Assignment 1

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Instructor: Prof. Jaya *Date:* February 8, 2025

1. Brief Overview -

- **Shape Creation: -** The Shape class is responsible for defining a polygon's shape and handling various operations like calculating its centroid, transforming it, and ensuring that it is valid for rendering. The class allows for the creation of a polygonal shape from an array of vertices, applies geometric transformations, and ensures that self-intersecting shapes are handled correctly.

  Upon initialization, the centroid of the shape is calculated using coordinates of the vertices. The vertices are converted to local space by subtracting the centroid from each vertex, which centers the shape at the origin of the local coordinate system. Shape object holds its own transformation matrix. After conversion of all vertices from Global space to Local space, the transformation matrix is updated so that the shape can still be rendered on correct position on canvas. If the polygon is self-intersecting (i.e., it has intersections between edges), the algorithm will split the polygon into simple polygons. Each simple polygon will then be triangulated.

- **Triangulation:** - The **Ear Clipping** algorithm is used to decompose polygons into triangles by iteratively "clipping" off "ears" (convex triangles) from the polygon. The algorithm iterates through the polygon, checking for convex vertices and whether the triangle formed by three consecutive vertices is an "ear." If a valid ear is found, it is clipped off (i.e., the middle vertex is removed), and the process continues with the remaining vertices. The loop terminates when only three vertices remain, forming the final triangle. This was used so that it would be possible to create and triangulate Concave shapes as well.

- **Shape Selection:** - The isPointInShape method is responsible for determining whether a point lies inside a given shape. This method uses the **Ray Casting Algorithm**. It works by transforming the clip-space point into the local space of the shape, considering the shape's transformations (translation, rotation, scaling), and then checking if the point lies within the shape's boundaries. After transforming the point into the local coordinate system of the shape, the algorithm casts a ray from the point in a specific direction. The method then checks how many times the ray intersects the shape’s edges. If the number of intersections is odd, the point is inside the shape; if even, the point is outside the shape.

2. Questions to be answered -

1. **When we perform transformations on the scene, we treat the scene as a grouping of all the shapes as a single entity. How would you implement grouping and ungrouping shapes if the user would like to choose which shapes will be treated together as a group for transformations?**

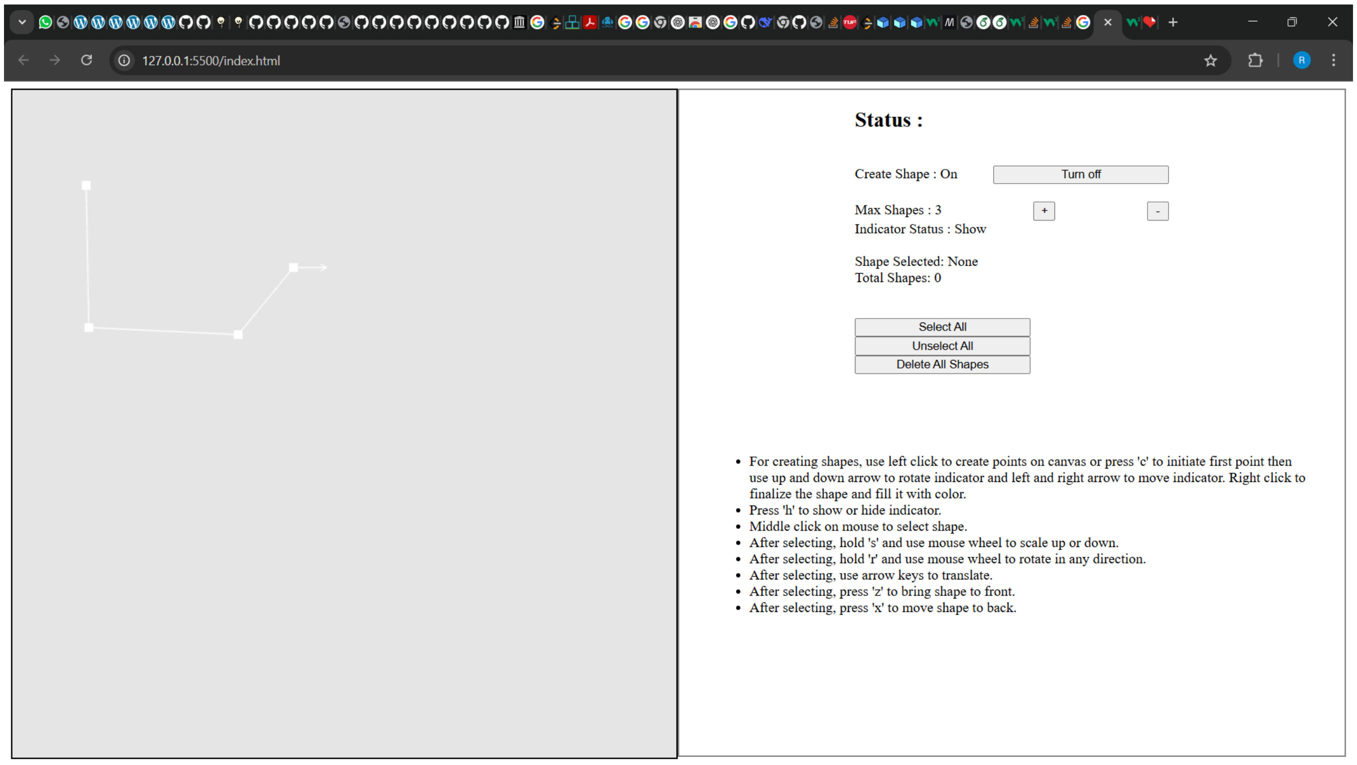
   - The Grouping of shapes for group transformations can be done by simply maintaining a data structure like list or a map which would keep track of the selected shapes. Also the Shape object will have a member variable "isSelected", it is set to true when the shape is selected and added to the selected shapes data structure (list). And when the shape is unselected, it will be removed from the list, hence removed from the group.

   - And as for applying the transformations on all the shapes in the group, when the event is triggered, the same transformation is applied on all the shapes in the list by iterating over all the shapes instead of only single shape. The isSelected variable in Shape object is used so that the shape can be highlighted during rendering so that it is visible which shapes are selected.

