Combat Symbol Color and Geometric Visual Coding Fusion Display Technology

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Abstract. For the information presentation of combat equipment and battlefield environment, a method is proposed to enhance the representation of color military semantics through geometric assistance, which is based on the fusion display technology of color and geometric visual coding of combat markers. In the meantime, Bézier curve is used to visually optimize the combat markers. With better smoothness and visual separation, the military expression ability and human-computer interaction function of the combat markings have been enhanced, and the fusion display style named "rectangle + Bézier curve" has also been designed to better advance the information presentation of battlefield situation.

Keywords: Combat Symbols · Color Military Semantics · Geometric Aids · Visual Coding · Bézier Curves · Human-Computer Interaction

1 Introduction

Modern warfare is changing rapidly, and military information is expressed through combat symbols, which can visually reflect the battlefield environment, state and its development trend, and provide the display and sharing of battlefield situation information.

In the combat symbol standards of various countries, it is stipulated that combat symbols of different colors are used to distinguish combat roles such as the enemy, me, and friends. The visual coding information carried by the colors adds military semantics to the combat symbols. In the current combat system, digital handheld terminals for individual soldiers [7], small displays for weapons and other equipment are widely popularized. However, due to the constraints of high power consumption, instead of using color display in many cases, black and white display mode is often used. In the mode, the military semantic expression of the color of the combat symbol is invalid, and it is very difficult to identify the symbol; in the field combat environment, because of the influence of external light and the interference of similar colors on the electronic map [10], even if it can be displayed in color, it will weaken the color variables. The sense of visual difference makes it difficult to identify combat symbols with color military semantics; moreover, the traditional symbols selected in the rectangular box have no military semantics, and it is necessary to strengthen the visual coding to make the symbols carry rich military information and realize human-computer interaction at the plotting

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level. Therefore, only relying on color to represent all parties in military operations is not disadvantageous for actual combat applications since it hinders the information presentation of equipment to a certain extent. Consequently, it is necessary to study the visual enhancement solution of color semantics.

This paper proposes a representation method that enhances color military semantics through auxiliary geometric shapes. For application scenarios including equipment and field combat environments, a new auxiliary geometric object design is given for the color military semantics of combat symbols, which can support system information construction of combat command.

2 A Geometric Alternative Representation Method for the Color Semantics of Combat Symbols

2.1 Military Semantic Description of Colors in Different Combat Symbol Standard Systems

The key to victory in modern warfare requires complex and accurate battlefield situation information as support. Combat symbols carry important military information. As an indispensable element in military combat maps, the development of combat symbols has gradually matured. Countries have stipulated different military symbol standards according to military graphics requirements respectively. The military semantics described under national standards will also vary, among which the attribute of color is described differently in diverse combat symbol standard systems.

Existing regulations state that military symbols are generally painted in red, pink, black, blue and green, and can be complemented by yellow or other colors when required. The main rules are as follows: on our part, team logo should be red and the team number should be black; on the friend part, the team logo should be pink and the team number should be black; on the enemy part, both the team logo and team number should be blue; the team logo and team number of unknown nationalities or neutral countries (regions) should be green. The research on common operational symbols in the United States has started early, and its system is comprehensive now. In the 2014 version of MIL-STD-2525D [12], the combat symbol standard system mainly stipulates that the team logo of the enemy should be red, the team logo of the friend team should be blue, the team logo of the neutral team should be green, and the team logo of the unknown team should be yellow. The standard system of combat symbols basically adopted by organizations like NATO is based on the system of US military [8].

In conclusion, the differences between the color military semantics of the two sides are obvious. Our country has not considered the equivalent display method of color military semantics in black and white display mode, therefore, at present, the research on this is blank. The US standard system of combat symbols has been designed on geometric shapes, mainly focusing on description of position. Besides, the system also has geometric aids in the distinction of combat roles with basic primitives and simple curves included, which is similar to the military semantics I presented, but is different from the design ideas of geometric aids this article focuses on. In the above-mentioned standard systems of combat symbols of countries, color has a specific military semantic expression effect, and is an important visual coding means to represent combat information.

