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Contents

The implementation of polycaprolactone (PCL) as an eco-friendly material in toy design development

ABSTRACT

Due to a substantial impact of hazardous materials in toy design, numerous toy companies have opted for an eco-friendly toy by promoting a legacy of innovation rather than waste and degradation. Furthermore, one of the most significant polymers for being recognised as a safe toy material is Polycaprolactone (PCL). However, in Malaysia, the study of Malaysian parent's level of awareness in buying eco-friendly toys, their behaviour in purchasing and managing toys at home, as well as the preferences of play type for their children, is not widely discussed. Thus, forty (40) Malaysian parents have participated in an online survey conducted by the research team. The result of the study found that most Malaysian parents has a low level of awareness in buying eco-friendly toys for their children, lack the skills needed in handling broken or unused toys, and have selected criteria to be considered when purchasing a toy. Furthermore, a set of semi-working toy design was successfully developed using PCL as a proposal for potential future development and production. It is hoped that the outcome of this study will contribute to inspire future toy designers to account for Malaysian parent's preferences when developing eco-friendly toys.

Muhammad Jameel
Mohamed Kamil [1,2] (iD)
Sarah Aliya Shaukat [3]

[1] Universiti Malaysia Sarawak, Institute of Creative Arts and Technology (iCreate), Sarawak, Malaysia
[2] Universiti Malaysia Sarawak, Design Technology Programme, Faculty of Applied and Creative Arts (FACA), Sarawak, Malaysia
[3] Debit Circle SDN BHD, Kuala Lumpur, Malaysia

Corresponding author:
Muhammad Jameel Mohamed Kamil
e-mail: mkmjameel@unimas.my

Introduction

Nowadays, environmentalists are concerned about how plastic takes account to about 90 per cent of the toys market, especially in terms of how toys are contributing to health and environmental effects. According to Babayemi et al. (2018), worldwide plastic creation expanded from 1.5 million tons (Mt) every year in 1950 to 245 Mt in 2008, and it has been projected that it could significantly increase by 2050. Its utilization has expanded twentyfold in the past 50 years and is expected to double again in the following twenty years. Plastics present a convoluted waste management challenge at their finish of life, albeit plastic is a waste stream with recycling and recuperation potential. The challenge of plastic waste management, particularly recycling, is quick turning into a worldwide issue. Compared to the rate at which virgin plastics are produced, the rate of recycling lags far behind, and a much higher extent of plastics is being discarded in landfills, dumpsites, and ocean than at any other time. This disposition transforms the Arctic Ocean ice into a sink for micro-plastics and can last in the marine condition for many years.

In addition, during recycling the emission of volatile organic compounds may pose acute and chronic health risks in the recycling process. A wide scope of plastics contains endocrine-disrupting chemicals, for example, phthalates or brominated or chlorinated flame retardants. Such contaminants are not usually taken out in the recycling of household plastic (Hahladakis et al., 2015). According to Ismail et al. (2020), the most commonly utilized plastic material in the assembly of delicate children toys are polyvinyl chloride (PVC), which have been

a significant wellspring of harmful lead especially to that of children. PVC materials that are consolidated with lead and cadmium results in improved quality, security, brightness, and adaptability. Consequently, these features have made these toys to be progressively appealing to children. Hence, a significant level of exposure to lead caused numerous adverse clinical impacts in consumers, particularly children. It can occur through oral contact when the children put the surface of toys product into their mouth, letting the lead contained inside to be moved into their biological system. Regardless of whether the item contains the low measurement of lead, this repeated exposure will put the wellbeing of the children at risk. This will, in turn, pose a danger to the cardiovascular system, kidneys, liver, immune system reproductive organs, and as well as affects the development of the brain and nervous system (Bhagwat et al., 2010; Pratinidhi et al., 2014; Tong, von Schirnding & Prapamontol, 2000). Consequently, large toy companies have opted for a greener toy design by promoting a legacy of innovation rather than waste and degradation. Besides, these companies are exploring the concept of green bioplastics (bio-based, bio composite and biodegradable raw material) as a sustainable plastic source for toys.

However, there is a lack of discussion regarding Malaysian parent's level of awareness in buying eco-friendly toys, their behaviour in purchasing and managing toys at home, as well as the preferences of play type for their children. Thus, this is a product design research paper that aims to investigate Malaysian parents' awareness, behaviour when purchasing and managing eco-friendly toys, and including the preferences for toy design. The investigation is hoped to generate a significant element of solutions for Malaysian parent's level of awareness regarding eco-friendly toys. Furthermore, throughout the literature, this paper also aims to understand the significant potential of PCL as an eco-friendly material, including the possibility of incorporating the material in the product design process. Product design is a discipline that has emerged as playing a crucial part in the development of an innovative product. Incorporating a various aspect into product design through researching human behaviour, challenges, materials, and demands is one of the current methods for raising human value and product quality (Kamil & Abidin, 2013; Kamil and Abidin, 2015; Matos et al., 2014; Kamil & Abidin, 2014a; Kamil & Abidin, 2014b; Kamil, Abidin & Hassan, 2018; Sani et al., 2019; Kamil, Abidin & Hassan, 2019a; Kamil, Abidin & Hassan 2019b; Chumiran, Abidin & Kamil, 2020; Kamil, Shi & Sani, 2020; Sani et al., 2020; Kamil & Sani, 2021; Kamil, Ying & Sani, 2022; Kamil, Hua & Sani, 2022).

As a method of gathering the empirical data, 40 Malaysian parents were asked to take part in online survey. The results of the online survey revealed that most Malaysian parents are not very aware of the need of purchasing eco-friendly toys for their kids, do not really

know how to handle damaged or underused toys, and have predetermined criteria to take into account when buying a toy. Following the design process, a set of semi-working toy designs made of PCL called Ebee the Interchangeable Robot was developed as a recommendation for potential future development and fabrication. The development of Ebee from PCL material is hoped to serve as a significant example for future toy designers to ensure the regulated degradability, miscibility, and biocompatibility when creating eco-friendly toys. It is also hoped that the development of toys made of PCL would assist Malaysian parents in managing broken or unneeded toys in an appropriate manner as opposed to having them go in landfills and cause major land pollution. Furthermore, the interchangeable and stacking toy body parts and other creativity and engagement concepts incorporated into the Ebee design would contribute make the toy a potential product to promote creative engagement and imaginative play.

Essential preferences in toy design

According to Gielen (2010), the design of toys and different products, including environment for playful use requires knowledge and abilities that are not all instructed in general design education. Theoretical understanding of children's play behaviour was shown to be difficult to integrate in realistic design practise on a daily basis. Strong expectations routinely overruled the knowledge; beliefs such as 'play is fun and laughter is good, so play is about laughing'. The core of play, however, can be defined as the ability to experience through self-motivated activities and behaviour at one's own discretion and will. Through the development of toys with specific functions, the needs of children can be addressed, the success of activities can be allowed, incapacity can be resolved, and frustration can be alleviated. The reliability of toys lies in how well users' explicit or implicit requirements (both children and parents) are fulfilled, both in their primary role and secondary purpose, such as affirming the sense of style and aesthetic desires of the children, or pleasant experience during use. These requirements are difficult to establish within the realm of play. However, Gielen argues that the one thing experts agree on is that play is an undertaking that is extremely open-ended.

From diverse viewpoints, which are all pleasant, fun experiences, the purpose of playing can be achieved. Play is characterised in its ability, efficiency, and content by its various degrees of opportunity. In comparison, play is coordinated for the experience itself, rather than producing a permanent effect or continuing to compensate for the effort made. Play is all about the process's enjoyability, every process. The content of play or its

points is thus impossible to describe in explicit, nitty-gritty steps that a critical thinking designer might strive for.

According to Boehm & Boehm (1986), a large number of studies was conducted by psychologists and educators to decide when and how children learn. The outcome of the experiments seemed to suggest that during play, learning occurs randomly, automatically and continuously. Play is important for subsequent intellectual function, and within the play environment, different talents and abilities are developed and improved. Children use play as a way to test the limits between reality and perception. They not only use their creative minds and inventive energy by playing, but at the same time work out how to perceive themselves, their emotions, and other innate abilities. Through playing, children make an interpretation of the world to child size and reasonable proportions, where they are in control. According to Ünver (1998), specialists have been urging parents for a great period of time to search for "open-ended" toys that can be used (played) frequently in different ways. A collection of blocks can transform today into a skyscraper, tomorrow into a zoo, and the next day into a space station. The unstructured design of blocks encourages children to form as many new environments as their imaginative imagination can imagine, in comparison to a plastic castle that reliably resembles a palace.

The basic method that a child makes use of while playing with a toy is transformation. Ünver (1998) argues that the ability to make one thing that represents another is a significant accomplishment. For instance, in making the transformations of blocks to represent a cat, children tend to "play" with the desire to symbolise, which is eventually required to create a cat-like symbol; represented through the four-legged furry creature. For their symbolic activity, young children need practical toys. For instance, a toddler needs a toy phone that looks like a real phone. The pre-schooler, on the other hand, can pick up a block as a phone and carry-on conservation. There are no set rules at the heart of the action, except those generated by the player. The primary factor that convinces children about the play's imaginative reality or reinforces the belief is the toy kept in their lap. Toys are an important instrument that helps children to replicate any framework of life they can imagine (and beyond). It is then crucial that through toys, playing exercise children's' problem-solving skills to develop intellectual insights through the imaginative process, including emotional management (Oppenheim, 1987).

Eco awareness in design

According to Ceschin & Gaziulusoy (2016), the ground-breaking thesis that has brought environmental issues into the design world is 'Design for the Real World: Human Ecology and Social Change' by Victor Papanek (Papanek, 1985). Papanek gave an inside out scrutiny of the profession in design bringing up its job in empowering utilization and subsequently adding to social and ecological degradation. His work mirrored a sophisticated response centring not only to boost the outputs of the design operation but advancing change of the design profession. Ceschin & Gaziulusoy (2016) argue that the early acceptance of 'green' attitudes in the design sector did not reflect a sufficiently deep appetite for transformational change. The early examples of green design practice fundamentally centred around the idea of bringing down environmental impact through redesigning singular characteristics of individual products (Mackenzie, 1997). This was typically achieved by following the waste hierarchy in the reduction-reuse-recycle (e.g., minimising the amount of material used in the product, reusing components or entire goods in the production of new items, substituting sterile materials with recycled materials, substituting unsafe / harmful materials with non-hazardous ones). While considering the design world meant improving the productivity of product and process engineering, the prefix was the lexicon of the design profession and enhancing the still true 'rules of thumb' for enhancing the environmental performance of products. Madge (1997) stressed that green architecture lacks content and political scope, it encouraged green consumerism and did not have a substantial capacity to achieve environmental benefits.

In reminiscing to the end life of the design output which usually end up in landfills, takes into account to acknowledge the term from Cradle-to-grave to Cradle-to-Cradle (C2C). According to Hauschild, Rosenbaum & Olsen (2018), C2C draws on the concept of imitating nature in the sustainable product and system design approach. In other words, C2C explains the idea for production and consumption to allow the reduction of negative consequences in eco-efficiency and zero-emission, thus defined as beneficial to the environment. The Swiss architect Walter R. Stahel usually credits the first use of the word Cradle to Cradle in the late 1980s. Stahel argued that the "cradle to grave" perspective was merely reinforcing the existing linear economic model and relied on end-of-pipe solutions. He argued that the more sustainable solution is to use durable goods in a loop form of "cradle back to the cradle" or contemporaneously known as the circular economy. Stahel stressed that the perspective of "cradle to grave" merely validated the current linear economic paradigm and focused on end-of- pipe solutions. He proposed that using sustainable solution in a circle type of "cradle back to the cradle" or contemporarily known as circular economy is the more efficient approach.

Quality-wise, eco-design has a huge distinction over green design, although it was interchangeably used with green design when it was initially introduced. For example, eco-design places emphasis on the total life

cycle of goods from raw material production to final disposal (Ceschin & Gaziulusoy, 2016). The initiative empowered profiling the environmental effect of products over all life-cycle stages, recognizing those stages with the most elevated environmental effect and in this way given key direction for design interventions. Life-cycle assessment methods helps the environmental impact assessment, empowering significant examination between various products ideas of a similar category and in this way, aides with design decision-making. On a global scale, the eco-design's aim is to minimize the utilization of energy, natural assets, and its consequent impact on the earth while augmenting benefits for customers. As proposed by Binswanger (2001) and Brezet & van Hemel (1997), through eco-design, the environment is held at the same regard as the more traditional, industrial values such as image, overall quality, aesthetics, functionality, profit, and ergonomics.

While eco-design 's life-cycle emphasis is of higher quality relative to early green design practise, it still has substantial deficiencies. As outlined by Gaziulusoy (2015), due to the lack of complexity, eco-design focuses exclusively around ecological performance and thus, ignores social elements of sustainability which involves the distribution of capital and the product's social effects of the commodity that cannot be taken into consideration in life cycle assessments. Furthermore, when so much focus is placed on the technological dimensions of eco-design, it pays little or no attention to the human-related factors (e.g., consumer actions during the process of use).

Polycaprolactone (PCL)

According to Labet & Thielemans (2009), Polycaprolactone (PCL) consists of hexanoate repeat units and is an aliphatic polyester. PCL relies on its molecular weight and its degree of crystallinity for its physical, thermal and mechanical properties. PCL is strongly soluble in chloroform, dichloromethane, carbon tetrachloride, benzene, toluene, cyclohexanone, and 2-nitropropane at room temperature; mildly soluble in acetone, 2-butanone, ethyl acetate, dimethylformamide, and acetonitrile; and insoluble in alcohols, diethyl ether, petroleum ether, and water. The uncommon property of PCL is that it is miscible with other polymers (such as poly (vinyl chloride), poly(styrene-acrylonitrile), poly (acrylonitrile butadiene styrene), poly(bisphenol-A) and other polycarbonates, nitrocellulose and cellulose butyrate) and is also mechanically compliant (polyethene, polypropylene, natural rubber, poly (vinyl acetate) and poly(ethylene-propylene) rubber).