2. **Why is the use of centroid important in transforming a primitive or a group of primitives? (Hint: transformations such as rotation and scaling.)**

   - When rotating a shape, we typically want it to rotate around its center, not some arbitrary point i.e. Origin of canvas. Using the centroid of the shape as the center of rotation ensures that the shape's orientation changes around itself and it does not translate during rotation.
   - Similarly, scaling a shape relative to its centroid ensures that the shape's proportions remain intact and the shape does not translate. If scaling were done relative to the origin or some other point, the shape might get distorted and it will translate towards origin of canvas

3. Screenshots –



Status :

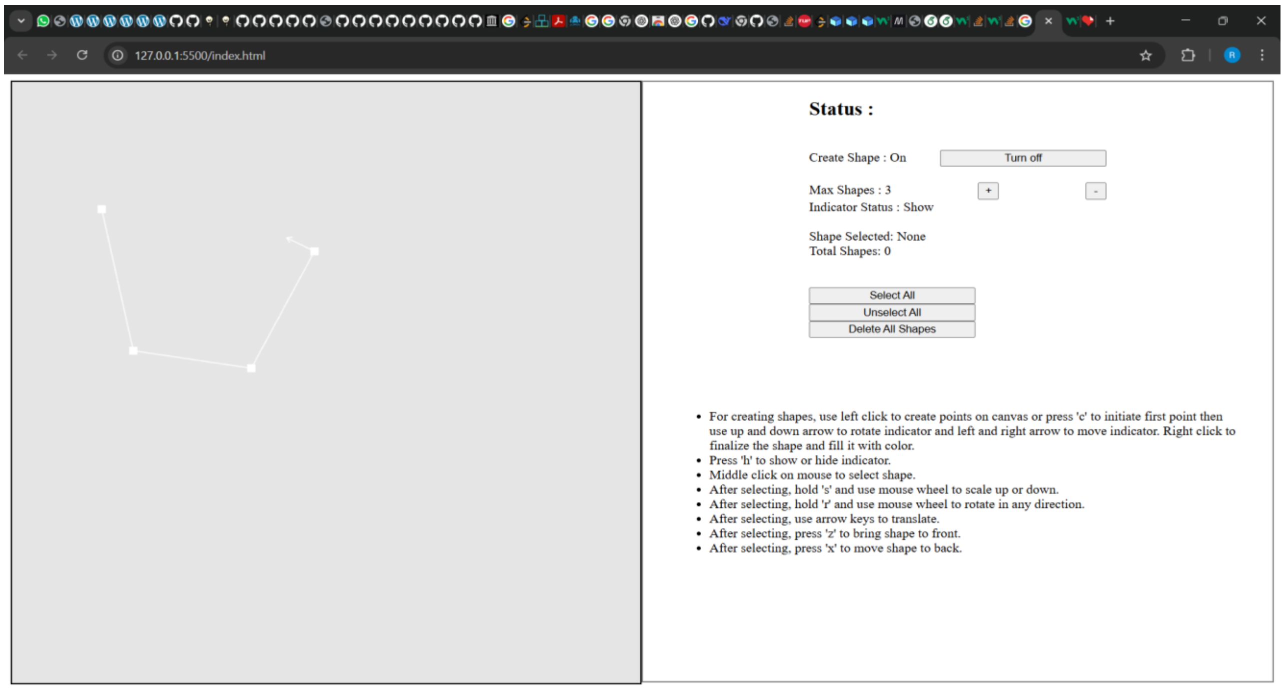
Create Shape : On

Max Shapes : 3
Indicator Status : Show

Shape Selected: None
Total Shapes: 0

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
- Press 'h' to show or hide indicator.
- Middle click on mouse to select shape.
- After selecting, hold 's' and use mouse wheel to scale up or down.
- After selecting, hold 'r' and use mouse wheel to rotate in any direction.
- After selecting, use arrow keys to translate.
- After selecting, press 'z' to bring shape to front.
- After selecting, press 'x' to move shape to back.

Fig. 1. Shape Creation



Status :

Create Shape : On

Max Shapes : 3
Indicator Status : Show

Shape Selected: None
Total Shapes: 0

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
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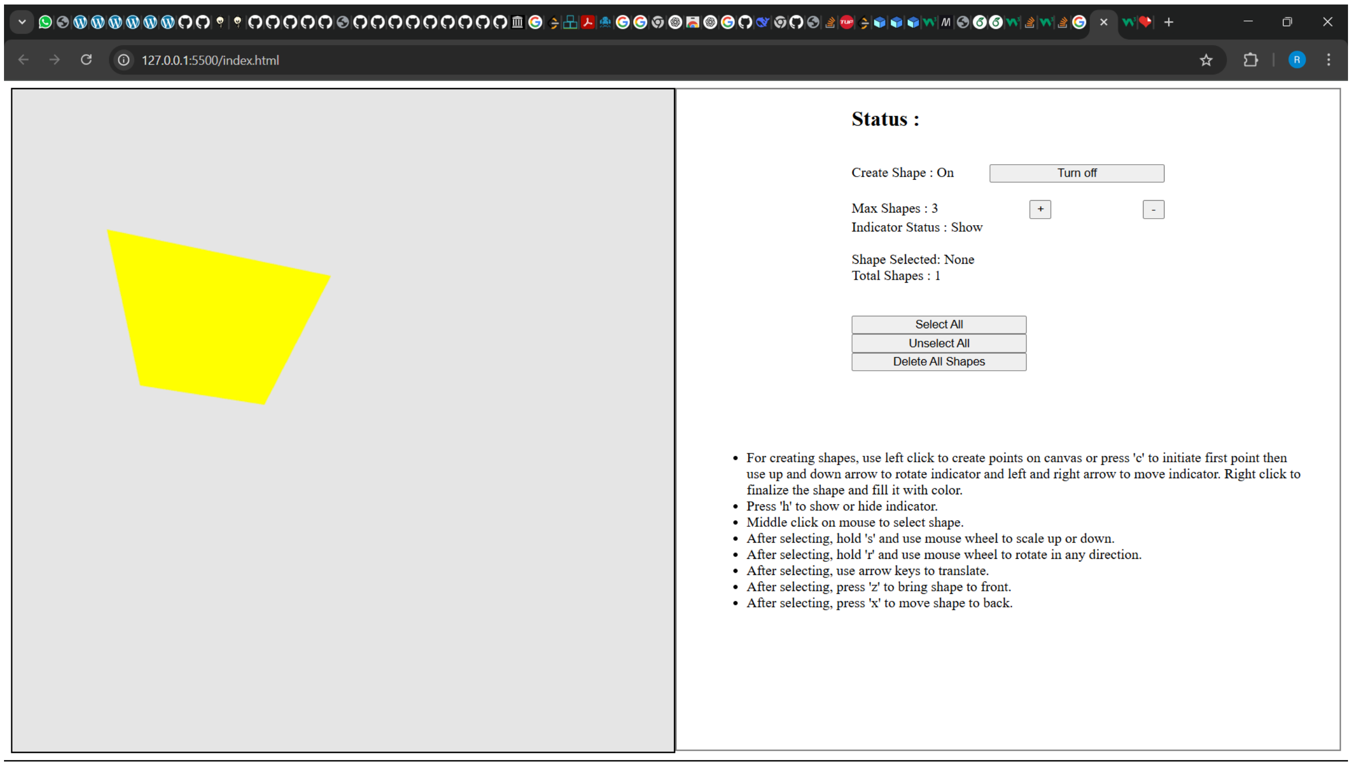
- After selecting, press 'x' to move shape to back.