Therefore, the visual enhancement design of color plays an important role in the display of combat situation.

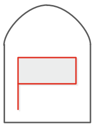
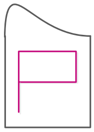
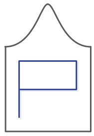
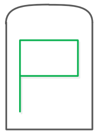
2.2 Logical Mapping Design of Color Military Semantics and Auxiliary Geometric Objects

In today's field of military operations, how to visualize the situation and provide valuable information for fighters deserves continuous research and discussion. Visual coding refers to the process of mapping processed data information into visual elements, and the same data set may correspond to multiple visual presentation forms after mapping [16]. The visual presentation result can be understood as a combination of a set of graphic elements which carry the encoded data information and when the user reads the information from these graphic elements, he actually decodes some information. Starting from the concept of visual coding, 21 visual channels which can be coded are derived [1]. These visual channels affect the user's visual cognition of reading pictures to a certain extent, but in the situational presentation of combat symbols, it will be obviously limited to only rely on colors to distinguish the design of combat roles in application scenarios. In view of the lack of geometric enhancement design in combat symbols, this paper proposes a new design idea, that is, the color visual coding of combat symbols, and then assists the visual coding of geometric shapes. By adding visual channels, the color space and geometric space are used to strengthen the military semantics of symbols and colors by auxiliary geometric objects.

Among the existing combat symbols, a single basic primitive has been used as an auxiliary geometric element, which causes visual confusion when plotting with multiple combat symbols. Therefore, this paper designs a "rectangle + Bézier curve" fusion display style, based on the geometrically assisted construction method, to reshape and strengthen the symbols of all parties in the combat role [5], and characterize the generated combat symbol military information. It can better solve the problem of distinguishing combat information based solely on color military semantics in existing equipment. The advantages of this design are reflected in three aspects:

(1) *Differentiation:* Visual cognition is a multi-dimensional information transformation process. When the data displays information and the user's visual stimulation behavior, the information read by the user continues to transform, and finally forms a visual stimulation response [6]. The addition of the Bézier curve makes the auxiliary geometric shape of the design better visually separate from the existing symbols, thereby affecting the visual cognition of the symbols by the fighters;
(2) *Visual effect:* The shape of the Bézier curve can be arbitrarily designed through the control node of the displacement adjustment curve, the smoothness of the Bézier curve can be adjusted by setting parameters, and the smoothness of the Bézier curve can be used to ensure a good visual effect [4];
(3) *Military semantics:* When designing new symbols, it is necessary to focus on the military semantics of the symbols. On the basis of the color semantics of the original symbols, the curve shape is also given to military information. The specific design ideas and presentation effects are shown in Table 1.

Table 1. The logical mapping table of color military semantics and auxiliary geometric objects.

military semantics	our side	friendly	enemy	Unknown or neutral party
Regulation color	red	pink	blue	green
map geometry				

In the above schematic diagram, the interior is the command post of combat symbols. The design ideas of this article are all taken as an example of the design of the command post. The design methods of other symbols refer to the command post. The outer black closed geometric curve is the auxiliary geometric object corresponding to the color.

3 Overall Design

Although the traditional combat symbol has a rectangular check box, it does not have any military semantics. The encircling curve designed in this paper enhances the human-computer interaction function from the perspective of military semantics. As a basic curve drawing method, Bézier curve has been widely used in computer graphics. Bézier curve interpolation has become one of the important methods of computer-aided geometric design because of its many excellent characteristics which are beneficial to curve design [11]. Starting from the participating parties in the battle, this paper elaborates the fusion display design of "rectangle + Bézier curve" from two aspects of geometry and algorithm implementation, which fully reflects the significant advantages of Bézier curve, such as geometric invariance, symmetry, convex hull, variation reduction, smoothness, convexity preservation, etc.