According to Tokiwa et al. (2009), there is a high amount of biodegradation in the blends of PCL and granular starch. PCL ([-OCH2CH2CH2CH2CH2CO-] n) has a medium melting point (60 °C) and a glass transition

temperature (Tg) of-60 °C but high ductility as a biodegradable synthetic partially crystalline polyester. The tensile strength of the PCL is ~16 MPa and the typical modulus of its elasticity is ~440 MPa. Tokiwa et al. argue that the action of aerobic and anaerobic micro-organisms that are commonly spread in different environments has been shown to degrade PCL. Depending on the molecular weight, the degree of crystallinity of the polymer, and the degradation conditions, PCL biodegrades within many months to several years. However, Tokiwa et al. stressed that Penicillium sp. was used to perform a study on the degradation of high molecular weight PCL. Soil-isolated strain 26-1 (ATCC 36507) and the test reveals that PCL has almost completely degraded in 12 days. The polymer at higher temperatures degrades by end-chain break, and at lower temperatures it degrades by random chain break. Carboxylic acids released during hydrolysis autocatalyze PCL degradation, but enzymes may also be catalysed, resulting in faster decomposition. In the atmosphere, while PCL can be enzymatically degraded, it cannot be enzymatically degraded in the body.

Thanks to its mechanical properties, its miscibility and biodegradability with a wide variety of other polymers, PCL is one of the most essential polymers to be known as a safe toy material. PCL has been used in various areas, such as tissue engineering scaffolds (Hutmacher et al., 2001; Jenkins et al., 2006; Peña et al., 2006; Lam, Teoh & Hutmacher, 2007), in long term medication delivery devices (in particular the transmission of contraceptives), microelectronics, adhesives and packaging (Ikada & Tsuji, 2000). Its broad applicability and interesting characteristics (controlled degradability, miscibility with other polymers, biocompatibility and the capacity to be manufactured from monomers derived from renewable sources) make PCL a very useful polymer if its characteristics can be controlled and cost-effectively manufactured.

Materials, method and result

Based on findings reported from previous studies, 40 Malaysian parents were selected as respondents to participate in the online questionnaire study. Respondents were given 20 minutes to complete the online questionnaire. The context of the survey study was specifically designed as follows:

1. Malaysian parents' awareness in buying eco-friendly toys for their children such as their awareness on any eco-friendly toys in their possession, and their willingness to buy (more) eco-friendly toys
2. Malaysian parents' behaviour when purchasing and managing toys for their children such as the purchase frequency, the expenses, and what kind of initiatives taken to manage broken and unused toys.
3. Malaysian parents' preferences in toy design for their children such as the significant level

of toy's criteria preferred in toy design and the type of play preferred for the children.

Phase 1: Assessing the Malaysian parents' acceptance of eco-friendly material and the preferences for toy design

The analysis of survey study was part of the design development process to inform design needs and enforce a defined design direction. During Phase 1, the survey results was analysed to get a knowledge of Malaysian parents' acceptance of eco-friendly material and the preferences for toy design. The results of the survey study are illustrated in the following figures.
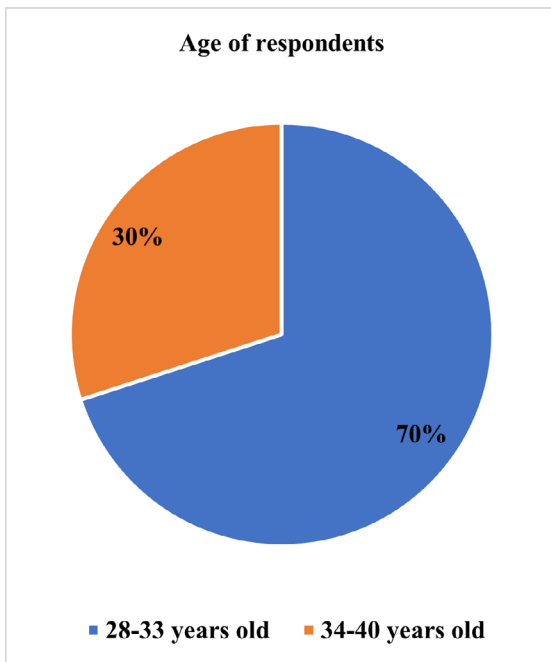
» **Figure 1:** *Age of respondents*

Figure 1 illustrate the age of respondents who took part in the survey. Based on the data, the majority 70% of respondents were made up from the age range of 28-33 years old, while only 30% of the respondents come from the age range of 34-40 years old.

Figure 2 illustrates the career status of respondents which indicates that the majority 45% of respondents are working in private sectors, while 15% of the respondents are working in government sectors. However, 40% of the respondents are unemployed.

Figure 3 shows the result of a survey in which respondents were asked if they were aware of any eco-friendly toys in their possession. Most Malaysian parents did not seem to be aware of any eco-friendly toys in their possession while only 7.32% of Malaysian parents did. It can therefore be inferred that

the level of awareness among Malaysian parents about the purchasing of eco-friendly toys is low.
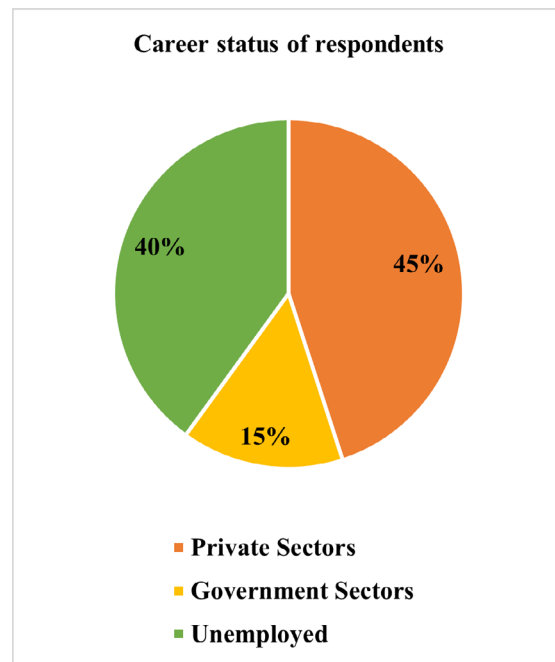
» **Figure 2:** *Career status of respondents*
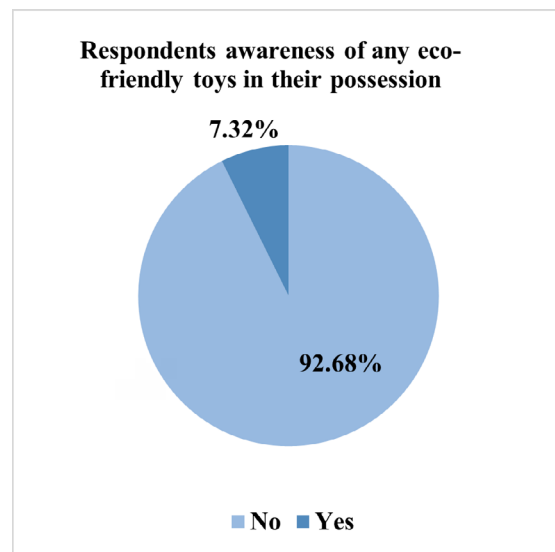
» **Figure 3:** *Respondents awareness of any eco-friendly toys in their possession*

Figure 4 shows the result of a survey in which respondents were asked about the willingness to buying eco-friendly toys for their children. Most Malaysian parents are willing to buy eco-friendly toys for their children, but 26.83% of them are not. Meanwhile, only a small minority (7.32%) are not sure of their decision. In conclusion, despite having a low awareness of any eco-friendly toys in their possession (Figure 1), there is still a glimmer of hope or potential market for eco-friendly toys in Malaysia.

Respondents willingness to buying eco-friendly toys

Yes ■ **No** ■ **Maybe**
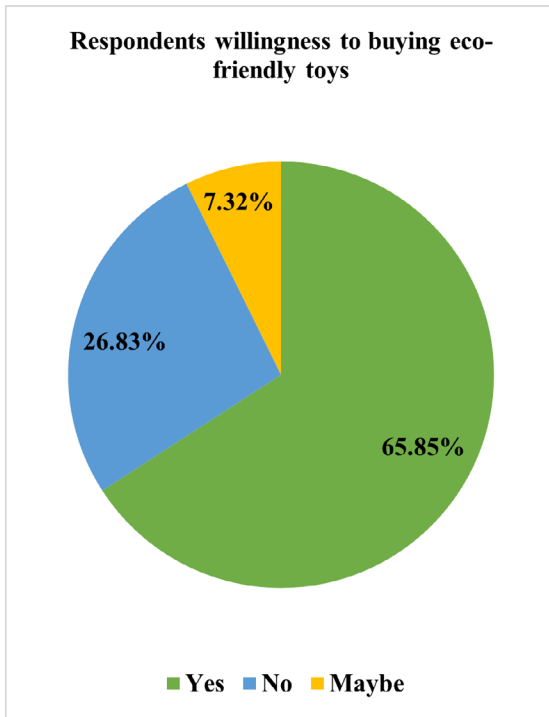
» **Figure 4:** *Respondents willingness to buying eco-friendly toys*

Frequencies of purchasing toys

■ **Every week**

■ **Every couple of week**

■ **Once a month**

■ **On special occasions**

■ **Never buy a toys**
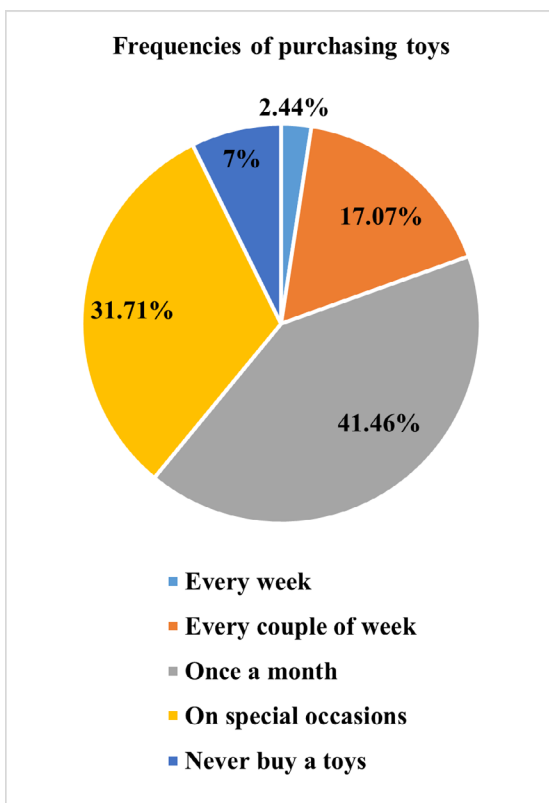
» **Figure 5:** *The frequencies of purchasing toys*

Figure 5 shows the result of a survey in which respondents were asked about their frequencies of buying toys for their children. Slightly less than half of the respondents buy toys for their child once a month

(41.46%). It also shows that slightly more than a third of the respondents buy toys for their children on special occasions (31.71%), followed by respondents who buy toys for their children in every couple of weeks (17.07%), and only 2.44% of respondents buy toys for their children every week. Meanwhile, another 7% of respondents never buy toys for their children. In conclusion, despite only 7% of Malaysian parents that never buy toys for their kids, it is clear that most of the Malaysian parents did despite the varying frequencies.

Figure 6 shows the result of a survey in which respondents were asked about the cost spend on toys. The respondents mostly spend more than Ringgit Malaysia (RM) 30 (53.66%) while 26.83% of the respondents anywhere between RM10 and RM20 on toys. Meanwhile, 12.20% of the respondents spend from RM21 to RM30, and a small minority (7.31%) spend less than RM10 on toys for their children. In conclusion, it is clear that Malaysian parents are mostly willing to spend more than RM30 on toys for their children. However, the second-largest set of parents spend in between RM10 to RM30 for their children's toys.

Cost spend on toys

■ **Less than RM10**   ■ **Rm10 - Rm20**

■ **Rm21 - Rm30**   ■ **More than Rm30**
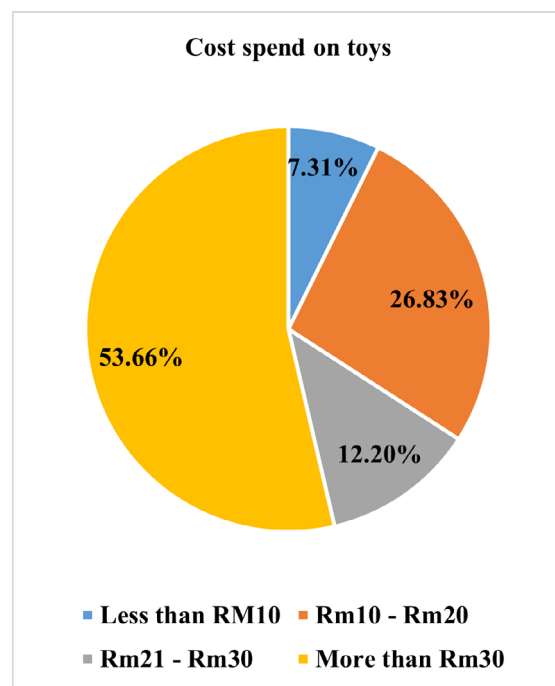
» **Figure 6:** *Cost spend on toys*

Figure 7 shows the result of a survey in which respondents were asked about the initiative taken for broken or unused toys in their possession. Most respondents throw broken or unused toys in the dustbin. However, it also shows that a sizeable portion of the respondents recycles or donate the broken or unused toys, with just 7.33% difference between the two. Only 2.44% of the respondents repair the broken or unused toys and continue to keep them as a collection. In conclusion, most of the Malaysian parents did not take

any initiative for the broken or unused toys by merely throwing them straightaway. This will lead to a situation where the broken or unused toys might end up at landfill and contribute towards severe land pollution.

Figure 8 shows the result of a survey in which respondents were asked about the significant level of toy's criteria to purchase. Most respondents agreed that safety is very significant to be considered in toys. At the same time, the second and the third-rated criteria are eco-friendly and value for money. Meanwhile, it also shows a various significant level from very significant to not significant in multiple toy-buying criteria such as durability, and appearance. In conclusion, despite having multiple significant levels in toy-buying criteria, safety, eco-friendly elements and value for money are the criteria to be considered. However, certain elements, such as durability and appearance, should be considered too.