Fig. 2. Indicator Rotated



Status :

Create Shape : On

Max Shapes : 3
Indicator Status : Show

Shape Selected: None
Total Shapes : 1

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
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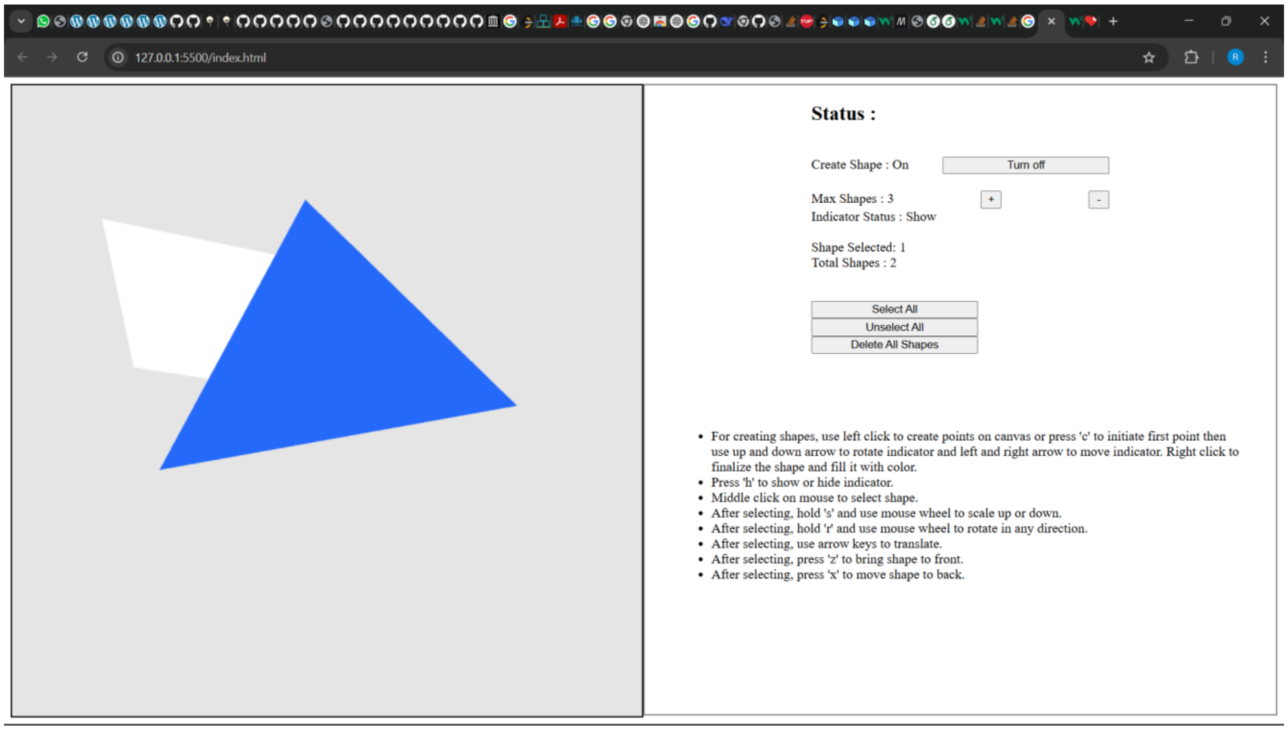
Fig. 3. Shape created



Status :

