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# Authentication of Colors and Textures Through the Chronographic Method

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## ABSTRACT

Graphical modelling is considered to be a suitable approach for displaying project data because of its ability to communicate information clearly and effectively. Despite this fact, little research has been undertaken in this area with regards to the construction sector, and current methods and software do not propose standard graphical protocols. Therefore, it has been up to each planner to individually set his or her own standard. To addresses these shortcomings, the Chronographical modelling proposes a standard protocol. This paper presents the validation of the first phase of this standard protocol for construction project scheduling. This phase proposes two ranges of light and dark colors and a graphical convention for textures and shapes. The validation process was performed through a case study that evaluates the texture convention and color limits followed by the application of the proposed graphical convention to a building scheduling. These validations were performed through case studies that evaluated the visual data and assessed the necessary mental effort for finding information on the schedule. The results demonstrate clearly that the proposed convention helps to improve the visual clarity while simultaneously seeking to diminish the mental effort necessary for finding information.

**Keywords:** Graphical modelling; precedence diagram; procurement; project

## INTRODUCTION

Graphical modelling is considered to be a suitable approach for displaying project data because of its ability to communicate information clearly and effectively [1]. Despite this fact, little research has been undertaken in this area with regards to the construction sector. Current methods and software do not propose standard graphical protocols and it has been up to each planner to individually set his or her own standard. In contrast, too many other areas possess their own standard graphical symbols and representation. The infrastructure sector has used its own standard manual for traffic signals since 1935 [2] while urban planning, somewhat related to the construction industry, has used a standard convention of colours for the classification of land use [3] since 1965. The geotechnical sector currently uses abbreviations, textures and colours to represent soil types according to ASTM D2487-11.

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## Graphical modeling

Construction project planning Graphical modelling is not widespread within construction project planning. Their research addresses three main components: the graphical representation of constraint types the interactive representation of recedence networks, and the comparison of different planning alternatives [4].

The Chronographic Modelling studies the graphical representation of the project in the spatial dimension. This approach analyses the visual interface, the graphic elements and the parameters associated with these elements. The goal is to establish a standard protocol for the graphical representation of construction project planning. Textures and colors are examples of graphic elements used by this protocol [5]. Carrier-Fraser propose guidelines for the use of these graphics in modelling the physical entity. According to these authors, activities can be represented by textures, and colors can be linked to resources and locations. Ardila and Francis validate the graphic convention of textures and shapes as a first phase of the validation of the new Chronographical standard protocol for construction project scheduling. The validation phase was performed through a case study in order to assess the suitability of the protocol and its visual clarity while simultaneously seeking to diminish the mental effort necessary for finding information.

## Information visualization

Effective communication of information depends in large part upon the way that data is graphically represented and how we perceive and interpret this information [6]. The developments of new visualization systems must take address the following three approaches:

- Technology-driven: what can be done with current technology;
- Perception-driven: what makes sense considering the constraints on the human visual system;
- Task-driven: what the user wants.

Considerable effort has been put forth towards the Technology-driven approach, where advancements in terms of information technology are remarkable. However, little attention has been given to the Perception-driven and Task-driven approaches. Tory and Moller argue that it is necessary to think about how we analyze and interact with graphic variables and how it can affect the information visualization. Indeed, the brain is able to perceive multiple graphical elements simultaneously, but it cannot process them in parallel. Our vision focuses on small areas of the visual field and watches one element after another in an unintended sequence named "Attention" .
Ware divides the Attention process into three sub-processes:

The Pre-Attention Process: A quick parallel process where one chooses the graphic elements to be analysed;

Visual Perception: A slow series of processes where one analyses the graphic properties of the

visual element comparing correspondence, differentiation, relationships, understanding and meaning;

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Interpretation: A process in which one interprets the analysed information and obtains results.

The design of visualization systems should seek to maximize the impact on the pre-attentive process. According to these authors, position, shape, colour and animation are among the graphic elements that favor the pre-attentive process.