Figure 9 shows the result of a survey in which respondents were asked about preferred play criteria for their children. Most respondents preferred creativity, while electronic and imaginative was rated as the second and the third preferred play criteria for their children. Meanwhile, it also shows various preferred percentage on different criteria such as educational, social, and manipulative. In conclusion, despite having a various preferred percentage on different criteria, creativity elements are paramount to be considered as the main play criterion.
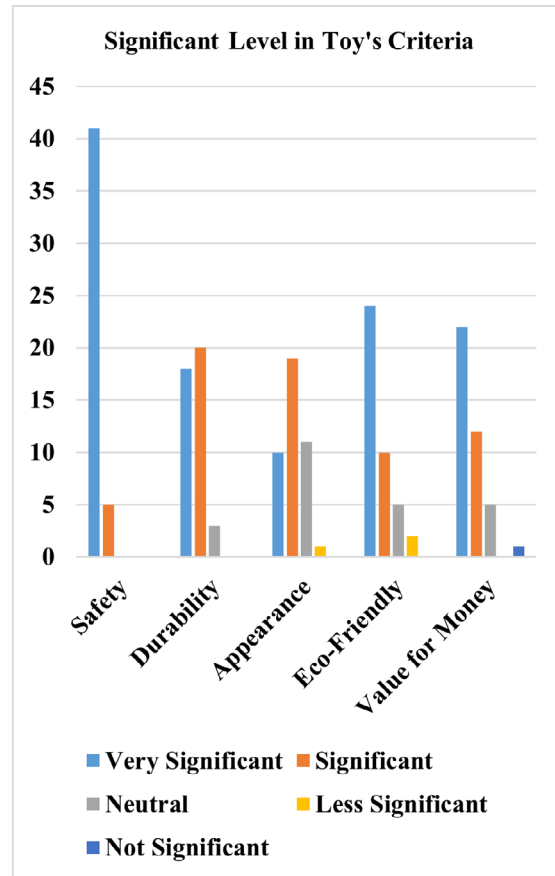
» **Figure 8:** *Significant level in toy's criteria*

Throughout the analysis of the survey, our study found that Malaysian parents did not seem to be aware of any eco-friendly toys in the possession, but they are open to the idea of buying eco-friendly toys for their children. Our study also found that Malaysian parents frequently spend on toys for their children, particularly on special occasions where the safety criteria in toys were highly considered by Malaysian parents, followed by the element of eco-friendly and the value for money. Despite having various elements in toys such as manipulative, educational, and social, creativity element in toys is highly preferred by most Malaysian parents.

These preferences are significance as a design thinking perimeter and guideline for designers to create an innovative eco-friendly toy design concept based on Malaysian parent's preferences in purchasing toys for their children. On the contrary, we also found that there is a lack of skills in handling broken or unused toys among the Malaysian parents where a broken and unused toy were simply throwed in the dustbin instead of repair, donate, recycle or keep them as a collection. This may lead to a situation where the broken or unused toys might end up at a landfill.

As global plastic dumping increased, it is now a drain in the Arctic Ocean ice for microplastics. It can remain for hundreds of years in the marine environment.

Play criteria preferred by Repondents' children

- ■ **Imaginative (e.g Barbie, Action Figure)**
- ■ **Manipulative (e.g. Puzzle, Maze)**
- ■ **Creativity (e.g. Lego, Playdoh, Building Blocks)**
- ■ **Social (e.g. Monopoly, Tea Set)**
- ■ **Educational (e.g. Rubric Cube, Chess)**
- ■ **Electronic (e.g. Robotic, Toy Car)**
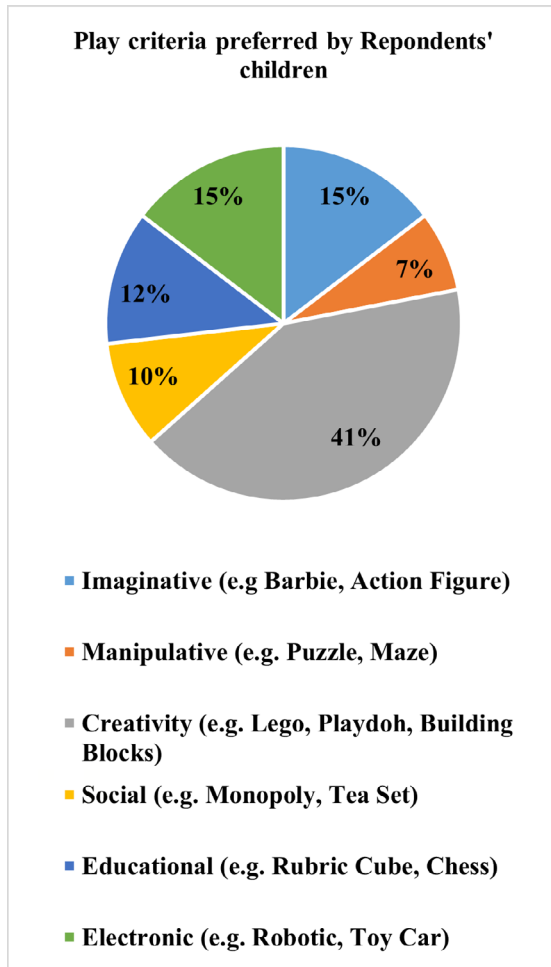
» **Figure 9:** *Play criteria preferred for respondents' children*

The understanding of Malaysian parents' acceptance of eco-friendly material and the preferences for toy design through the survey study help to determine the design knowledge that may be improved further in the toy design process. As a result, the elements of solutions were developed based on the summary of the survey study (see Table 1).

Table 1

The description elements of solutions

Elements of solutions	Descriptions
Using biodegradable material in toy design	Components of a material that is safe, regulated degradable, miscible, broadly reusable, and cost effective for a life cycle of the toys.

Phase 2: Generating design ideations

Prior to this, in Phase 1, the elements of solutions were developed as a result of survey study. Meanwhile in Phase 2, the elements of solutions aid in the brainstorming process to provide the design criteria for the toy design (see Table 2).

Table 2

The description of design criteria

Design Criteria	Descriptions
Interchangeable design	Stacking, slotting, and hooking the toy body parts to express creativity and imagination.
Emotional design	The interchangeable body parts activate the touch sensor to change the robot's 'emotion'.
Children's-inspired colour and shape	Invoke the interactive and appealing senses.
Eco-friendly material	PCL is safe, regulated degradable, miscible, broadly reusable, and cost effective for a life cycle of the toys.

Through the concept of interchangeable design, the toy design will incorporate imaginative and interactive elements. Through interactive activities like stacking, slotting, and hooking the toy body parts, it is envisioned that potential users will be able to express their creativity and imagination. A minimalist interface and touch sensor technology will also be incorporated into the toy design, giving potential users an emotional interactivity. The touch sensor is expected to be activated by the interchangeable body parts, changing and displaying the robot's 'emotions' through the installed interface. Additionally, to increase positive feelings in potential users and make the design form and interface more appealing, children's-inspired colour and shape will be employed in the design. The colour of the child-inspired design form and interface is meant to appeal to the user's visual sense and make the design look appealing and entertaining. As a safe, quality, flexible, and environmentally friendly material for design production, we have also proposed using PCL.

Phase 2 saw the initial implementation of the mood board design concept (Figure 10). Based on the design objectives, a mood board was created as a visual reference. The visual guideline utilised in this study was made using forms, shapes, colours, and interactive elements inspired by children. Based on the results of the survey study, these visual guidelines aid the research team in selecting the optimum design direction.

The design ideation process was begun with a sketching activity (Figure 11), which was based on the design concept of the mood board.

The aesthetic contour of the toy design was developed during the course of the process using elements produced from design criteria and visual guidelines in the mood board design idea.
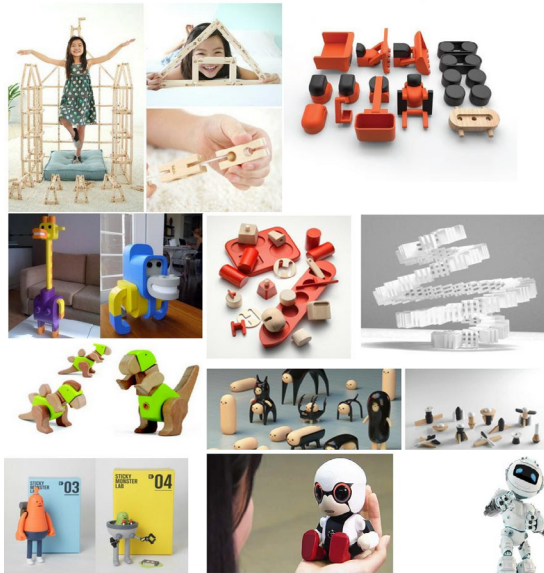
» **Figure 10:** *Design concept mood board*

» **Figure 11:** *Design ideations development*

At the end of Phase 2, the output of the sketching activity was transformed into a three-dimensional (3D) design using Autodesk Inventor 3D Design software (see Figure 12). During the process, the design's dimensions and aesthetic quality were raised in a realistic manner. Gaining a complete understanding of the toy design, including textures, colours, and product dimensions, is made easier by the 3D design outcome.

Phase 3: Model making process

Model making process was carried out in Phase 3. The creation of a model aids the research

team in determining the physical appearance of the product and its viability. 'Enders 3' 3D printer was used to print the model in three dimensions (based on 3D files generated in Phase 2).
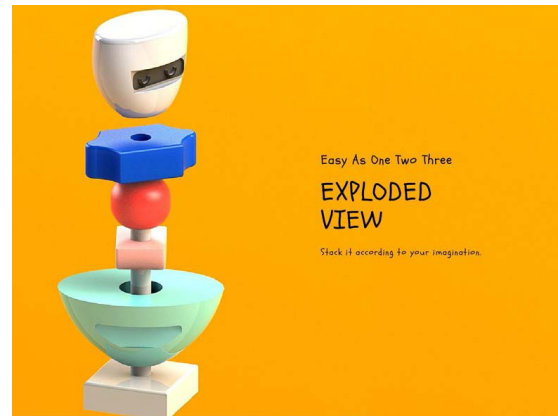
» **Figure 12:** *3D design visualization*

The Polycaprolactone (PCL) filament spool was loaded into the 3D printer and fed directly into the extrusion head assembly, which is where the printer's nozzle is located. The motor heats the printer's 0.4mm nozzle to the necessary temperature (around 200-210 °C), allowing it to melt, and then forces the filament through the nozzle. The chosen coordinates are followed by the extrusion nozzle, enabling the blackened material to solidify and renew on the plate. This cross-section printing cycle is carried out again, layer by layer, until the model is completely formed (see Figure 13).
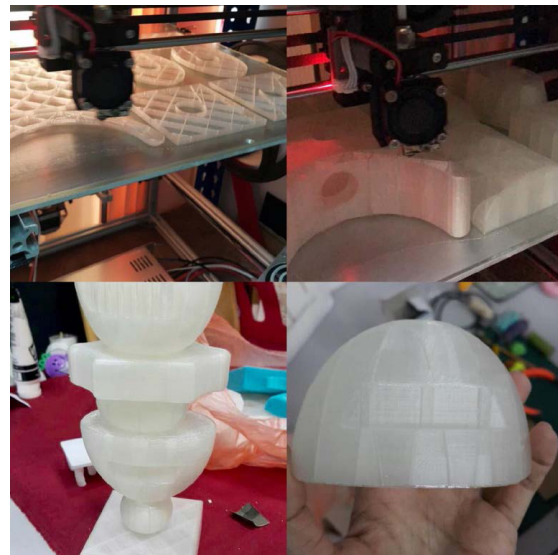
» **Figure 13:** *3D printing process*

Implementing an emotional aspect in design is one of the generated design criteria, as described in the study. The 1602 blue screen LCD monitor and Arduino Nano were therefore used to programme an interactive interaction. Conduit cables, a buzzer, a 1602 blue-screen

LCD display, and an Arduino Nano (breadboard-friendly board) were all included during the model-making process. Arduino boards are extensively used in robotics, embedded systems, automation, Internet of Things (IoT), and electrical applications. These boards were originally created for non-technical customers and students, but they are now often used in industrial applications. The connectivity with other controllers and computers can be set up on Arduino boards. The board is programmed by Arduino software called IDE, equally compatible with Windows, Linux or Ios operating system. Arduino Nano is a compact, easily dismantle, and completely recyclable (Komal Kumar, Vigneswari & Rogith, 2019). In this study, the robot's (toy) expression of emotions (programmed using Arduino software) is changed by the touch sensor and displayed on the 602 blue screen LCD Display.
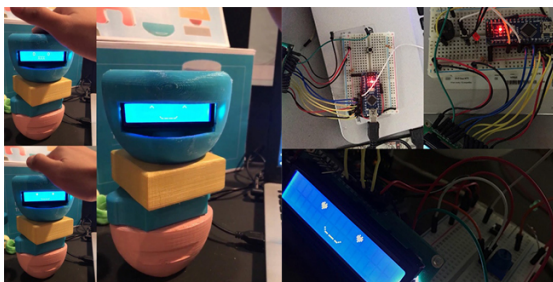
» **Figure 14:** *Components installation*

» **Figure 15:** *The final semi-working model*

To make sure that all design defects were fixed, continuous investigations into the technical components of the toy design were conducted throughout the process. By the time this phase was complete, a basic understanding of the constraints imposed by the toy design and how actual users would act, think, and feel while using the finished product had been attained (see Figure 14).

The final semi-working model is finished after the serial iteration phases, which involve numerous alterations to match the appropriate comfort of the user (see Figure 15 and Figure 16). The most important characteristics supporting the semi-working model include the aesthetic elements combining the current toy design style or fashion as well as the technological consideration showcasing how actual users would act, think, and feel when using the finished product.

