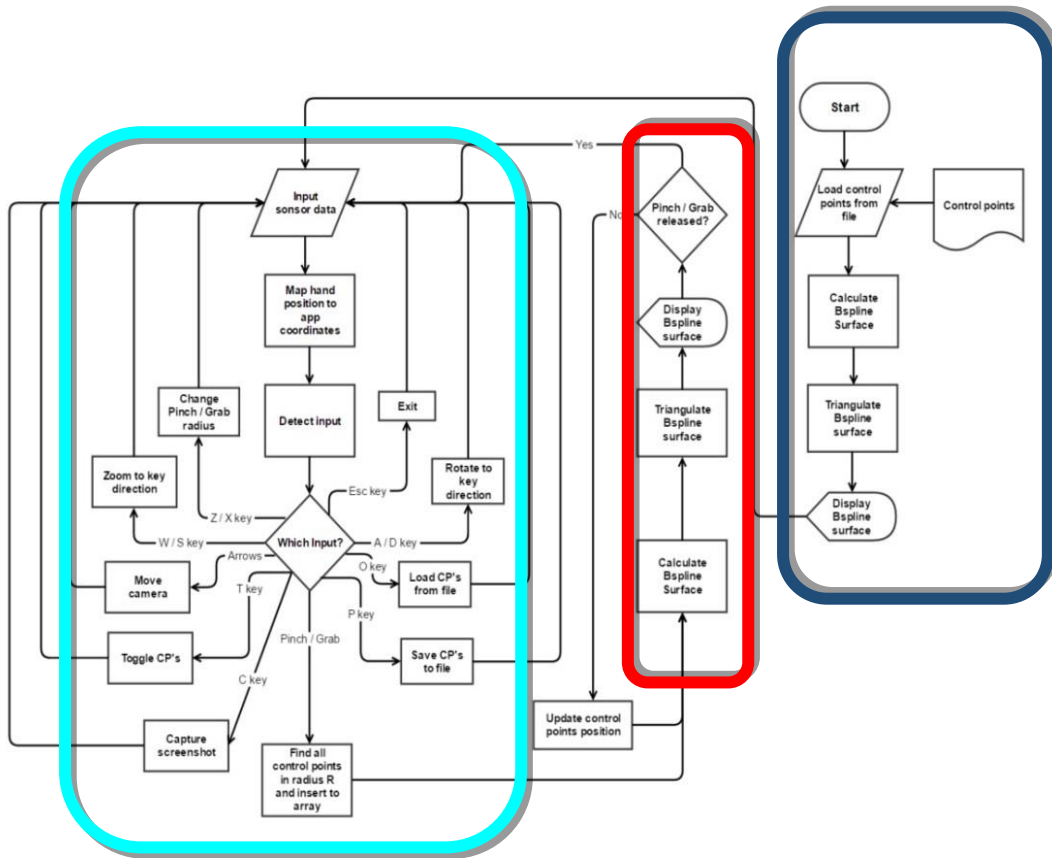
Fig. 1: A flowchart of the developed 3D sculpting system.

*Overview of the system*

Pre-Processing: (marked in blue in figure 1)

- Load the selected object, defined by its control points, into the graphical engine.
- Calculate the NURBS/B-splines surface defined by the loaded control points, knots and weights [xxx].
- Display the 3D object and the control points of the surface a.

3D sculpting consists of the following steps: (marked red and cyan in figure 1)

- **Acquire Leap Motion sensor data**: Acquiring the sensor data is done by analyzing the images using the feature recognition module. Joints of hands and fingers are sufficed, and define recognized 3D image of a human hand. The device enables a 3D hand and finger representation and can successfully recognize both hands simultaneously.
- **Mapping geometries between hand position and object coordinates:** The sensor provides coordinates in real world units within the Leap Motion frame of reference. To use relevant information from the Leap Motion device, it is mandatory to interpret and map the input sensor data into 3D software

coordinate system. This is done by implementing various transformations and a normalization procedure.

- **Find the nearest surface control point**: For the NURBS/B-splines surface to be modeled and modified in an intuitive and human design manner, closeness of the human gesture and the surface is evaluated. For creating 3D sculpting modifications, the position of at least one of its control points must be transformed. The user is able to flexibly define the radius of nearest surface control point from the hand. This feature is depicted in Figures 2 and 3)
- **Changing surface control points positions**: This is done by selecting control points within the chosen radius, each time using the defined hand gesture. After selecting the control points, the hand movement changes the coordinate positions causing changes in the surface simultaneously. These modification are done through two basic features: Pinch and Pull, detailed in Figures 2.
- **Re-calculate the surface**: The B-splines surface needs to be recalculated after each frame when pinching or pulling effective on control points. The new 3D surface is re-triangulated and rendered in real-time.