Create Shape : On

Max Shapes : 3
Indicator Status : Show

Shape Selected: 1
Total Shapes : 2

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
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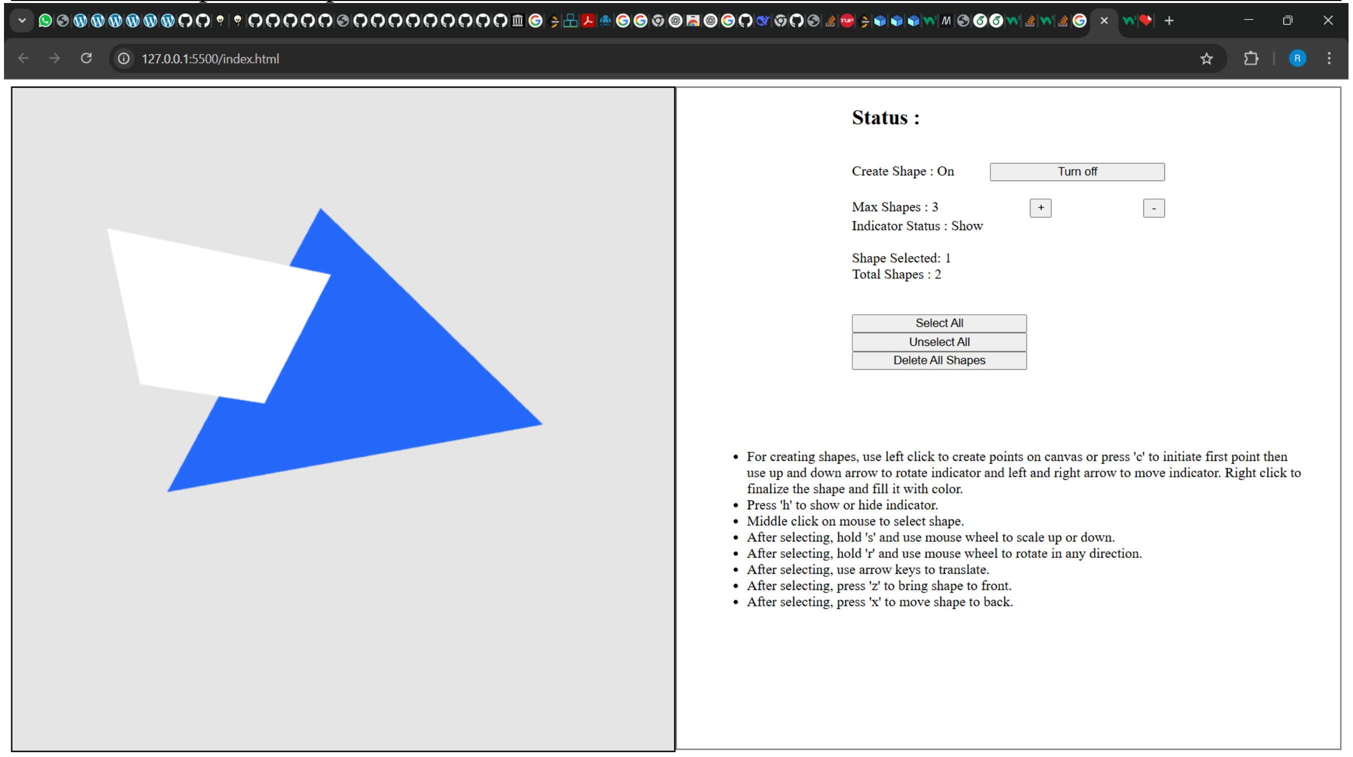
Fig. 4. Shape selected



Status :

Create Shape : On

Max Shapes : 3
Indicator Status : Show

Shape Selected: 1
Total Shapes : 2

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
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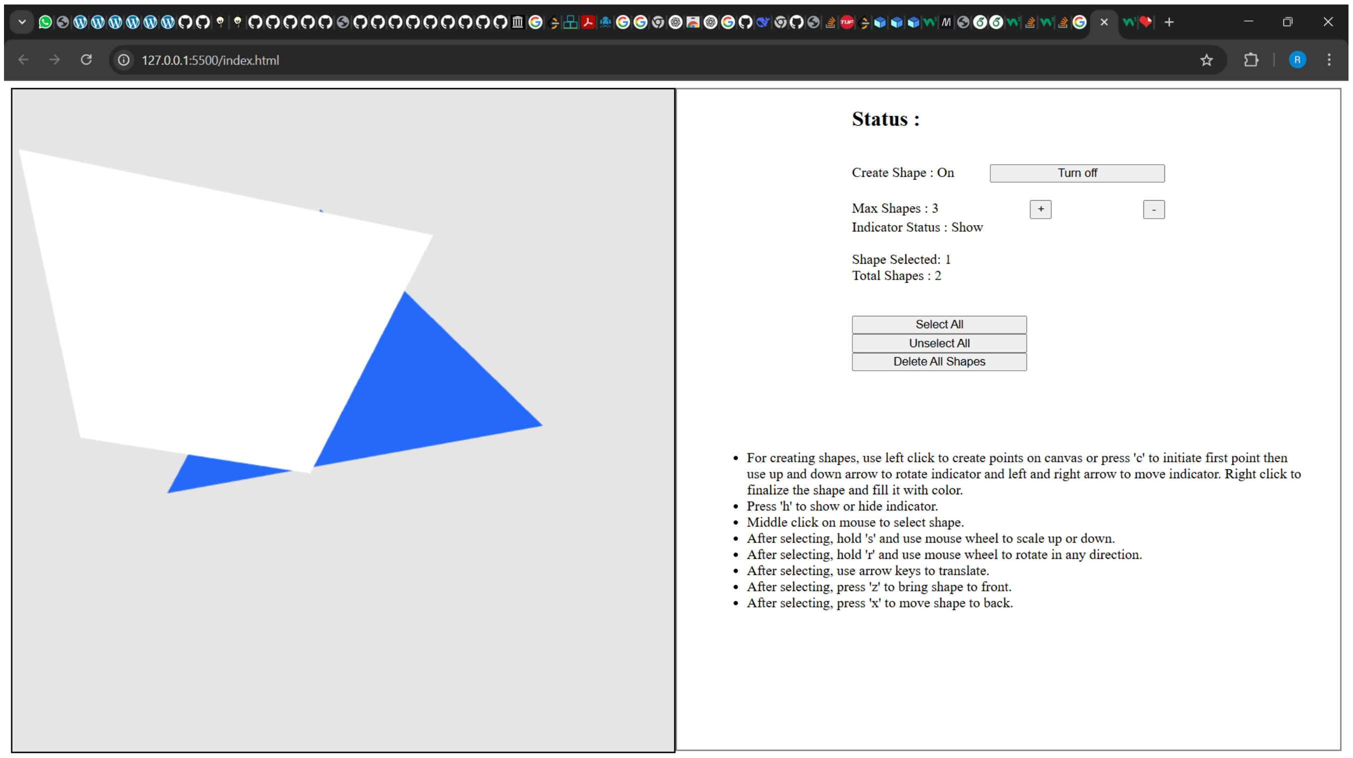
Fig. 5. Shape moved to top