3.1 Geometric Design Method

3.1.1 Bézier Curve

Bézier curve is a mathematical curve adopted in two-dimensional graphics applications [19]. It is a basic tool for computer graphics and image modeling, and is a classic curve approximation method. The curve drawing in this paper mainly uses cubic Bézier curves. Cubic Bézier curves combine interpolation and approximation, P_0 where the tangent crosses P_1 and P_2 the tangent crosses P_3. P_0, P_1, P_2 and P_3 four points define a cubic Bézier curve in a plane or in three-dimensional space [18]. A Curve starts at P_0 a point, goes toward P_3, and comes from P_1 a direction P_2. Generally not passing

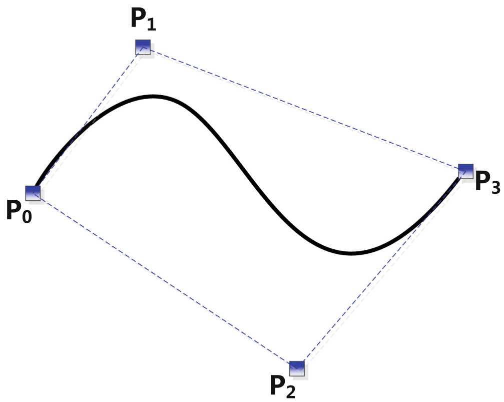


Fig. 1. Schematic diagram of control point distribution of cubic Bézier curve.

P_1 or P_2; these two points only provide trend and direction information. The schematic diagram of the cubic Bézier curve is shown in Fig. 1.

The parametric form of the interpolation curve:

$$B(t) = P_0(1-t)^3 + 3P_1t(1-t)^2 + 3P_2t^2(1-t) + P_3t^3,$$
$$t \in [0, 1]$$

3.2 Bézier Curve Design for All Parties

Under the geometric aided design, the combat symbols of all parties in the battle adopt the fusion drawing method of "rectangle + Bézier curve". The new combined symbol is divided into two parts, including the original color semantic symbol and the outer curve envelope. Among them, the rectangular frame part is the geometric auxiliary object corresponding to each combat party, which is taken from the rectangular bounding box of the combat symbol, and then expands the rectangular bounding box of the symbol by 10%, and finally removes the upper border; the Bézier curve above the symbol is mainly to control the direction of the processing curve through different layouts, and then adjusts the shape of the curve. The detailed drawing methods of the geometric auxiliary objects corresponding to the symbols of each combatant are as follows:

1) *Red (our side) symbol Bézier design*

First of all, our combat symbol is red, and the design of the Bézier curve adopts a protruding and full curve line, which highlights the concept of winning with our side as the leading force in military operations. The drawing method is shown in Fig. 2. The horizontal line passing through point A and point B is the H_1, and its vertical bisector OM is made through the midpoint O. Take point C on OM and make OC equal to 1/2 AB. Make parallel line H_2 of H_1 passing through point C. Point P_2 and point P_3 are made respectively at the two sides of point C and make $CP_2 = CP_3$, both of which are

1/6 of AB. Take point P_1 above point A and point P_4 above point B. Make $AP_1 = BP_4 = CP_2 = CP_3$. The shape of the entire curve is divided into two sections, and the curve AC and the curve CB use Bézier curve interpolation for three times to approximate the curve to the shape of Fig. 2(a).