*System Features*
- Pinching and Pulling one control point

    The scenario is using the pinch gesture to choose and pull 1 control point resulting in a change of the surface visible to the user.
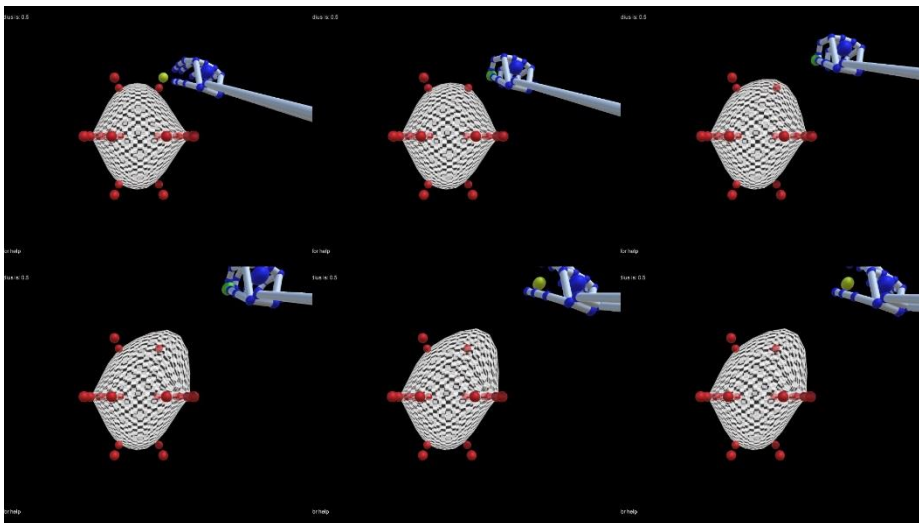


Fig. 2: Pinching and pulling a group of control points based on a flexible radius defined by the designer.

Figure 4 depicts a scenario using the pinch and pull features for both hands. In this case the hands are two independent modification features processed simultaneously. The system enables the user to define different and independent radius of control points to be manipulated and modified.
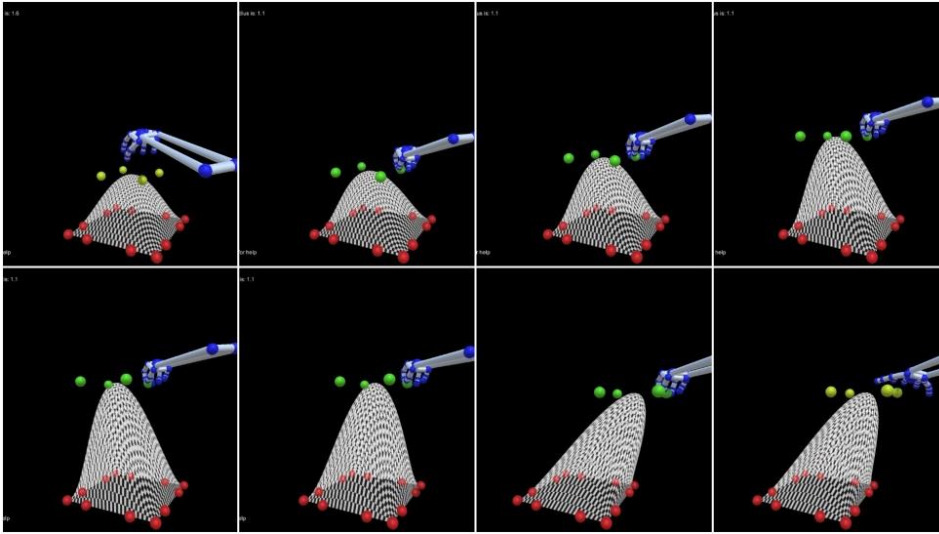
Fig. 3:    Pinching and pulling a group of control points based on a flexible radius defined by the designer.
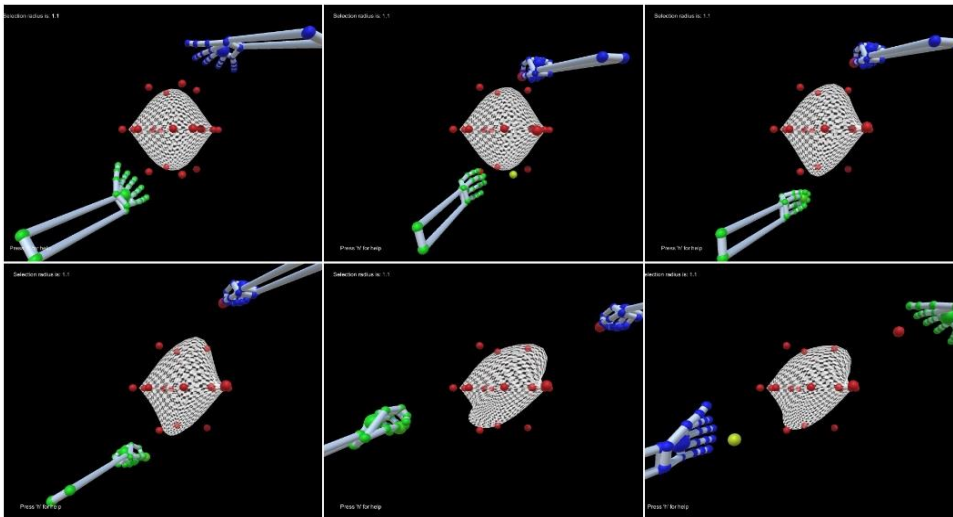