Status :

Create Shape : On

Max Shapes : 3
Indicator Status : Show

Shape Selected: 1
Total Shapes : 2

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
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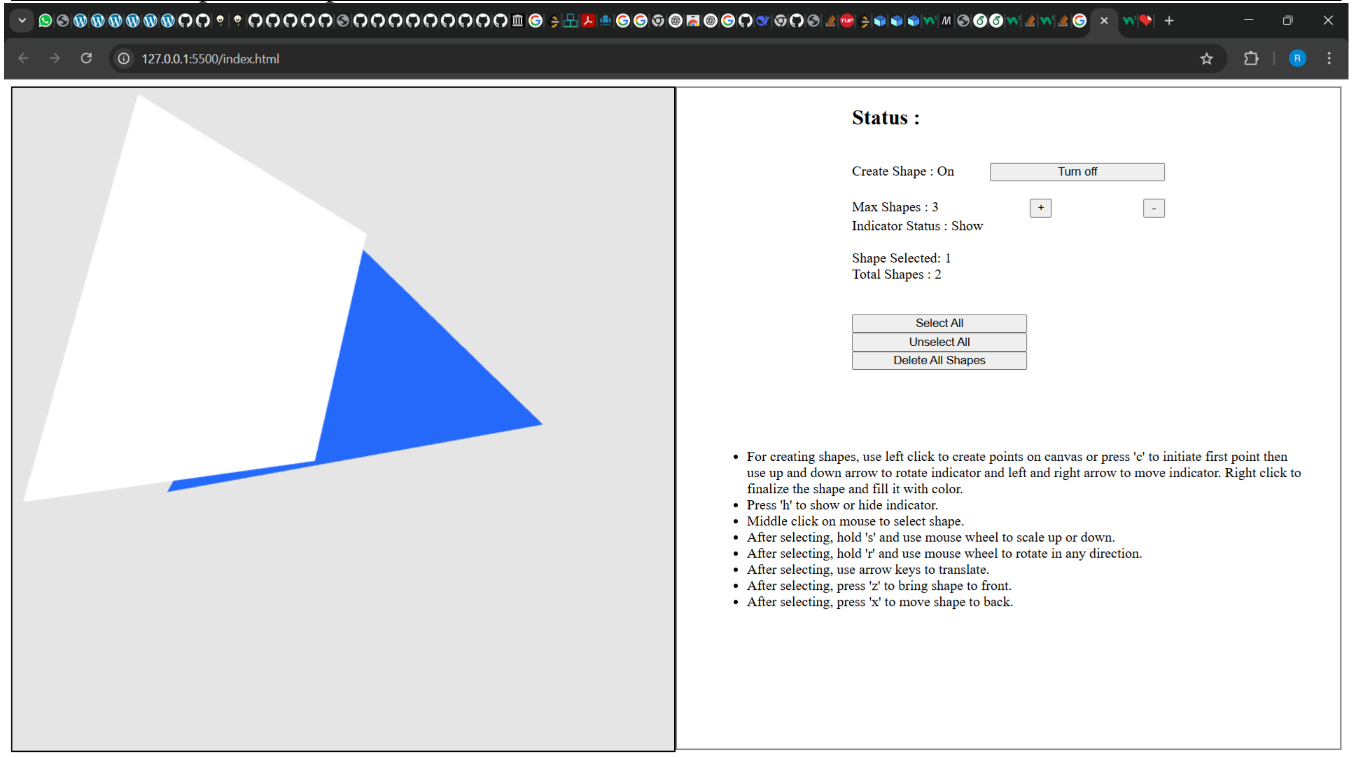
- After selecting, press 'z' to bring shape to front.
- After selecting, press 'x' to move shape to back.

Fig. 6. Shape scaled


127.0.0.1:5500/index.html

Status :

Create Shape : On — Turn off

Max Shapes : 3 + -
Indicator Status : Show

Shape Selected: 1
Total Shapes : 2

Select All
Unselect All
Delete All Shapes

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
- Press 'h' to show or hide indicator.
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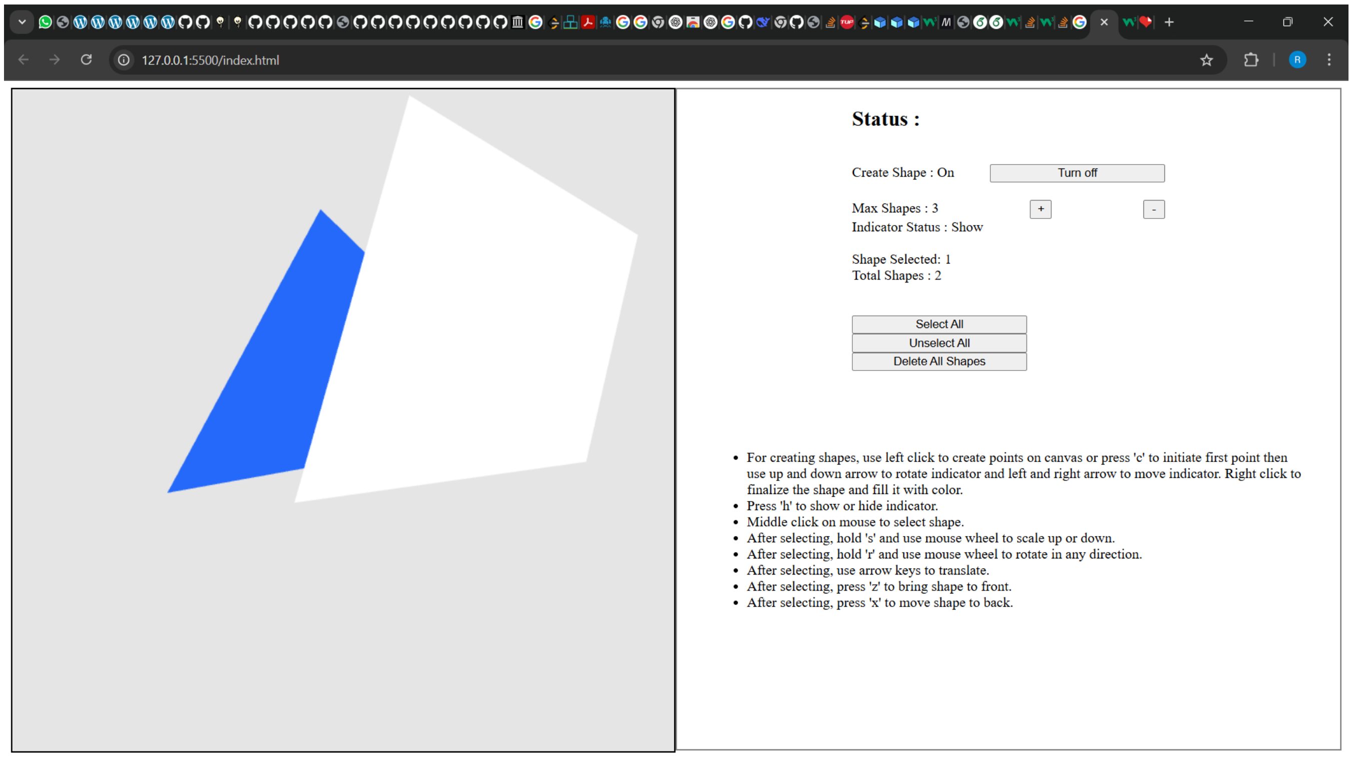
- After selecting, press 'x' to move shape to back.