**Visualization systems using colors**

The color is also among the graphic variables that promote the pre-attentive process. Color is the second most efficient graphical variable for the encoding of nominal information. Because of its separation properties, it is possible to easily identify and differentiate information. Therefore, the use of colors would facilitate the information search process on a schedule [7].

Color consists of three components: hue (H), saturation (S) and lightness (L). Each of these components has different qualities. Hue has separation qualities while saturation and lightness have, at the same time, separation and hierarchy qualities. By varying these components, we can obtain a significant number of colors. However, the number of colors to use is limited by the capacity of the human eye to differentiate them. Seven colors is the optimal number to maintain a search in parallel. In addition, they must belong to the seven color categories identified as follow: Red (R) Yellow-Red (YR), Yellow (Y), Green (G), Blue (B), Purple (P) and Red-Purple (RP).

There are many ways to encode information through color
scales. Color scales can be grouped into three categories according to the nature of the data to be encoded, the information to be highlighted and the tasks to be achieved:

Hierarchical scales, which highlight the progression order of the data;

Qualitative scales, which emphasize the separation between data, regardless of importance or progression;

Divergent scales, which combine the concepts of separation and progression to enhance the average data and extremes.

The American National Standards Institute (ANSI) and the

International Organization for Standardization (ISO) proposed standards for the use of textures.

**THE TEXTURE CONVENTION**

Presentation of the texture convention

According to the Chronographical Modelling , activities can be represented by textures. Texture convention aims to facilitate finding, interpreting and memorizing information on aconstruction schedule.The Chronographical texture convention includes three levels of information, each of which is represented on a different layer [8]. The base level represents the construction divisions according to the Master Format Classification System . The graphical elements of this level include: hatching, objects, symbols, lines, and texts. The proposed texture convention is based on the

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standard elements listed in the US National CAD Standard commonly used for the graphical representation of information in construction has been privileged.

**Validation of the texture convention**

We conduct a case study in order to validate the proposed texture convention and assess its acceptability by planners following the steps recommended by Lam et al. : i) setting a goal; ii) picking suitable scenarios; iii) considering applicable approaches; iv) creating evaluation design and planned analyses. The case study was conducted in two stages by following two of the seven evaluation scenarios proposed by the same authors, namely, the VDAR: Evaluating visual data analysis and reasoning and the CTV: Evaluating communication through visualization. The first stage assessed the suitability of the texture convention and its visual clarity and the second stage evaluated the mental effort required to find the desired information on a building construction schedule.

**Evaluating suitability of the texture convention**

The suitability of the texture convention and its visual clarity was evaluated using a questionnaire consisting of fourteen questions. The first eight tested the intuitiveness and the simplicity of this convention while the last six questions aimed to gather the experts' opinions.First, participants were asked to intuitively associate each construction division with the appropriate element of the graphic texture convention. The purpose was to assess, without any prior explanation, the intuitiveness of the texture convention. Secondly, participants were asked to repeat the same exercises. This time, however, they have to attend an explanation session of the convention. The aim was to evaluate the ease of memorization of the convention. The final six questions surveyed the participants' opinions.

This proposal has taken into account the suggestions for improvement made by participants.The third level, presenting the construction stagedifferentiates between two main stages: pre-construction and construction implementation. The dotted border lines indicate a pre-construction stage (e.g. the preparation and approval of workshop drawings) while the solid border lines indicate the construction implementation phase (e.g. equipment installation). The interior dotted lines indicate the support activities or the first task in the implementation process of a construction work (e.g. temporary work or formwork task in reinforced concrete slab implementation); the interior solid lines indicate the second or intermediate task in the implementation process (e.g. reinforcing steel bars in reinforced concrete slab implementation) while the interior bold lines indicate the last task in the implementation process (e.g. pouring concrete).

second level of the construction elements and four (4) items for the third level of construction phases. Using these three levels of information, the texture convention is extended to 1056 representation items.