» **Figure 16:** *Kids interaction with the semi-working model*

Discussion and conclusion

Ebee the Interchangeable Robot, built of PCL, was successfully created as an outcome of this research. Based on the study, PCL is a good option for the creation of the toy design due to its wide range of applications and intriguing properties including controlled degradability, miscibility, biocompatibility, and the ability to be made from monomers generated from renewable sources. These will let Malaysian parents to dispose of their broken or unused toys appropriately rather than having them landed in landfills and contribute to serious land pollution. Furthermore, based on the study, Malaysian parents are often prepared to spend more than RM30 on toys for their children, making PCL both

commercially viable and cost-effective. Meanwhile, the study also shows that after electronic, imaginative, educational, social, and manipulative play, most Malaysian parents favoured creativity as their children's preferred form of play. This makes Ebee as a potential product to encourage creative engagement and imaginative play through the concept of interchangeable body parts. Children may express their ingenuity and imagination by borderless stacking, slotting, and hooking the toy body parts. The manipulative and collaborative element embedded in the toy design will also encourage the positive learning. The aesthetic component of Ebee through the amalgamation of children's-inspired colour and shape also envisaged to invoke the interactive and appealing senses of the children. However, this study has a limitation in that full user testing and performance evaluation of the product are needed soon to further analyse the applicability of the proposed toy design. Ebee's effectiveness as an environmentally friendly toy design has to be further investigated.

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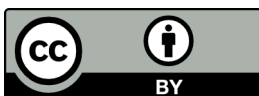
Masculinity in advertising: The power of verbal cue

ABSTRACT

The portrayal of men in print advertisements has been less attentive subject in comparison to woman depiction analysis, even though research on gender advertising has increased over the last decades. This paper examines the effectiveness of print advertisements in which the visual ad register was developed at the level of the "iconogram" of a muscular mesomorph. Comparing the findings of numerous studies which indicate less affective response towards the images of nudity of the same gender, a hypothesis was proposed: the effectiveness mediator of advertisements is the verbal cue of the advertisement when a universal quantifier of muscular mesomorph is being used. In the first study, we conducted the content analysis to target the most frequent representation of a man in advertisements for health and beauty products. The second study was designed to test the proposed hypothesis using photographs from International Affective Picture System database. The stimuli were in a form of advertisements designed for the purpose of research combining IAPS images and the verbal cue. The experiment included 100 male students aged 20 to 31. Overall, our findings confirm negative response to male pictures (ads without verbal cue) when the figure is not fully dressed. However, we discover that visual register significantly affects the increase self-reported positive valence ratings, in health and beauty ads for men when they are depicted as iconogram of muscular mesomorph. This study contributes to our understanding of how male consumers respond to same-sex imagery in print advertisements when there is not fully dressed muscular mesomorph depicted.

KEY WORDS

Advertising message, emotional response, muscular mesomorph, verbal register

Uroš Nedeljković[1] ⓘ
Irma Puškarević[2] ⓘ
Nace Pušnik[3] ⓘ

[1] University of Novi Sad, Faculty of Technical Sciences, Department of Graphic Engineering and Design, Novi Sad, Serbia
[2] Wichita State University, College of Fine Arts School of Art, Design and Creative Industries, Wichita, Kansas, United States
[3] University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Textiles, Graphic Arts and Design, Ljubljana, Slovenia

Corresponding author:
Uroš Nedeljković
e-mail:
urosned@uns.ac.rs

Introduction

According to the cultural theory, the images we are saturated with daily through the means of television, billboards, video games and movies, define us in many ways. The matter is that we do not just choose what we like or dislike but live under the influence of these images that shape our tastes, attitudes, and decisions. Therefore, the progression of male and female beauty ideals and stereotypes considerably results from propaganda messages. Research on gender in advertising has increased during last decades where most of the gender research focuses on gender roles. Specific interest has been given to role portrayal of women in advertisements, but also to the depiction of men and women together (Goffman 1979; Klassen, Jasper & Schwartz, 1993). Less attention has been given to the portrayal of men. However, definitions of the ideal men and prospects of modern masculinity are more than present in the literature. Stern (2003) outlines how the ideals of masculinity are portrayed over time and proposes a definition of the ideal male body type – muscular mesomorph. According to this descrip-

tion the iconogram of ideal man encodes an average, but well-proportioned build man, satisfied with his body when it depicts the ideal of power and gracefulness. Advertisers mostly rely on these descriptions and social norms when promoting health and beauty products. When reviewing beauty products, women mostly rely on each other's opinion, whereas men rely on advertisements (Nair & Pillai, 2007). However, it can be disputed whether this type of visual codification is the appropriate choice of the advertisers when we take into account the findings of numerous studies (Belch et al., 1982; Lang, Bradley & Cuthbert, 2008; Sciglimpaglia, Belch & Gain, 1979; Simpson, Horton & Brown, 1996) presenting male responses to be more favourable to female nudity and sexual behaviour, and less favourable to nudity of a man and vice versa. Although men's perception to men's beauty and body care has changed drastically in last decades, we can assume that heterosexual men are burdened with the notion of their own sexual orientation when asked to respond emotionally to male nudity. Accordingly, we consider the analysis of print ads for men's beauty products to be of great significance.

Theories of masculinity and representation of the ideal man

New proposals for definitions of masculinity, according to Seidler as cited by Stern (2003), led to crises of the contemporary meaning of the term which, at the same time, meant termination of monistic concept of masculinity and femininity. We can no longer find one single apprehension of the masculinity, yet there are a great number of various definitions of the term. After the studies of male sexuality have reached considerable amount of success, the male image had changed, leading to redefinition of "What does it mean to be a man?" which could no longer be described as "the social norm" (Stern, 2003). Many will readily accept the notion that modern masculinity is pluralistic and dependent on feminist discourse (Clatterbaugh 2018; Seidler, 1997; Stern, 2003). However, the definition of masculinity is not restricted to that which,h is opposed to femininity but also spans to the opposite notion to male countertypes. Until now, considered a symbol of intellectual and moral value, the male ideal of beauty has been signified by numerous stereotypes (superheroes and the emotional macho) with the characteristics of superiority, harmony, well considered movement and temperance in contrast to countertypes whose physical unattractiveness is equated with their inner deformity (Stern, 2003). In the historic context, developed aesthetic criterion of the ideal male differed from unopened outsider whose physical deformity was considered an external expression of inner illness and moral defect (Mosse, 1998). Stern further explains that a new sort

of man emerged in the middle of the 20th century, the so-called third gender, with his disharmony of the body due to the long hair, skinny appearance, and lack of physique he represented an opposition to the tidiness and symmetry of the established masculinity norm. This led to a belief that the male ideal was defined by behavior and appearance that was not only different from that of a woman, but from all other countertypes.

As the definition of masculinity changed, also the concept of beauty changed, understandably since the concept of beauty is regarded as relative term dependent on specific social group categorizations. Interestingly, beauty was always considered a property of women and in this way determined through the perception and the desire of a man. Perfecting physical beauty through the application of different products mostly connotes feminine activity. As of recent it has become preoccupation of men as well. It is assumed that the number of men using cosmetic products increases from day to day. Iida (2005) argues that the shift in male perception of masculine beauty is often described as the "feminization of masculinity" which is a logical consequence of the "feminization of society" in the modern age where human bodies have been transformed into visible, representative objects. She proposes that this trend among young people in Japan stems from a desire to get closer to girls since this way their gender identity becomes ambiguous and provisory. In conclusion modern magazines, beauty industries and media within the pop-culture cooperate mutually to create a very sensitive aesthetic awareness in the young male.

Images of the ideal man in advertising

A manly man, according to cultural heritage criteria, should be powerful, strong, efficient, and destructive when needed. The ideal manly body type is "muscular mesomorph", a man with average, yet proportional figure, unlike ectomorph who is thin, or endomorph who is oblique (Mishkind et al., 1986). Stern (2003) describes the features of the ideal man which are by triangular aesthetic – well-built chest, defined arm muscles, and wide shoulders that narrow around the waist. Furthermore, there are features of a physical condition such as high level of energy, flat stomach, stamina, and height/weight in proportion. The attractiveness of the face is very important as well. Therefore, ideal man must have clean skin, healthy hair, sculpted nose, and inconspicuous ears. Altogether, the ideal man is satisfied with his body when it reflects the ideal of power, grace, and potency.

The men are very much aware of their real appearance and the ideal one, so they feel unsatisfied if the two do not match. Considering that men work hard

to lose extensive weight and signs of aging, to ideally shape their body, numerous products can be found in the market for bridging the gap between the real and the ideal body. Stressing the importance of dieting and fitness work out led to the popularization of health clubs, low-fat products, and personal trainers. In 1990s aesthetic surgery has been accepted as transformation means from the real to the ideal state.

Advertising has a great influence on how men and women see themselves in terms of the beauty ideal. Therefore, emission of messages and images of the ideal male body are set in the context related to a need for controlling and improving one's body. In such circumstances, a lot of men are dissatisfied with the way they look (Mishkind et al., 1986) and this situation is recognized as "gold mine for consumerism" (Bordo, 1999). Regardless of the findings from numerous studies which confirm that there is negative affective response towards the same-sex imagery (Belch et al., 1982; Lang, Bradley & Cuthbert, 2008; Sciglimpaglia, Belch & Gain, 1979; Simpson, Horton & Brown, 1996) the "iconogram" of muscular mesomorph is still used intensively in ads for men's health and beauty products. In this light, our intention was to examine if this iconography of ideal man imposed by advertisers is received by male consumers in a positive light.

Research question

The purpose of this research was to determine in what way advertisements coded with iconogram of muscular mesomorph for men's health and beauty products influence positive valence in the subject's emotional response. According to research findings on consumer response in advertisements the emotional response is the mediator of the attitude toward the brand (Holbrook and Batra, 1987) as well as a powerful predictor of intention (Morris et al., 2002). The question arises whether this type of visual codification is a smart choice from the advertisers' part, considering that men emotionally react more positive to female nudity images and sexual behavior and less positive to male nudity images. Although male perception of men's beauty and health care has changed drastically over the past decades, we can assume that heterosexual men are obsessed with their own sexual orientation when asked to rate their emotions toward male nudity (Etcoff, 2011). A study by Mishkind et al. (1986) shows that male participants are more and more concerned about their physical appearance and the ways to improve it.

According to Eco's (1973) explanation of the levels of the visual register, we can discuss one particular visual figure at the tropological level found to be favorite among advertisers. When describing antonomasy, Eco regards that everything preceding a logical sign, which is called

the universal quantifier, points to the symbol "x" that is interpreted as "all x". This mechanism, relevant in advertising communication, is based on psychological processes of identification where an individual message is interpreted as a universal one. Accordingly, the iconogram of a muscular mesomorph displayed in advertisements is a representative of all males. It imposes a norm that every man must achieve in order to, as the normative definition of masculinity explains (Connell, 2005), identify himself with the ideal imagery that represents the social norm. In addition, Lang, Bradley & Cuthbert (2008) have developed IAPS database providing ratings of affect for color photographs that are emotionally-evocative. While analyzing IASP mean values of ratings for images portraying "muscular mesomorph" it was noted that the emotional response of the male participants is less favorable than that of female participants, and vice versa when female sexuality was depicted. Accordingly, the present material was used as the basis for our experimentation.

Study 1

The aim of the study 1 is to identify the most frequent representation in advertisements for male health and beauty products. More specifically, we investigate if there is frequent semiotic canon about muscular mesomorph iconogram as proposed by Stern (2003).

Method

Identification of the male model representation in advertisements for male health and beauty products was performed with content analysis. After the unit of content had been defined the process of content identification was divided in two stages. The first stage started by choosing the magazines where products for men's health and beauty were advertised. After sampling some of the most frequently found men's magazines at the time of the research, six magazines were chosen: Best Man, CKM, Esquire, GQ Maxim, Men's Health, and Men's Journal. Following the magazine selection, the first stage also included the work of two coders. Two trained judges, blind to the treatment, independently scored ads on the perceivable sexuality upon sampling the ads for men's health and beauty products. After the coder's identification, the authors looked at all the ads. Overall, out of 1155 total ads 150 (12,9%) were judged as advertisements for men's health and beauty products. Duplicated ads were counted only once for the purposes of analysis. The second stage involved coding for sexual themes i.e., appeals. Narrative scenes in ads with the sexual appeal, created to offer an assurance for consumers to regard, may include different interpretations such as sexual attractiveness, sexual behavior or sex-esteem (Reichert, 2002). Based on these interpretations, the judges independently coded ads with sexual appeal according to three variables: the main subject of the ad (human

behavior or product), the behavioral patterns of the male model, and the way the male model is depicted.

Results and discussion

Correlation between the unit of content and advertised themes showed that ads, when analyzed according to the main subject, classify in three distinct layouts. In the first layout the dominant subject is a man (54, 67%); the second layout depicts the product only (11,33%); and in the third layout these two subjects coexist (34%). However, apart from the depiction of product the male model is also paired with a female model, friends, or members of the family. Analyzing ads according to behavioral patterns we concentrated on the way the models in ads are attracting the viewer's attention. The most prominent behavioral pattern was found to be through nudity (35,33%). Also, social acceptance (22,67%), famous people (10,67%), emotional transfer (2,67%), and the stand-alone product (7,335) were present. According to the third variable ads were coded with it was evident that male models can be represented in the surroundings such as nature, modern apartment, or an office, place they use for sports or body care (fitness center, playground, bathroom) which connotes that he is independent, active, and carefree. Sometimes he was accompanied by a female partner, friend, or family member. Therefore, coding values for this variable gave these results: a man standing on its own (82,44%); a female model next to the main male subject (12,89%); a man represented with family members (3,05%); a man represented with friends (1,53%). The results of the first content analysis provided the basis for the second analysis. It was determined that the most frequent portrayal of a male model in ads for health and beauty was independent (stand-alone), nude or semi-nude male. Another set of coders scored 31 ads on three variables: portrait of a man with torso (64,52%), portrait of a man (22,58%), and the whole male figure (12,9%). For the purposes of the second study, targeted photographs were the ones that had more than 20% appearance in ads i.e., the stimulus for the second study was developed based on a photograph portraying independent, nude man and additional photograph of man's torso added to the content.