2) *Pink (friend side) symbol Bézier curve design*

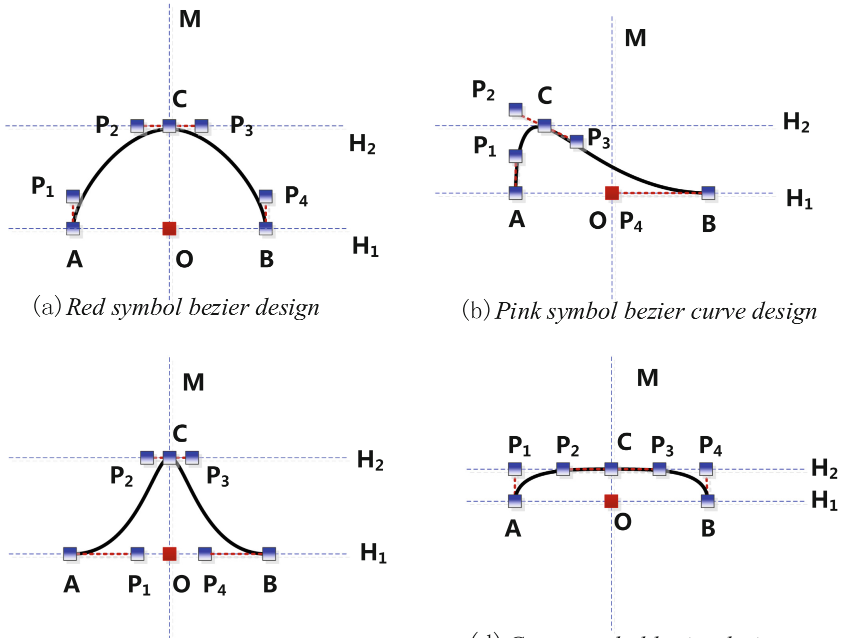
In military operations, the friend combat symbol is specified to be pink. Under the support of color semantics, the geometric auxiliary curve shape is designed to be the left-side convex and right-side sliding shape at the top, which better reflects the friendly preference of the friend side to us. The specific drawing method is shown in Fig. 2. The horizontal line passing through point A and point B is the H_1, and its vertical bisector OM is made through the midpoint O. The H_2 is the parallel line of H_1, and its height is the half of AB. Point C is on H_2 and is 1/6 of AB far away from the vertical line passing through point A. In the direction of the straight line CB, point P_2 and point P_3 are made respectively at the two sides of point C and make $CP_2 = CP_3$, both of which are 1/6 of AB. Take point P_1 above point A, and make AP_1 is 1/6 of AB. Take point B at the left side of P_4, and BP_4 is 1/2 of AB. Again the whole curve is divided into two sections, and the curve AC and the curve CB use Bézier curve interpolation for three times to approximate the curve to the shape of Fig. 2(b).

3) *Blue (enemy side) Bézier design*

The enemy's combat symbols are usually blue, and the mapping geometry of blue symbol is a sharp and prominent curve. To highlight the danger to our combat, the impact of the visual effect is required to be significant, so the upper curve is designed to be convex in the middle. The specific drawing method is shown in Fig. 2. H_1 is the horizontal line that passes through point A and B. OM is the vertical bisector of H_1 with point O as the midpoint. Take point C on OM and OC is 1/2 of AB. Make parallel line H_2 of H_1 passing through point C. Point P_2 and point P_3 are made respectively at the two sides of point C and make $CP_2 = CP_3$, both of which are 1/6 of AB. Take point P_1 at the right side of point A and point P_4 at the left side of point B. Make $AP_1 = BP_4$ and both of them are 2/3 of AO. Again the whole curve is divided into two sections, and the curve AC and the curve CB use Bézier curve interpolation for three times to approximate the curve to the shape of Fig. 2(c).

4) *Green (unknown nationalities or neutral countries) Bézier design*

Unknown and neutral sides in combat are defined as green symbols, and the mapped geometric shapes need to be designed for military semantics. The lower symmetrical and smooth curved borders reflect the neutral attitude of combat roles to the battlefield situation. The specific drawing method is shown in Fig. 2. The horizontal line passing through point A and B is the H_1, and vertical bisector OM is made through the midpoint O. Take point C on OM and make OC is 1/6 of AB. Make parallel line H_2 of H_1 passing through point C. Point P_2 and point P_3 are made respectively at the two sides of point C and make $CP_2 = CP_3$, both of which are 1/4 of AB. Take point P_1 above point A and



(a) *Red symbol bezier design* (b) *Pink symbol bezier curve design*

(c) *Blue symbol bezier design* (d) *Green symbol bezier design*

Fig. 2. Bézier curve Design for All Parties.

point P_4 above point B. Make $AP_1 = BP_4$ and both of them are 1/6 of AB. Again the whole curve is divided into two sections, and the curve AC and the curve CB use Bézier curve interpolation for three times to approximate the curve to the shape of Fig. 2(d).