Fig. 7. Shape rotated


127.0.0.1:5500/index.html

Status :

Create Shape : On — Turn off

Max Shapes : 3 + -
Indicator Status : Show

Shape Selected: 1
Total Shapes : 2

Select All
Unselect All
Delete All Shapes

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
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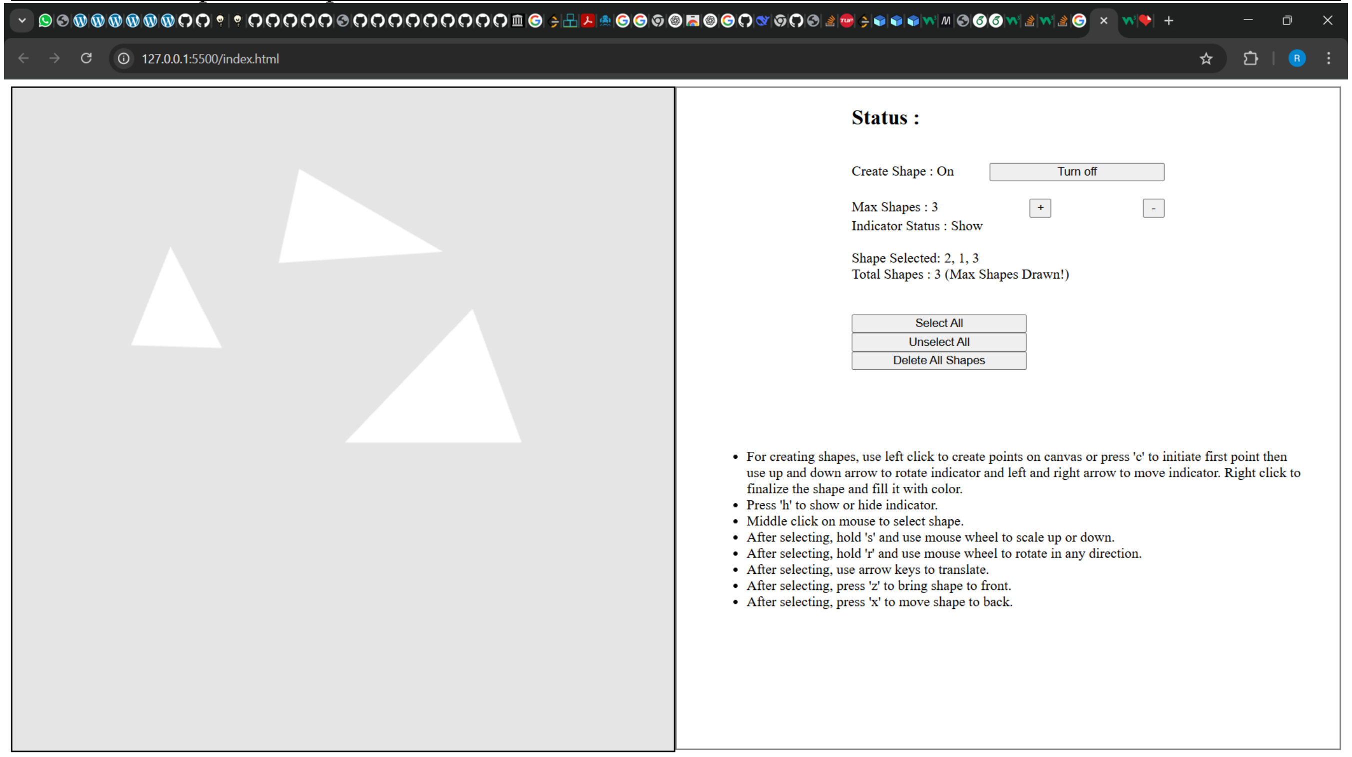
- After selecting, hold 'r' and use mouse wheel to rotate in any direction.
- After selecting, use arrow keys to translate.
- After selecting, press 'z' to bring shape to front.
- After selecting, press 'x' to move shape to back.