Study 2

Some considerations were considered in selecting visual and verbal material to be featured in the target advertisements. One such consideration was attended with content analysis which provided necessary material for the pictorial part of the ad. Considerations for the verbal part were made by sampling figurative and non-figurative ad copies. Rhetorical figures have been found to be frequent elements in print advertisements (Deighton, 1985; Delbaere, McQuarrie & Philips, 2011; Huhmann & Albinsson, 2010; Kim, Baek & Choi, 2012; Leigh, 1994; Myzoughi & Abdelhak, 2011) which resulted in numerous testing of rhetorical perspectives leaving behind elaborative theoretical background (Gkiouzepas & Hogg, 2011; McQuarrie & Mick, 1996; McQuarrie & Mick, 1999; McQuarrie & Mick 2003). McQuarrie and Mick (1996) underline that "any particular figurative expression can deviate to a greater or lesser extent…" supporting their argument firstly, by developing taxonomy of rhetorical figures in advertising and describing how figuration can be integrated relating it to common consumer responses, and

Table 1

Male model depictions in magazine advertisements: indicators and values on three established variables

Variables	Values	Indicators
The main subject of the ad	Dominance of a man	Business efficiency, elegancy, sports activities, grooming
	Dominance of a product	Water, workspace, product with verbal message
	Division of domination	Touching, hugging, strength as courage, casualness, seduction
The behavioral patterns of the male model	Nudity	Parts of the body without clothes
	Integration into society (Success, accaptance)	Cars, modern environment (flats, offices), classic business look (clothing)
	Use of rhetorical figures	Surreal scenes
	Famous individuals who confirm the quality of the product	Actors, athletes
	The glorification of the product	Exaggeration
	Emotional transfer	Parent-child relationship
The way the male model is depicted	Depiction of single man	Parts of the body without clothes, activities in the nature, grooming
	Depiciton of a man with a woman	Parts of the body without clothes, activities, seduction
	Depiction of a man with family	Children, parents
	Depiction of a man with friends	Hanging out with friends in the nature, hanging out with friends in a café

secondly, by offering what are beneficial effects of artful deviation regarding the persuasiveness of the printed ad. Another study by the same authors (McQuarrie & Mick, 1999) investigates application of rhetorical figures parallel to those found in language on both verbal and visual part of advertisement varying the level of motivation to process the ad. When testing the incidental-exposure condition rhetorical figures highly influenced positive response, enhancing ad recall and ad attitudes. The importance of their findings also lies in presenting that visual figures have a greater impact than verbal figures under the same condition of incidental exposure. However, pictorial part of advertisements is greatly supported by verbal cue since visual signs can be ambiguous and mislead inferences (Eco, 1973). Therefore, a pretest was conducted using 50 male students to assess emotional response towards four ad verbal cues enhanced by rhetorical figure and four that were non-figurative. Verbal cues were rated on three-dimension SAM scale (will be explained later in text). Independent samples t-test was used for the analysis. Means on arousal dimension (figurative: M = 5.93, SD = 1.58; non-figurative: M = 5.61, SD =1.42; p < .05) indicate participants did experience emotional variability along different figuration levels. Dimensions pleasure and dominance were not significant.

After conducting content analyses, it was disclosed that advertisements for men's products and use visual convention of the male model where most images depicted a man by himself (82,4%) and less when he is accompanied by a woman, family or friends. Also, the analysis presented that most popular way of getting the viewers' attention was through male sensuality and seductiveness. In the research of Simpson, Horton & Brown (1996), the effects of male dress level were examined. Their findings indicate that female respondents react much more favorably to ads enhanced by increasing level of male nudity, whereas male respondents react favorably to ads that contain no model and the full-dress ad. Male respondents accepted nudity only when there was a strong logical connection between model nudity and the product. Based on these findings we can conclude that favorability to male nudity in ads depends on the picture-product connection which, alongside the data obtained from prior research and content analysis in the first study, led us to construct the research question: is the emotional response of men to "muscular mesomorph" dependent on the context of the image alone or on the context of the advertised message? The advertised message as a whole communicates through two interconnected levels, the visual and the verbal register. As it was discussed by Eco (1973) the chief function of the verbal register is to determine the message mainly because the visual components alone often give the impression of being ambiguous. Based on these questions and assumptions the main hypothesis was presumed:

H1: The emotional response of men towards print advertisements will be more positive when the iconogram of muscular mesomorph is complemented with verbal register i.e., when put in the function of advertised message.

Method

Stimulus development

Considering that the computer technology enables manipulation of graphic elements between stimuli treatment, the stimuli used were ads designed exclusively for the purposes of this research. The development of the ads utilized computer graphic software to produce the final visual solution. The ads were designed by adding a verbal message and a fictional logotype of the brand (consisting of only one word) to the IAPS photos (#4525, #4574). The verbal message for Ad#1 read: A day without a smile is a day without the sunshine. The fictional product advertised here was Unforgivable, Men's Cosmetics. The verbal message for Ad#2 read: It's not a luxury to feel good—it's a necessity! The fictional product advertised here was Clean, Men's Cosmetics. For each of the ads within the experiment, the same font was used, a uniform logotype and similar positioning of verbal elements by which any typography induced variability was excluded (Figure 1).

» **Figure 1:** *An example of stimuli design used in the experiment* [1]

[1] In accordance with the IAPS rules, the researchers are not allowed to publish the photographs from this date base in any print format. Therefore, we used pictures with similar content and the stimuli that resembles the ones we used in the experiment.

The third element of the ad was the logotype of the brand product whose function was to define the verbal message more accurately. All logotypes were designed with the same sans serif font, set in white color and capital letters and framed with a same white line. The selected brand products fall into a group of beauty and health products for men and are unheard of in the Serbian and regional market.

Procedure

The experiment was designed to test the hypothesis that addresses the affective response of consumers to male figures in advertising. The experiment was conducted in the university laboratory where, upon their arrival, the participants were randomly assigned to one of the two treatments. They were presented with an electronic booklet containing eight print ads in the experimental group, and eight images and rating scales in the control group. The print ads/images were randomly placed, two target ads and six, filler ads, i.e., two target and six filler images. Firstly, the participants in the control group rated the images, and the participants in the experimental group rated the print ads. They were given six seconds for this task. After viewing each image, the participants were asked to rate their emotions on a three-dimension SAM scale—pleasure, arousal, and domination. Each dimension had nine fields, and the participants were asked to mark the field that represented their emotions the best at that moment. Participants had 15 seconds for the rating process. For each of the ads within the experiment the same font was used, a uniform logotype and similar positioning of verbal elements by which any typography induced variability was excluded.

Participants

In the experiment 100 male students participated with age range 20-31 years old, with an average age of 24,3 years. The participants were students from three universities from the University of Novi Sad, University of Nis and the University of Belgrade. The students were chosen for this experiment since they are the target group of such advertisements, and we chose them as participants because we believed that their response would be most relevant for our research.

Variables

The dependent variables used were PAD (pleasure, arousal, and dominance) values of SAM, a graphic representation of the three fundamental emotional dimensions. Each dimension groups some factors that connect existing feeling states to other indices of emotional response. These values were chosen because they are one of the most accepted measures of the emotional response when it comes to self-assessment (Bradley & Lang, 1994; Morris et al., 2002).

Results and discussion

Data analysis was performed using descriptive statistics, independent samples t-test, paired samples t-test, and ANOVA. Age factor did not appear to have significantly affected perceptions of male models in stimuli material. This factor will be excluded from further analysis. The data analysis of participant's emotional response was performed through t-test for independent samples. The values acquired based on self-assessment emotion measurement for target ads in the control group were compared to the IAPS responses.

Table 2
The difference between experimental and control groups—pleasure

Group						SD	
Pleasure, stimuli 1	Experimental (viewed ads)	0	,5400	652	2,36	,707	091
	Control (viewed photographs)	0	,8000	831	1,94		
Pleasure, stimuli 2	Experimental (viewed ads)	0	,3200	561	1,69	,197	000
	Control (viewed photographs)	0	,2400	059	1,66		

Table 3
The difference between experimental and control groups—arousal

Group						SD	
Arousal, stimuli 1	Experimental (viewed ads)	0	,0400	156	2,38	,863	065
	Control (viewed photographs)	0	,1600	181	2,34		
Arousal, stimuli 2	Experimental (viewed ads)	0	,5200	196	1,98	,772	000
	Control (viewed photographs)	0	,2200	296	2,00		

Table 4

The difference between experimental and control groups—dominance

	Group						SD	
Dominance, stimuli 1	Experimental (viewed ads)	0	,1000	463	2,22	,145		000
	Control (viewed photographs)	0	,3400	636	2,01			
Dominance, stimuli 2	Experimental (viewed ads)	0	,5800	092	2,00	,194		000
	Control (viewed photographs)	0	,1400	791	1,93			

Using independent samples t-test, data between experimental and control group was analyzed on eight images and eight print ads for the three dimensions. For the pleasure dimensions, results indicate that there is a significant difference in participant's response within experimental (M = 6.54, SD = 2.37) and control group (M = 5.80, SD = 1.95) for stimuli 1, and within experimental (M = 7.32, SD = 1.69) and control group (M = 5.24, SD = 1.66) for stimuli 2 (Table 2).

The results of the second dimension of arousal also indicate that there is a significant difference in participant's response within experimental (M = 5.04, SD = 2.38) and control group (M = 4.16, SD = 2.34) for stimuli 1, and within experimental (M = 5.52, SD = 1.98) and control group (M = 3.22, SD = 2.00) for stimuli 2 (Table 3). There is noticeably smaller difference for the stimuli 1 (p<.1) whereas the difference is much more significant for the stimuli 2 (p<.000). Results of control groups (negative valence) were expected considering the IAPS stimuli are standardized based on ratings of pleasure and arousal. On the other hand, associative activation was positively charged when participants viewed stimuli with verbal cue i.e., male model (muscular mesomorph) was received with pleasant feelings. The third dimension of dominance for both stimuli shows more positive response (stimuli 1 p<.000; stimuli 2 p<.000) in favor of the print ads (stimuli 1: experimental group M = 6.10, SD = 2.22, control group M = 4.34, SD = 2.01; stimuli 2: experimental group M = 6.58, SD = 2.00, control group M = 4.14, SD = 1.93). Dominance ratings are highly correlated with ratings of hedonic valence, and based on our results, we can conclude that significant difference on this dimension is present due to increased interest in the advertised stimuli. Here, the viewer rates stimuli highly when it starts to dominate over him i.e., the viewer is a factor in communication. These results can be explained by the change of context the picture of muscular mesomorph is set in. When asked to respond to associative activation of the image, participants had negative ratings. Once the picture was determined with verbal cue and the viewer became an active participant in the communication, he reacted more favorably to presented male model.

Considering that the codes in advertisements function through two distinct registers, verbal and visual, we analyzed the visual register without the verbal one to achieve valid results and test our hypothesis. Later we analyzed the combination of the two registers within one ad. We determined that there is the significant statistical difference between the values of the control group that represents emotional response to IAPS photographs and the values of the emotional response to the ads (stimuli with the verbal message). These results imply verbal message leads to a significant increment of the emotional rating. This notion confirms the alternative hypothesis. We can see this when comparing values of all three dimensions. The verbal cue determines the meaning of the overall message by increasing its effectiveness and consequently changing the attitudes of the participants toward the message; it eliminates the ambiguity of the message by describing the product more clearly and establishing the connection between the viewer (customer) and the ad. The message is being decoded on a personal level that connects it directly to the viewer (customer).

Interpretation of the ad message, among other things, depends on the way it has been encoded and on the target group it has been encoded for. Through the research with experiments, testing its effectiveness, we discovered that these messages influence a positive emotional response of the participants; more positive than neutral for pleasure dimension; neutral instead of negative for arousal dimension; more positive than neutral for dominance dimension. The verbal register determines the message placing it in the context of the media message the subject is accustomed to be guided towards. That way, the iconogram of a muscular mesomorph gains an antonomastic value by which males identify themselves "all of you who are MM" or "all of you who would like to be MM". Therefore, the social norm of masculinity despite the pluralistic interpretation of masculinity is imposed today by the advertisers as the muscular mesomorph, a man full of confidence who uses beauty products.

Conclusion

This study examines the effectiveness of male imagery portraying the iconogram of muscular mesomorph on consumer affective response on two levels of interest: when images are viewed without complementary verbal

cue, and when images are determined by verbal cue. Results indicate there is the significant difference in responses to these two conditions. Male respondents reacted much more favorably to images depicting muscular mesomorph when they were complemented with a verbal cue. Our hypothesis was confirmed giving support to prevailing practice of advertisers to use muscular mesomorph in health and beauty products advertising context. This finding is significant because emotional response dominates over cognition (Morris et al., 2002) which represents more of the variance in conative attitude. Benefits of a figurative verbal cue are also presented in the pre-phase of the second study. The artful deviation is know to enhance persuasiveness, and in the case of merging rhetorical figures in ad copy with male nudity in the pictorial part, participants responded with higher emotional rating. Consequently, this study provides implications to advertisers concerning the use of pictorial conventions in advertisements targeting males. We propose that advertisers may use newly imposed norms of masculinity, emphasizing the necessity to embody the self-representation in the form of a muscular mesomorph. However, this study had limitation in the selection of advertising context for testing. Advertisements for products such as shoes, cars, denim, etc. were not included. Future research should attempt to examine male response to the image of muscular mesomorph when depicted in advertisements for products not connected to health and beauty (body care). In the process of developing our first study, it was noted that disputed iconography was present in, for example, sunglasses and denim advertising. It is possible that favorability toward nude male body will be low in this case since there is small congruency with male dress level and advertised product (Simpson, Horton & Brown, 1996). Furthermore, future studies should consider testing different levels of verbal figuration alongside the semiotic analysis of male portrayal. We base this proposal on previous research of verbal register in advertisements which mostly focuses on the rhetorical figures (schemes and tropes) and less on the language functions (Jakobson, 1960) which through associated factors relate to an effective verbal communication.

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Using artificial intelligence for predictive eye-tracking analysis to evaluate photographs

ABSTRACT

The goal of the study was to determine how close the eye-tracking results predicted by the AI model are to actual measurements and whether they can be used in scientific research or in real business cases. The study was based on a carefully prepared photo database of 30 photos of varying complexity and colour. The photos were shown to 110 participants (age and gender evenly distributed), and eye-tracking device (Tobii X120) was used to measure how the photos were viewed. In comparison, the same photos were tested using an AI-based application (Expoze.io). The final results show the comparison between the heatmaps and transparent gaze visualisations of the collected data with the two used measurement methods. Suggestions are made in which cases and how the two described methods should be used.