Figure 2 is the drawing style of the Bezier curve of all parties in the battle, showing the design in the order of our part, the friend part, enemy and unknown or neutral part. It uses the fusion display design method of "rectangle + Bézier curve" and is of great significance for the geometric expression of combat symbols. First, at the level of enhanced representation design of auxiliary geometric objects of color military semantics, it can provide key color military semantic enhancement expressions for various terminal equipment displays, greatly promoting equipment-level situational information display technology; secondly, at the level of humanistic design, color semantics It can provide color vision enhancement design for color-impaired people in the world [9], which has wider social value; in terms of human-computer interaction, it can enhance the visual experience of war fighters in the process of reading pictures and plotting, which provides a new idea for commanding the combat field.

3.3 Drawing Process of Geometrically Enhanced Representation of Combat Symbol Color Semantics

BaseD on the above-mentioned related designs and studies, the complete process from symbols to generating auxiliary geometric objects is given below. The processing flow of geometrically enhanced representation of combat symbol color semantics is divided into seven steps, as shown in Fig. 3.

1) *Calculate the rectangular* AABB *bounding box of the symbol* [2]*:* AABB has a relatively simple structure, small storage space, and has the simplicity of intersection testing and better compactness. Therefore, the bounding box strategy is determined from the perspective of geometric logic mapping, and is constructed according to geometric features. The corresponding AABB bounding box;
2) *Expand the bounding box by 10%:* Then expand the rectangular bounding box of the symbol by 10%. The expansion of the rectangular bounding box can cause a good separation effect, forming a geometric and visual separation from the original combat symbol;
3) *Draw lower polyline:* draw the left, bottom and right sides of the bounding box according to the expanded rectangle;
4) *Draw the upper Bézier curve:* According to the expanded rectangle, the military semantics of the symbols, the combat roles of the enemy, me, and friends, etc., based on the geometric aided design described above, by encapsulating the Bézier interpolation algorithm, find the control point Position, provide an interface function to draw the corresponding upper Bézier curve;
5) *Curve optimization and generation:* control the start point, end point and intermediate point to fit the first curve, and take the end point of the first segment as the starting point to ensure that the position and slope are consistent [15]. To fit the second segment of the curve, it is necessary to locally effectively control the single-segment Bézier curve, and smooth the curve during the curve drawing process to optimize the drawing process. To ensure the continuity and fit of the lower polyline and the upper curve at the connection, a complete and smooth closed curve can be drawn;
6) *Visual fusion display:* In order to strengthen the integrity of symbols and auxiliary geometric objects, the closed auxiliary geometric objects can be filled with semi-transparent color. The filling color is the color of the symbol, and the transparency is 30%–50% [17], the symbol is drawn on it to ensure that it is not blocked. Moreover, by filling the color, the symbol can be visually separated from the background, and the symbol can be highlighted.
7) *Interactive test:* Draw the generated curve combination to generate a new combat symbol. It is necessary to set various modifiable attributes such as color, line type, line width, angle, and whether to fill, and save it to the corresponding container [14]. In order to increase the user's comfort and conform to the user's reading habits, it is necessary to conduct multiple tests and tests on the generated combat symbols, so as to achieve a better display effect when drawing different curves, and at the same time ensure the accuracy of military information.