Fig 4: Two hand modification feature.

Conclusions:

We have presented a 3D sculpting system using the Leap motion modeling and manipulating NURBS/B-Spline surfaces. The designers' intuitive process of manipulating on a basic surface (as clay), to a desired resulting object, is done by gesture recognition of features. Pinch a pull actions for flexible influence on control points is defined. The use of single or both hands are presented, offering the designer a variety of resolution tools.

3D sculpting on NURBS surfaces, which are explicit mathematical expressions, provide excellent mathematical properties (local control, continuity, fitting etc.). This initial phase of modeling can be used for further analysis in advanced processing systems.
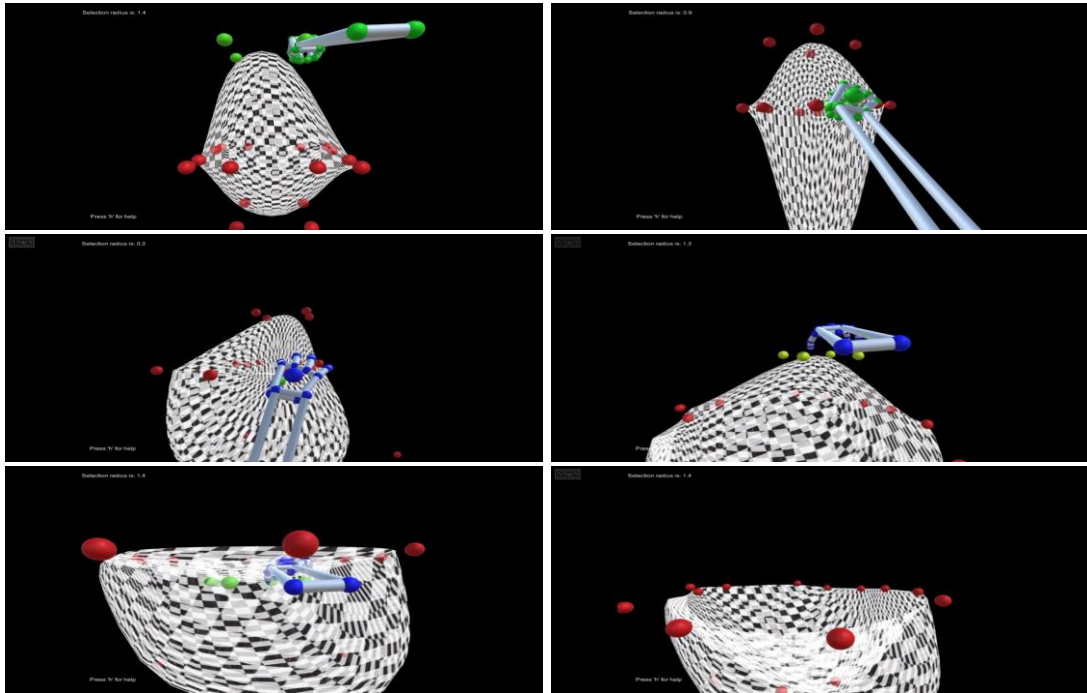


Fig. 4: Snapshots of a design process.

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