Jure Ahtik

University of Ljubljana,
Faculty of Natural Sciences and
Engineering, Ljubljana, Slovenia

Corresponding author:
Jure Ahtik
e-mail: jure.ahtik@ntf.uni-lj.si

Introduction

When a photograph is going to be published, three different aspects are considered: the technical, the artistic and the content/meaning. The technical aspect is usually not a problem nowadays. Digital cameras are now so advanced that an experienced photographer can be confident that exposure, sharpness, colour reproduction etc. are almost always correct, even under the most difficult conditions. The second aspect is an understanding of artistic variables, such as composition, which usually comes with experience. Both the technical and artistic aspects should be at a high level of quality when it comes to professional photography that can be considered for publication. The final decision on what to publish is based in most cases on the third aspect – content/meaning.

Photography is mainly used for communication purposes and has become one of the main sources of information with more than 54,000 photos taken each second (Phototutorial, 2022). An author or editor wants to transfer the information to the end user, and confidence if a

photograph can do this is critical. Deciding which photo will best convey the message is the biggest part of the decision-making process and predicting it can sometimes be difficult. It is important to understand which elements of the photo the user spends the most time on when viewing it. If the user is distracted by secondary elements, the main message may not be transferred. In the past, many different subjective and objective methods have been used to determine the communication value of photographs, one of which is eye-tracking (Ahtik & Starešinič, 2017; Molina et al., 2018; Mañas-Viniegra, Veloso & Cuesta, 2019; Mitu & Bota, 2021; Loceye, 2022). In order to conduct such a study, many resources are needed: the main difficulties are the number of people we need to test in order to get a representative result and the time needed for the measurements. The procedure can be also expensive. In scientific research, all this is not a problem in most cases. But if you are trying to conduct such a study in an advertising agency or a graphic design studio, for example, the available resources are in most cases unfavourable. The industry needs the results at the moment when new information/

products are created, and the use of reliable eye-tracking measurements is not possible in most cases.

In recent years, artificial intelligence (AI) has proven to be useful in many fields, and photography is no exception (Kong et al., 2022). There are well-known and commonly used cases of computational photography and image recognition and we can even see some algorithms capable of generating a photographic-looking images based on just a few keywords (OpenAI, 2022; Dechterenko & Lukavsky, 2016). There are also new approaches to analysing the perception of photos based on content, composition, and appearance (Müller, Kappas & Olk, 2012). To speed up the photo evaluation process and make it more available, machine learning methods based on neural networks trained by a large number of eye-tracking measurements have been introduced. We call this method *predictive eye-tracking* (Expoze.io, 2022).

The aim of the study was to determine whether traditional eye-tracking measurements could be replaced by predictive eye-tracking for assessing the communication value and visual attention of photographs. The study involved selecting an image database, conducting eye-tracking measurements, performing predictive eye-tracking calculations, comparing data collected by both methods, and final data analysis.

Materials and methods

Materials

The study was conducted using the novel image database first introduced in 2017 (Ahtik, Muck & Starešinič, 2017; Ahtik & Starešinič, 2017). The database consists of 30 reference photographs (Figure 1), which differ mainly in content complexity and colour variety. In addition, the photo database also contains 300 different modified images (10 per reference) for image quality assessment, which were not used in this study. Photographs were carefully selected for the novel image database to examine the impact of image complexity on the way we perceive them (see Figure 2 for details overview).
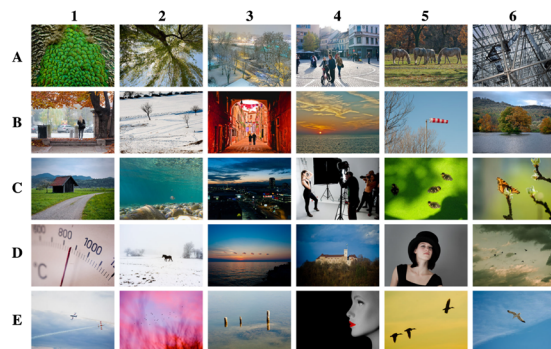

» **Figure 1:** *Image database*

Photos are ranked in order of highest complexity (Figure 2: A1) to lowest complexity (Figure 2: E6). The range of overall detail coverage (complexity), was calculated as the average pixel value of the images with exposed edges as shown in Figure 2, is from 99 % (Figure 2: A1) to 22 % (Figure 2: E6), with an average of 77 %. This is significantly better than the image database most commonly used in other research – TID2008 (Ponomarenko et al., 2009).
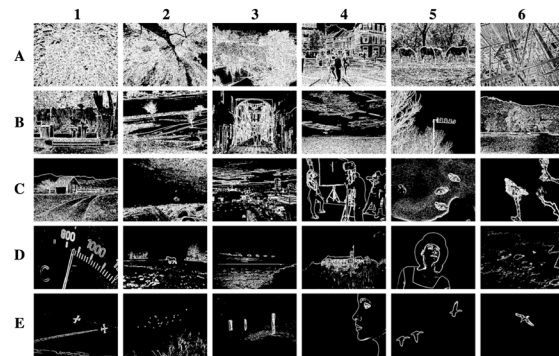
» **Figure 2:** *Image database with exposed detail complexity.*

Eye-tracking

A Tobii X120 eye tracker, a HP ZR24W LCD monitor, a PC, a controlled dark room environment, and Tobii Studio 3.4.4 software were used to perform the eye-tracking measurements. The photographs were displayed in the centre of a black screen with a fixed resolution of 840 × 630 px, and each observer had the same sitting position and viewing angle of the photographs (Figure 3). Each photograph was displayed for 5 seconds, followed by 2 seconds of dark screen. The entire test lasted around 4 minutes. The only instruction to observers was to observe, after which no questions were asked. There were 110 participants in total, 50 % female and 50 % male, 50 % under 30 years of age and 50 % over 30 years of age. The average age of all participants was 33.39 years. All participants were from Slovenia and had normal or corrected-to-normal vision. The final results were exported as an average of all observers in the form of heat maps and transparent gaze visualisations.
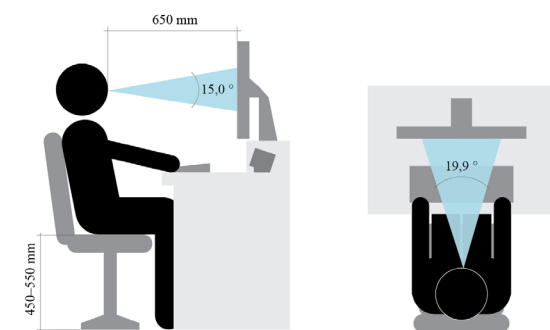
Figure 3: *The eye-tracking measuring condition.*

Predictive eye-tracking

Predicting what and how observers would look was done using an artificial intelligence application called Expoze.io. This is a subscription-based online application that allows the analysis of static images and video recordings. The attention prediction generated by Expoze.io is created using a generative adversarial network (GAN). The input are the RGB values of image or video and the output is the attention prediction. On the input side, a ConvNet (Convolutional Neural Network) is used, which has been trained to recognise objects with over 14 million images (The data science blog, 2016; Expoze.io, 2022). The neural network was than trained on the attention data of thousands of participants that looked at more than 10,000 images (Expoze.io, 2022).

The application has been tested on various graphic design examples, user interfaces, packaging, and commercials, and according to a study (Expoze.io, 2022), it offers 95 % accuracy compared to eye-tracking. This probability provides a high enough confidence factor for the method to be taken seriously. The method has not yet been tested for analysing communication value on a photographs before. We used the same photographs that were used for the eye-tracking measurements. The settings for generating the final heat maps and the gaze opacity images for export were standard.

Analysis and data evaluation

The final data were exported from both used applications (Tobii Studio 3.4.4 and Expoze.io) in similar and comparable ways. There are three common ways to display eye-tracker data in general: numerically, as a heatmap, and as a gaze plots. Tobii Studio offers all possible exports with many additional options, while Expoze.io only offers export of heatmaps (*Normal* setting) and a transparent view on gaze plots (*Reveal* setting), where only the parts of the photos that were viewed most are visible. Expoze.io doesn't offer numerical export, so the evaluation had to be done based on visualised data exports.

The analysis of the measured and calculated data was then performed in two ways:

a. the data presented in the form of heat maps was evaluated by subjective visual assessment,
b. the data presented in the form of transparent gaze visualisations was evaluated with an objective assessment using the structural similarity (SSIM) index, which has been shown in previous studies to be a suitable method for comparing two similar images (Tong, 2005; Ahtik, Muck & Starešinič, 2017). Expoze.io also did their similarity studies using the same metric (Expoze.io, 2022).

The SSIM index is calculated on various windows of an image. Equation (1) shows the measure between two windows x and y of common size N×N, where μ_x is the average of x, μ_y is the average of y, σ_x^2 is the variance of x, σ_y^2 the variance of y, σ_{xy} is the covariance of x and y, $c_1 = (k_1L)^2$, $c_2 = (k_2L)^2$ are two variables to stabilize the division with the weak denominator, and L the dynamic range of pixel-values, $k_1 = 0.01$ and $k_2 = 0.03$ by default.

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \tag{1}$$

Results and discussion

Heat map visualisations

The results of the eye-tracking measurement are shown in Figure 4, and the results of the predictive eye-tracking calculations are shown in Figure 5. In both cases, the results are presented as visualised heat maps of the areas viewed and the areas predicted to be viewed. The exported visualisations are similar and can be compared visually, as this type of visualisation is intended for visual evaluation. Red areas represent the elements that are seen the most, and green/blue areas the least. Areas that are not coloured in the heat map were not viewed or are not predicted to be viewed by the observers.

When comparing the visualisation of the two methods, the main interest is whether and how the main areas of interest were seen and observed. Some photos in the image database have clearly visible elements that stand out from the background (e.g., A4, A5, B1, B5, C5, D2, D5, E1, E3-6 ...), and some photos have less clearly visible elements (e.g., A1-3, A6, B4, C2, D3 ...). The visual comparison shows that both methods correlate most with photos that have clearer areas of interest, while there is less or no correlation for some other examples where there are fewer elements on which to fixate the eyes. Since predictive eye-tracking separates clear elements from the background and predicts that the human eye will fixate on these elements the most, the result is predictable. For the photos with less recognisable elements, especially example A1, the prediction is unclear and has no real relation to the real measurements.