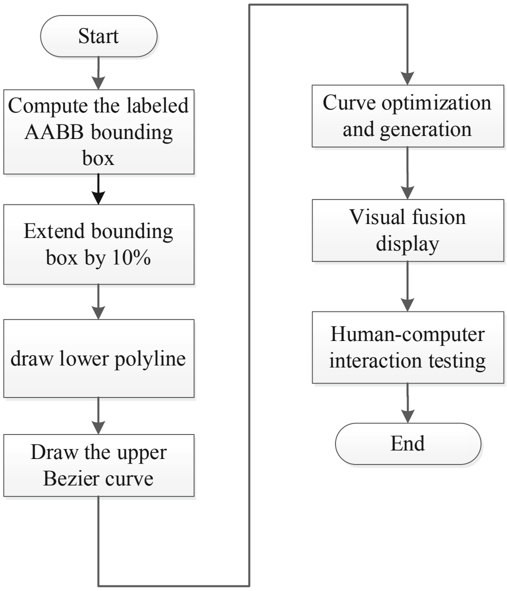


Fig. 3. Flowchart of Geometrically Enhanced Representation of Color Semantics of Operational Symbols.

Figure 3 is the flow chart of the geometrically enhanced representation of the color semantics of combat symbols.

In order to quickly display situational information and improve computing power and rendering efficiency, visualization processing of rendering the underlying interface package can be performed. The entire drawing process generates four specific smooth curves through different layouts of Bézier curve control points. These curve shapes correspond to the military semantics of different colors. The geometric shape is more suitable for the cognitive habits of our army fighters [13], with strong image, concise and easy to remember.

3.4 Fusion Display Renderings

The display effects of the four curve designs are visualized using geographic information systems and plotting software. The simulation process is to use the topographic map as the bottom display layer in the absence of color display mode, and the design effect of the combat command post as an example. The combat symbols aided by geometry make the plotters pay attention to the changes in the situation, which can better highlight the military participating parties and convey military combat information. In the case of weakened military semantics of colors, it provides a strong guarantee for combat map reading and battlefield command. The display effect of each combat symbol design is shown in Fig. 4.

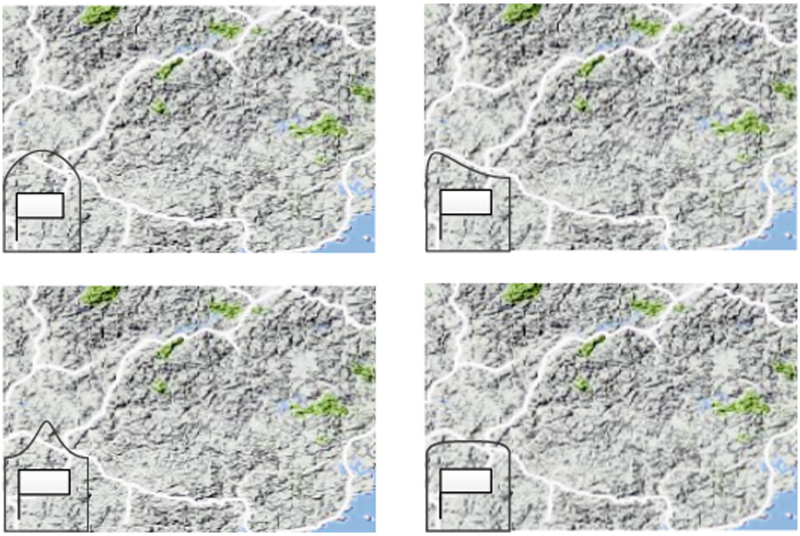


Fig. 4. The fusion display rendering of the geometrically enhanced representation of the color semantics of the combat markings

4 Concluding Remarks

In the view of the identification and application scenarios of combat symbols like equipment and field environment, the essay takes the command post in combat symbols as an example and gives a new type of auxiliary geometric object design for the military semantics of the color of combat symbols, which provides a basis and supports for the construction of combat command and training systems. In the future, we can learn from this idea to further optimize the display of operational symbols in the command center and other scenarios, improve the situation display effect through a variety of visual coding methods, and apply the geometrically assisted enhanced representation design to a wider range of symbol types and multi-scale situational display capability of weapon terminals [3].

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