Nearly 90% of the participants succeeded in memorizing the meaning of these textures after attending the explanation session. In the case of textures using objects and symbols, the results were lower. However, despite these lower results almost 67% of the participants were able to remember the meaning of textures after the explanation session. Concerning the second and third level of the convention, representing the construction elements and stages, the results was very encouraging

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with a success rate of 100% when evaluating the ease of memorization. With three levels of information, the texture system is a logical knowledge system. This system simplifies and facilitates the memorization of information by decreasing the number of elements to memorize; it consists of 33 items in the first level of construction divisions, eight (8) items for the

Questions 9 through 14 aim to gather expert opinions about the meaning and graphical quality of the textures and graphics used. Participants had the opportunity to express their opinions and make suggestions for improvement. Three people worked individually and twelve people worked in teams: i) two teams of three; and ii) three teams of two. Despite the fact that participants used only the knowledge acquired during the first part of the case study, almost 70% of the questions were answered correctly a rate which jumps to 84% when considering partially-correct answers. People working in teams were able to establish group discussions which positively influenced the accuracy of their responses compared with those who wrote the test individually. However, the number of people per team does not appear to have had a significant impact on the performance of the group.

**Evaluating the mental effort required to find the desired information**

This stage tested the ability to search for information, on a building construction schedule, based only on the texture convention. The schedule does not include any other indications, markings or texts. The timeline presented the design, the procurement and the construction stages of the foundations, structures, finishes and systems for a building project. Participants were asked to answer 16 open questions regarding searching for information and demonstrating the comprehension of the Convention.

The schedule was presented as a Gantt chart in PDF format in order to avoid influencing performance by using an unfamiliar presentation method or planning software. Participants could graphically interact with the schedule by performing simple actions, such as zooming, and moving throughout the schedule. To answer questionnaires, participants had no prior training and had to use the knowledge gained in the previous phase outlined above.

Bar annotations and activity labels were added for the comprehension purpose of this paper. Annotations on activities A to D indicate the different levels of information according to the texture convention. Annotations on bars representing activities E to H indicate the activity names based on the texture convention interpretation.

## THE COLORS CONVENTION

The Chronographical model defines the Physical Entities (PE) that represents all work, resources and locations (work placement) required to perform the construction operations.

The graphical Protocol representing the work is mainly shown using the texture convention as demonstrated in the previous section. Resources and locations use colors as the main graphical means. While resources use a range of dark-colored fills, location is shown through a range of light-colored fills. The objective of this section is to define the two different ranges of colors, a dark range and a light range of fill colors.

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A significant number of colors can be obtained through the variation of their components: hue (H), saturation (S) and lightness (L). However, the capacity of the human eye to differentiate colors limits the number of colors to use in order to favor the pre-attentive process.

To address this constraint, propose working with light and dark color scales independently with regard to maximizing the number of colors available while simultaneously minimizing the impact on user performance. In addition, light color scales also allow simultaneous use of other graphical elements such as texture and text .

In order to obtain a light and a dark range of colors, it is necessary to evaluate the following:
The variations in colour components;
The limits between light and dark colours;
The limits between the colour categories;
The maximum number of colours per category.

Regarding the color categories, Healey argues that seven colors is the optimal number to maintain a search in parallel. However, it could be possible to increase the number of colors by using variation patterns of color components. These variation patterns follow Bertin's theory . Hue is used as the primary variable to ensure differentiation between colors because of its separation qualities. Lightness and saturation are used as auxiliary variables to improve differentiation between colors. Hue, saturation and lightness limits for each color category and the number of colors recommended by category. Notice that the limit values of color components are different for light and dark colors.

1 Saturation between 80% and 100% 2 Lightness between 85% and 90%
According to Bertin hue has separation qualities while saturation and lightness have, at the same time, separation and hierarchy qualities. The primary colors for the additive color system (RGB) and subtractive color system (CMYK). Each primary color has a different value of hue, yet they have the same value of lightness (50%) and saturation (100%).

Dark color scale obtained by using a specific variation pattern of color components
The validation process was conducted through a case study in order to assess the suitability and the visual clarity of the dark and light range of colors, the limits between light and dark colors, the limits between colors categories and the maximum number of colors per category. The results of the color case study allowed for the validation and adjustments of the results. This will allow users to build their own scales based on the proposed parameters.

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