The other conclusion that can be drawn is that prediction is more successful with less complex photographs (Figure 2). Less detail means that the machine learning algorithm can more easily distinguish between elements and background. Since Expoze.io was originally developed for evaluating graphic designs, where the elements are usually clearly visible – which is the main function of the design process itself – the results are also not surprising.
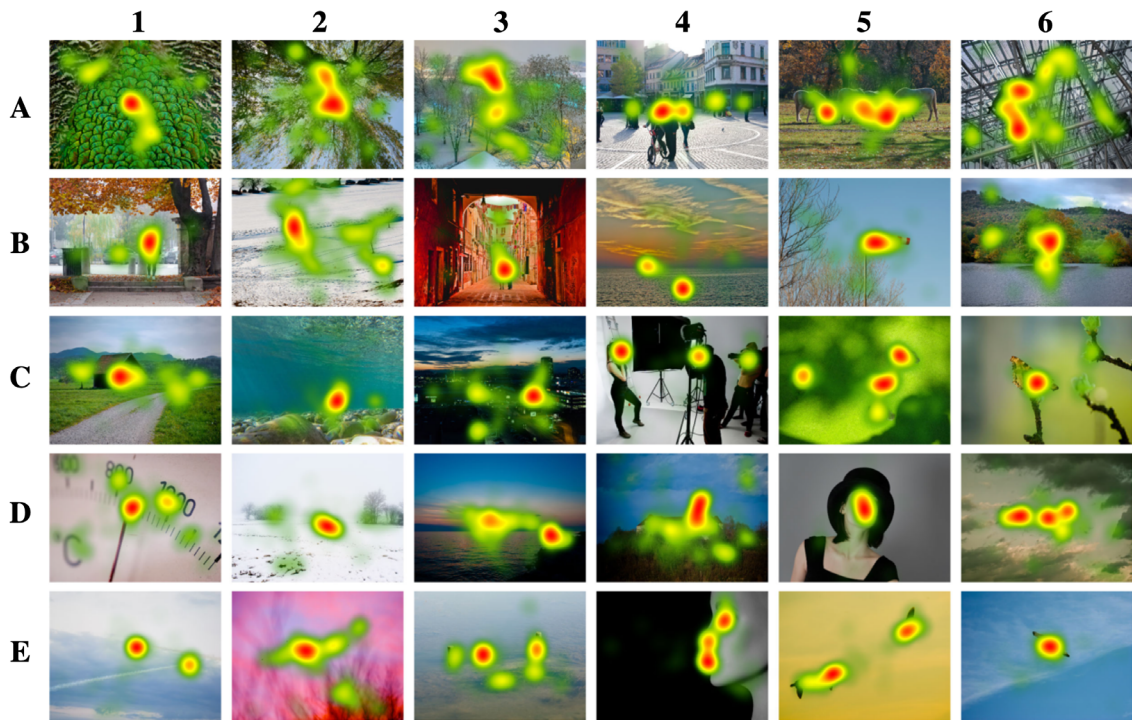
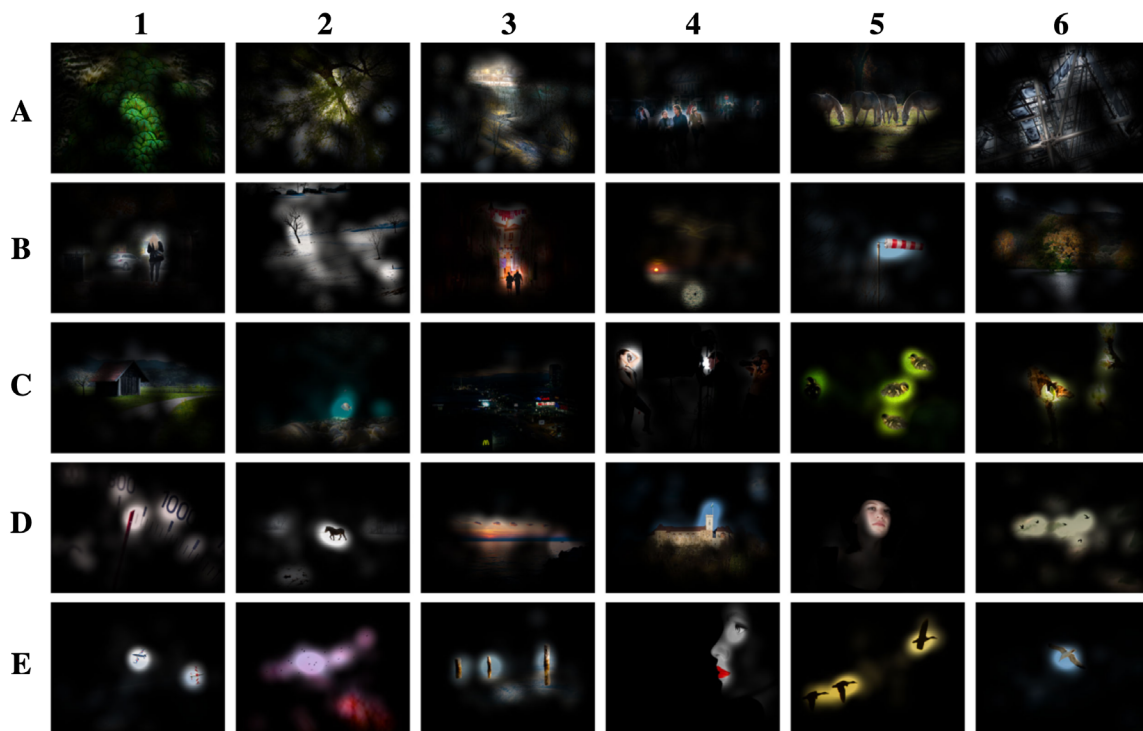» **Figure 4:** *Data measure by the eye tracker Tobii X120 presented as heat maps*
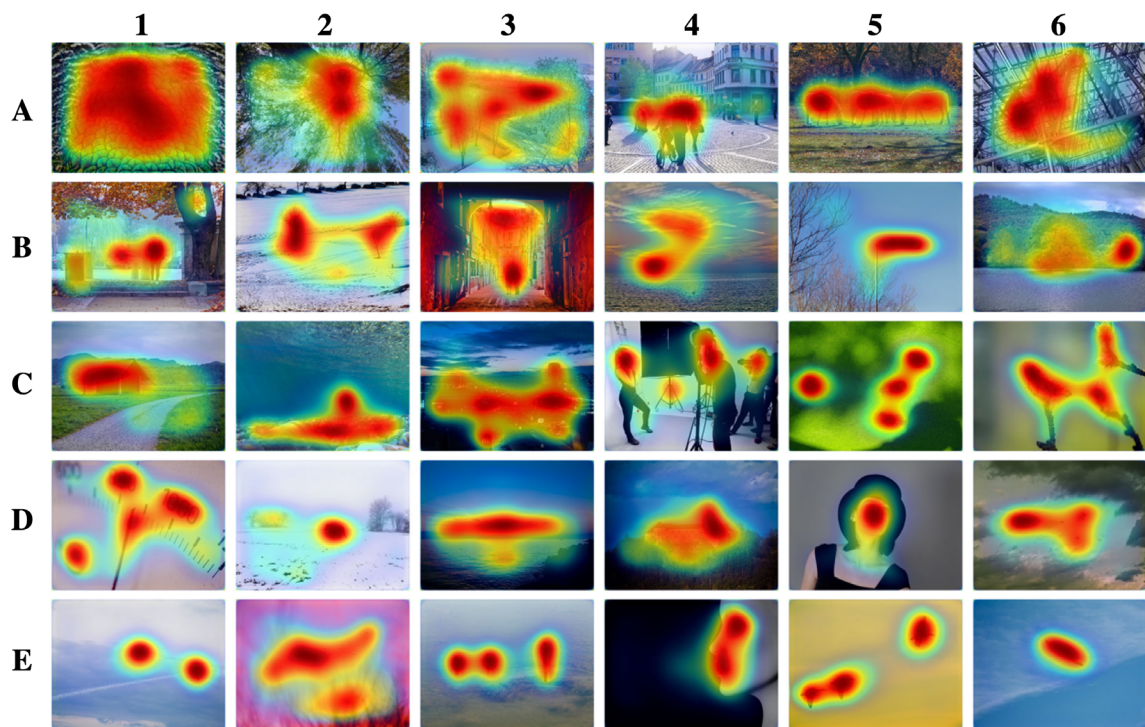
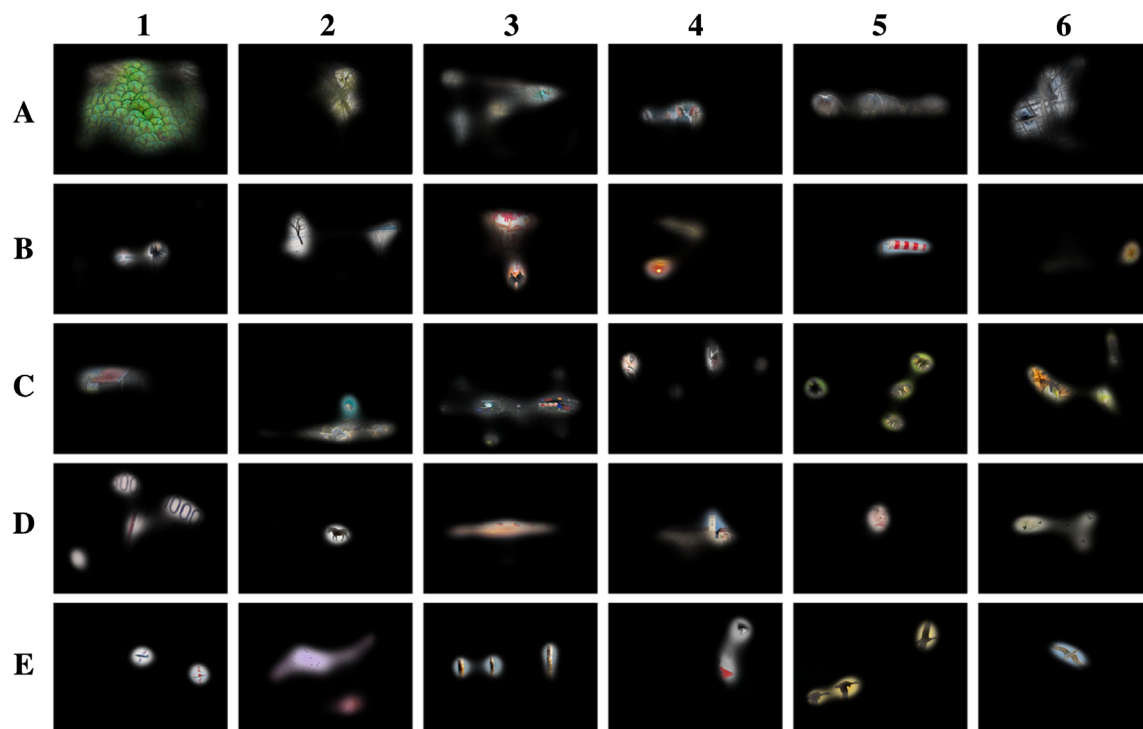» **Figure 5:** *Data calculated by predictive eye-tracking application Expoze.io presented as heat maps*

Transparent gaze visualisations

Unlike heat maps, where the exported visualisations from the two applications used are not fully comparable, there is a better way to do this when analysing transparent gaze visualisations. Measured transparent gaze visualisations are shown in Figure 6 and predicted transparent gaze visualisations in Figure 7. In the visual evaluation of the visualisations of both methods, the similar conclusions can be drawn as for the heat maps. But the greater similarity of the visualisations gives us the opportunity to make more objective calculations. The SSIM index gives us an objective result of how structurally similar the images are to each other. We compared predictive eye-tracking visualisations to eye-tracking, and a higher result means better similarity or in this case a better pre-

» **Figure 6:** *Data measured by the eye-tracker Tobii X120 presented as transparent gaze*

» **Figure 7:** *Data calculated by predictive eye-tracking application Expoze.io presented as transparent gaze*

diction. The calculations are consistent with the results of visual evaluation, where dependence on image complexity has also shown that prediction is better when photos are less complex. As shown in Figure 8, in some cases, e.g. E4 or D5, the SSIM index is very high, almost 0.9, while in other cases, e.g. A1 or A2, it is much lower, even below 0.4. The trend is clearly in favour of less complex and is steeply dropping towards more complex images.

are less complex. As shown in Figure 8, in some cases, e.g. E4 or D5, the SSIM index is very high, almost 0.9, while in other cases, e.g. A1 or A2, it is much lower, even below 0.4. The trend is clearly in favour of less complex and is steeply dropping towards more complex images.
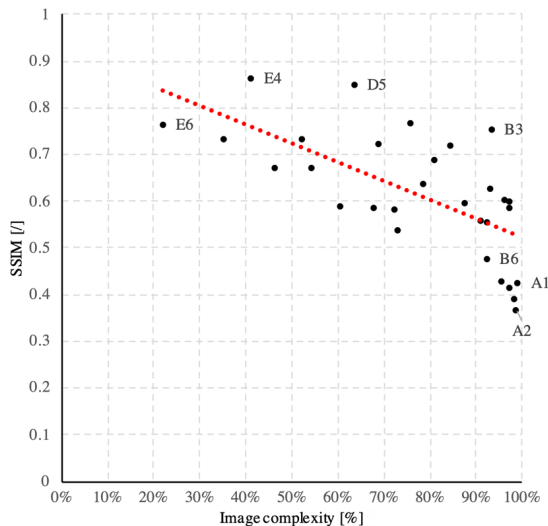
» **Figure 8:** *SSIM index calculated between transparent gaze plot images of both used methods compared to image complexity of tested images.*

Conclusions

The study showed that predictive eye-tracking technology based on machine learning with neural networks can be used to predict how users will view a photo when the content of the photo is distinguishable from its background or the structure of the photo is not very complex. Considering that the image database used for the research contains some examples of highly complex photographs that are not usually used as main communication elements in advertising campaigns or graphic designs, the conclusion may be less rigorous. In any case, when working with complex or abstract photographs, we cannot rely on an accurate prediction.

The recommendation that can be made based on the following study is that predictive eye tracking is not recommended for scientific purposes because it is not suitable for thorough image evaluation. However, for real-world business cases where a quick result is needed, the technology provides useful and reliable results. We expect the technology to evolve, with respect to some other use cases of machine learning technologies that are currently available to a wider audience. Accordingly, in the future, creators will increasingly become curators of content generated or evaluated by artificial intelligence, which will improve the quality of visual communication.

Acknowlegment

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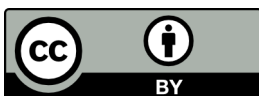
Fast mosaicing method based on image resizing pre-processing

ABSTRACT

In recent years, mosaic images have found great success thanks to the increasing development in the field of imaging as well as the technological evolution of computer systems (camera, mobile, etc.). Mosaic images are obtained by merging several images of the same scene. The process incorporates several steps, each of which requires resources and execution time depending on the size, quality and resolution of the images used. In this paper, we propose a new image mosaic method that significantly reduces the execution time. The idea is to apply the stages of registration and search for the best inliers, necessary for the calculation of the geometric transformation, to the miniature of images. This allows the minimization of the overall processing time without altering the quality of the results. The experiment, on a database of images, shows that the proposed algorithm provides rapid results compared to similar methods. Also, we have extended our method to generate 360° panoramic images.

KEY WORDS
Stitching, mosaic, fast, sift, best inliers

Abderrahmane Laraqui [1] iD
Mohammed Laraqui [2]
Abderrahim Saaidi [3] iD

[1] *Research in Computer Sciences Laboratory, IMS, Ibn Tofail University, Kenitra, Morocco*

[2] *FP Ouarzazate ibn zohr university BP 32/S, Morocco*

[3] *LSI, Department of Mathematics, Physics and Informatics Polydisciplinary Faculty of Taza, Sidi Mohamed Ben Abdellah University, Morocco.*

Corresponding author:
Abderrahmane Laraqui
e-mail:
*abderrahmane.laraqui@gmail.com*

Introduction

Each and every day, digital images are used in various fields (such as computer vision, e-learning, security, etc.) and continue to reach other areas. Due to the limited vision field of digital camera sensors, only a small area can be captured of the real scene. To obtain a larger view of the latter, the reconstruction of the mosaic image becomes imperative. The current methods of image mosaic are numerous and are mostly based on the registration methods (Zitova & Flusser, 2003; Koo & Cho, 2011; Ghosh & Kaabouch, 2016) that make up the first step (Figure 1) in the image mosaic process and is also the most important one. Its role is to detect the remarkable objects in two or more images and

compare them to detect existing matches that will in turn serve to create a geometric relationship between images. Despite their effectiveness, these methods remain costly in terms of processing time. The speed of image mosaicing depends essentially on the matching phase that consumes the largest part of the overall processing time. The matching process depends on the image size, texture, the number of control points that may exist (upon which the calculation of the geometric transformation is based). All of these factors influence the execution time of the mosaic process.

In this article, we propose a new method for creating a mosaic image that is similar, in the majority of steps, to the conventional methods (based on registration)

(Zitova & Flusser, 2003; Koo & Cho, 2011; Ghosh & Kaabouch, 2016). However, we apply the steps of matching and search for the best inliers (see section 3.2) to the miniature of the input images. In other words, the images used in the process of the mosaic will be resized to a lower scale. This way, the time consumed by the matching process and the search for the best inliers is reduced, which optimizes the overall time. Then we look for the equivalents (in the original images) of best inliers already detected (in the miniature images). Finally, we calculate the geometric transformation in order to realize the mosaic.
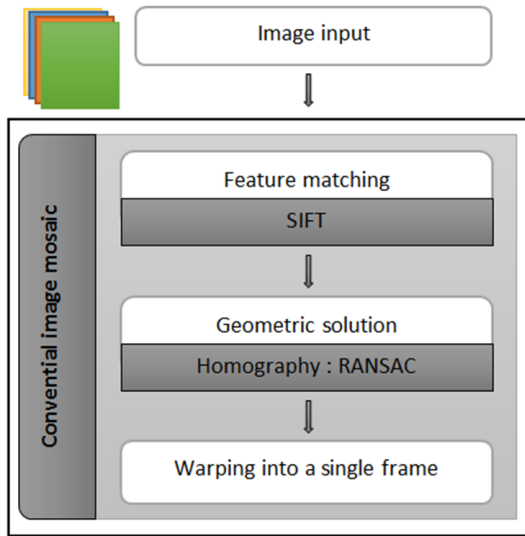
» **Figure 1:** *Structure of mosaicing method based on registration*

The paper is organized as follows: after this introduction, the related work is reviewed in Section 2. Details of the proposed approach are presented in Section 3. Experiments and results are discussed in Section 4, and the conclusion is in Section 5.