Fig. 8. Shape translated



Status :

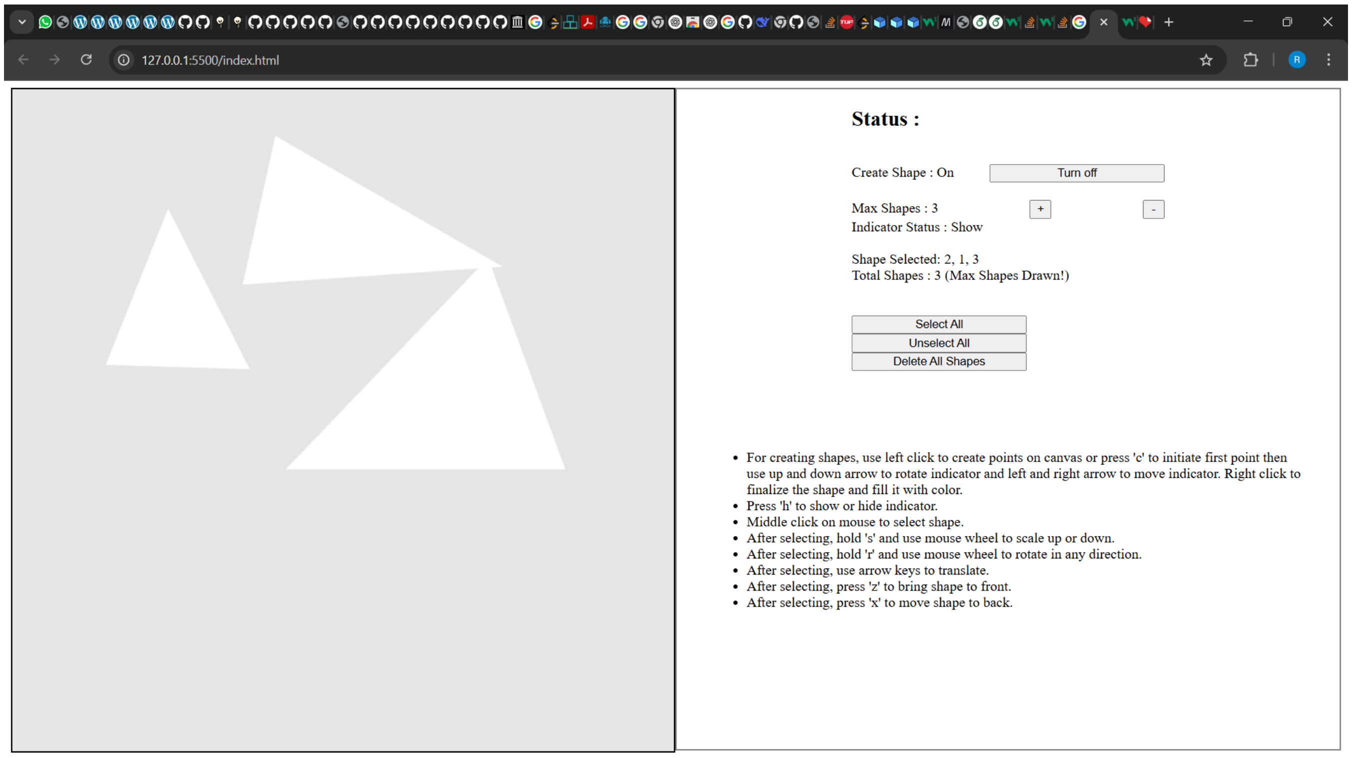
Create Shape : On

Max Shapes : 3
Indicator Status : Show

Shape Selected: 2, 1, 3
Total Shapes : 3 (Max Shapes Drawn!)

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
- Press 'h' to show or hide indicator.
- Middle click on mouse to select shape.
- After selecting, hold 's' and use mouse wheel to scale up or down.
- After selecting, hold 'r' and use mouse wheel to rotate in any direction.
- After selecting, use arrow keys to translate.
- After selecting, press 'z' to bring shape to front.
- After selecting, press 'x' to move shape to back.

Fig. 9. Group selected



Status :

Create Shape : On

Max Shapes : 3
Indicator Status : Show

Shape Selected: 2, 1, 3
Total Shapes : 3 (Max Shapes Drawn!)

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
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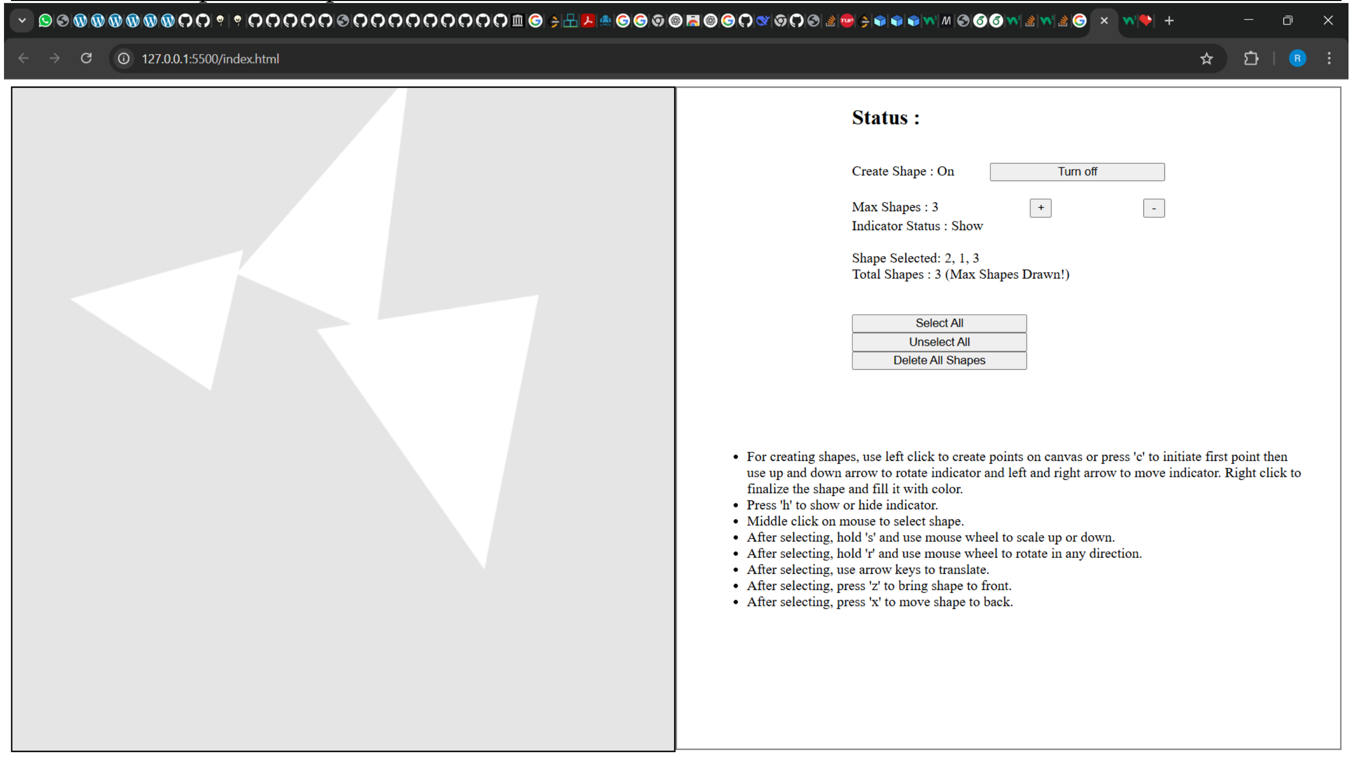
- After selecting, press 'x' to move shape to back.

Fig. 10. Group scaled



Status :

Create Shape : On   Turn off

Max Shapes : 3   +   -
Indicator Status : Show

Shape Selected: 2, 1, 3
Total Shapes : 3 (Max Shapes Drawn!)

Select All
Unselect All
Delete All Shapes

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
- Press 'h' to show or hide indicator.
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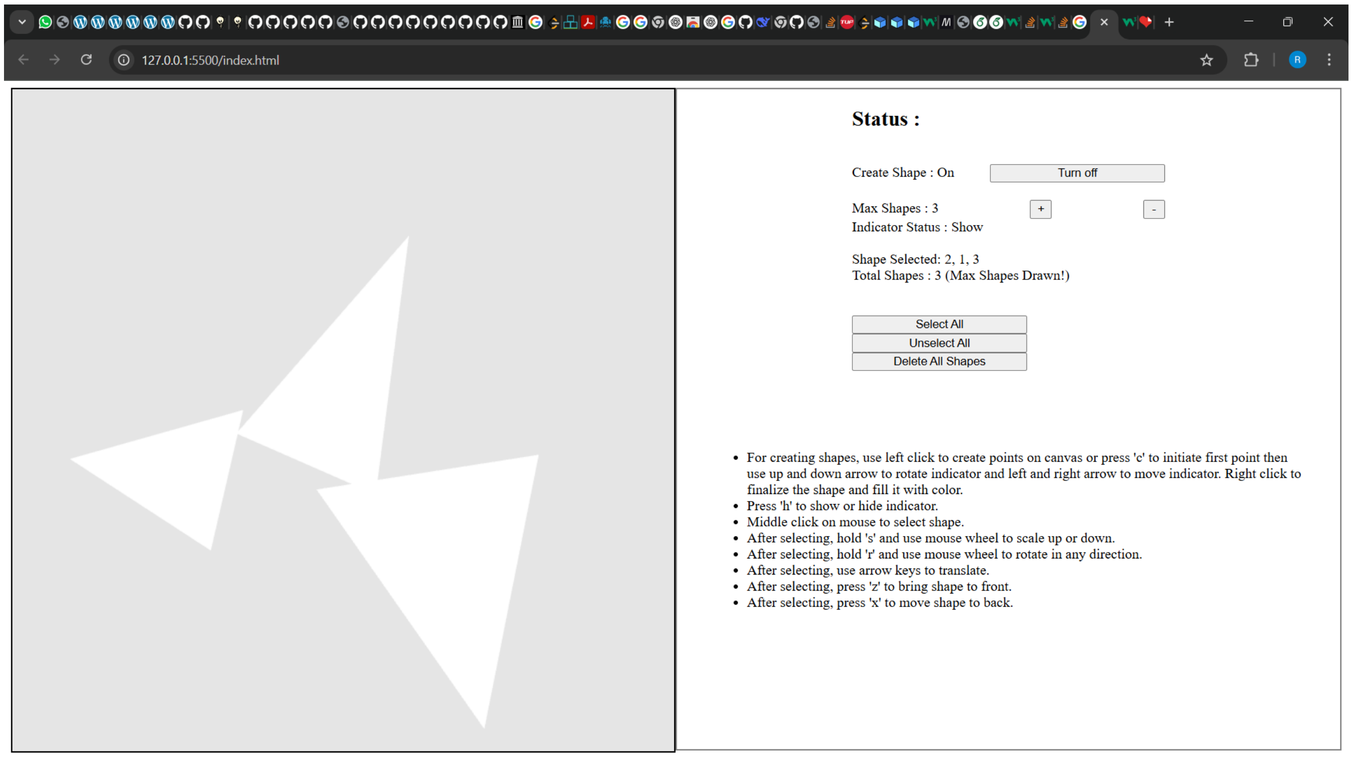
- After selecting, press 'x' to move shape to back.

Fig. 11. Group rotated



Status :

Create Shape : On   Turn off

Max Shapes : 3   +   -
Indicator Status : Show

Shape Selected: 2, 1, 3
Total Shapes : 3 (Max Shapes Drawn!)

Select All
Unselect All
Delete All Shapes

- For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
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- After selecting, press 'x' to move shape to back.

Fig. 12. Group translated

1 Keyboard / Mouse Controls -

1. For creating shapes, use left click to create points on canvas or press 'c' to initiate first point then use up and down arrow to rotate indicator and left and right arrow to move indicator. Right click to finalize the shape and fill it with color.
2. Press 'h' to show or hide indicator.
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6. After selecting, use arrow keys to translate.
7. After selecting, press 'z' to bring shape to front.
8. After selecting, press 'x' to move shape to back.

2 Video Presentation Link –

https://drive.google.com/file/d/1fgHk7K2B4lInnUYHtiCRuwSYMwVCUNi4/view?usp=drive_link

3 References –

https://www.geometrictools.com/Documentation/TriangulationByEarClipping.pdf
https://en.wikipedia.org/wiki/Polygon_triangulation
https://en.wikipedia.org/wiki/Ray_casting_algorithm