Related works

The image mosaic is a technique of combining two or more images in a wider visualization context. Many categories of mosaic algorithms (Figure 2) are able to take images, of the same scene, that overlap and to stitch them into a panorama. The techniques based on registration (Zitova & Flusser, 2003; Koo & Cho, 2011; Ghosh & Kaabouch, 2016) are still the most famous among others. This category of methods is based primarily on registration. So it is almost impossible to achieve mosaic reconstruction without the implementation of a robust and accurate registration system, which highlights the importance of this time consuming phase. Below is a brief presentation of registration techniques proposed in the literature and previous works.

The image registration techniques (Brown, 1992) can be grouped into area-based (Zitova & Flusser, 2003) (Figure 3.a) and feature-based methods (Zitova & Flusser, 2003) (Figure 3.b). Recently, with the appearance of a set of local feature descriptors techniques, feature-based methods have become increasingly used in image registration. The highlight of these methods is due to their invariance to rotation and scaling. So they can be used to match images with large deformations, while the area-based methods apply only to pictures in translation and on the same scale. These methods include Features from Accelerated Segment Test (FAST) (Trajković & Hedley, 1998; Rosten, Porter & Drummond, 2010), Scale-Invariant Feature Transform (SIFT) (Lowe, 2004; Laraqui, Saaidi & Satori, 2018) and Speeded Up Robust Features (SURF) (Bay et al, 2008).

The category of mosaic methods based on registration includes several techniques. First of all, we start with Brown and Lowe method (Brown & Lowe, 2007) considered the reference method in this category. It is based on SIFT algorithm and RANdom SAmple Consensus (RANSAC) method (Márquez-Neila et al, 2016; Misra et al, 2012). It also recognizes several panoramas in a set
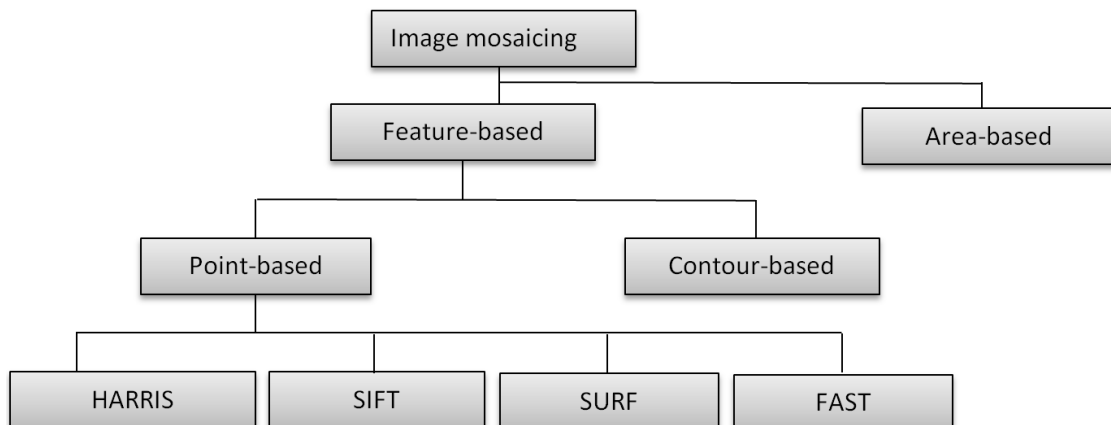
» **Figure 2:** *Classification of mosaic methods based on registration*

of unordered images. In (Zaragoza et al, 2014) a new estimation technique called Moving Direct Linear Transformation (DLT Moving) is able to adjust or refine the projection and greatly reduce ghosting without compromising the geometric realization of the mosaic image. In paper (Zhou & Luo, 2012), the authors introduce a representation of a multi-view image mosaic algorithm based on the CSIFT detector (Color Scale Invariant Features). The authors of (Saeed et al, 2015) propose a unified scheme, which manages two transformations. A recent approach of image mosaic that is based on Voronoi diagram at the moment of matching and the phase of projection to replace the random choice of Ransac method was proposed in (Laraqui et al, 2017). A method of the mosaic image based on a camera-auto calibration technique has been proposed in (Baataoui et al, 2015).

a)

b)
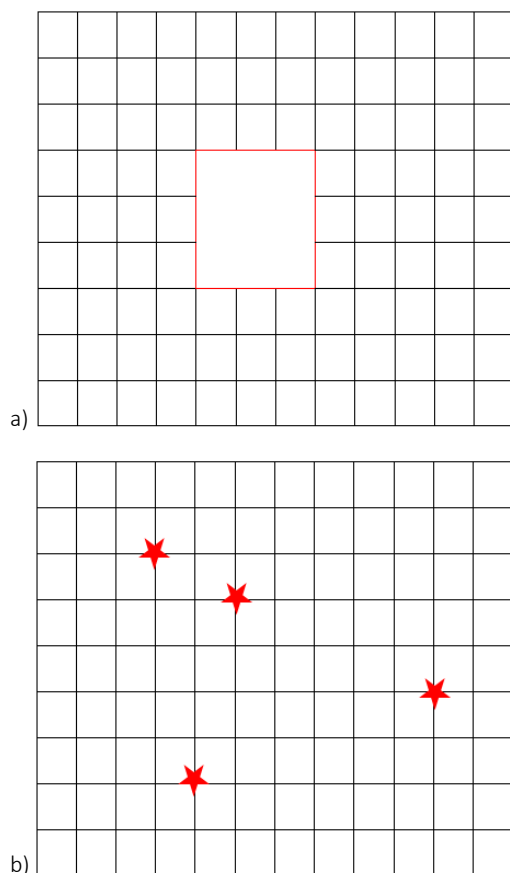
» **Figure 3:** *a) area-based matching,*
*b) feature-based matching*

Our approach

The majority of image mosaic methods based on registration follow the following steps:

- Detect and match keypoints (using Sift)
- Find the best inliners and estimate optimal homography *H* (using RANSAC)
- Project onto a sruface (alignment)

In this paper, we propose an improvement of image mosaic methods based on the steps previously cited. This improvement is intended to minimize the calculation time without compromising the quality of the mosaic results.

Matching

To search for matching points between the input images, we used SIFT (Lowe, 2004) because it is invariant to rotation, scale changes and affine transformations. It is clear that the step of matching consumes the larger part of the execution time in the process of the mosaic. This has led researchers, in this area, to look for alternative methods such as seam-based mosaic techniques (Pan and Wang, 2011; Zeng et al, 2014). In this article we offer a solution to reduce the calculation time of matching phase. This is possible by resizing the input images to a lower scale that reduces the time consumed in this step.
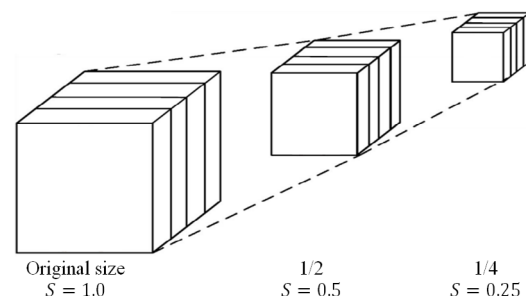
» **Figure 4:** *Image resizing scale. Inspired from (Shin et al, 2016)*

We will resize the input images to a scale *S* that ranges from 0 to 1. Figure 4 shows the size of an image with respect to the value of *S*.

Find the best inliers

After the matching phase, we get a set of matching pairs between images. At this stage, we search for the best inliers (available within the matches found) upon which the computing of geometric transformation *H* will be based (using Ransac algorithm (Márquez-Neila et al, 2016; Raguram, Frahm, & Pollefeys, 2008; Misra et al, 2012).

The RANSAC algorithm permits the estimation of parameters of a mathematical model by random sampling. The basic assumption is that the data consists of "inliers", i.e., data whose distribution can be explained by some set of model parameters, and "outliers" which are data that do not fit the model. The best inliers are inliers that have obtained the best scores compared to the others

In the case of homography (Brown, 1992; Szeliski, 2006), We need four pairs of points. Figure 5 shows the best inliers found between the resized images.
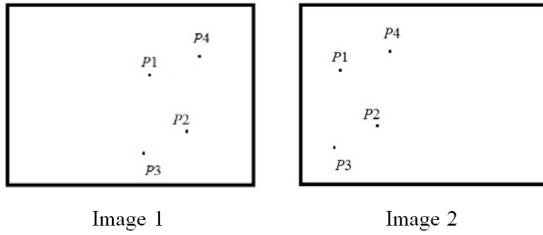
Image 1   Image 2

» **Figure 5:** *Best inliers between resized images (image 1 and image 2)*

At this stage, we need to combine the original images to their original sizes. Therefore, the use of resized images stops here. We will look for the coordinates of the best inliers (previously found in the resized images) in the original images (Figure 6).

This occurs by the multiplication of C (coordinates) of each point found (in the resized images) by the inverse of S to obtain C' which represent the positions in the original image (Equation 1).
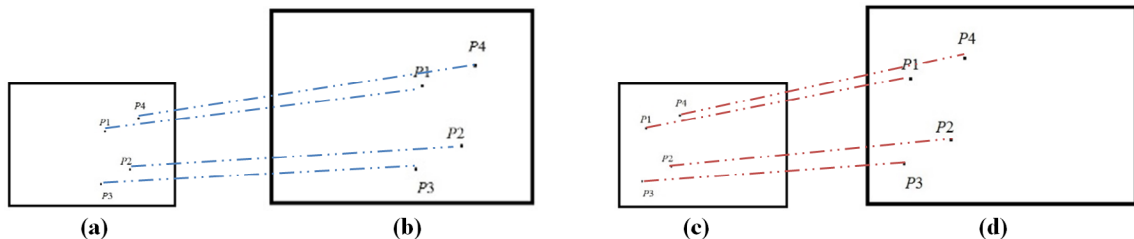
$$C' = C \times S^{-1}$$ (1)

With:

- C : The coordinates of the best inliers in resized images.
- C': The coordinates of the best inliers in the original images.
- S : Scale value.

For more precision, the four pairs ofoints found are matched by SIFT (Lowe, 2004).

Calculate the geometric transformation and alignment

At the end of SIFT, we get a list of match pairs. From these data, we want to determine as precisely as possible the homography matrix *H*, which links our two images.

We need to determine eight parameters. It is therefore necessary and sufficient to have four pairs of points to

determine *H*. It has the following form (Equation 2):

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & 1 \end{bmatrix} . \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$ (2)

The optimal matrix is the one that obtained a lower projection error score compared to the others

So far, we have obtained the best inliers necessary for the calculation of the transformation *H*. This transformation will link the original images based on the equation 3.

$$p_{ki} \sim H_{ij} \, p_{kj}$$ (3)

With p_{ki} the point *k* of image *i*, p_{kj} the point *k* of image *j* and H_{ij} represents the geometric transformation of 3x3 size which connects the images *i* and *j*.

The last step is merging the two images in a single frame that represents an enlarged view of the scene (Figure 7)

Image 1   Image 2
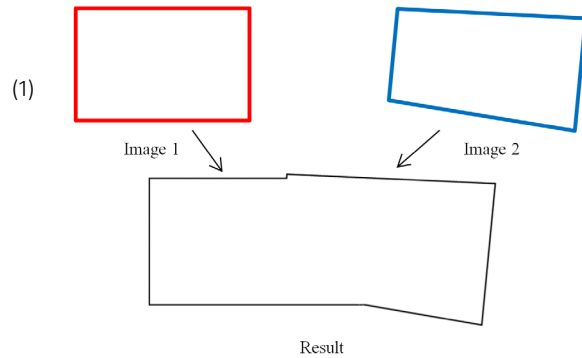
Result

» **Figure 7:** *Alignment of the two images on a plane surface*

Experimental results

To show the effectiveness of our approach, we carried out the tests on a database of images (Brandt, 2010). Also, we have compared our method with the existing methods ((Brown & Lowe, 2007) in the case of two images and (Wang et al, 2016) in the case of panorama) in terms of execution time, allocated memory and quality of results. We implemented our approach and existing

(a)   (b)   (c)   (d)

» **Figure 6:** *a) Best inlier in miniature of image 1 b) Best inlier in original image 1 c) Best inlier in miniature of image 2 d) Best inlier in original image 2*

methods, using Matlab 2014b and a computer system characterized by: Intel (R) i3 2.2 GHz with 6 GB of RAM.

Image mosaicking

In this section, we will test our approach by a database (Brandt, 2010) of 10 sequences. Each contains two images of size 1024 x 683px.

In order to show the robustness and the effectiveness of our approach compared to other techniques, the obtained results are compared with the results of method (Brown & Lowe, 2007). It is based on the SIFT detector and RANSAC method. This reference method (Brown & Lowe, 2007) widely used in comparison with other mosaic techniques. The general principle of the method has been replicated in several recent papers such as (Mills & Dudek, 2009; Ma et al, 2015). Our approach improves this method by using miniature images in the matching phase (as explained in section 3).

Figure 8 illustrates the pairs of images from the database Adobe System (Brandt, 2010) (4 sequences among 10). The scale value S applied in our approach, on the test images, was 0.25 (25% of the real size of images).

Figure 9 represents the results obtained by the two approaches. These results do not contain any processing such as interpolation (Allène, Pons & Keriven, 2008), deletion of intensity change and deghosting (Uyttendaele, Eden, & Skeliski, 2001) in order to test the reliability of the two methods and measure exactly the real calculation time.

In terms of mosaic reconstruction quality, both methods provide satisfactory results and are almost identical. This can be explained by the fact that the two methods are able to find the best inliers able to calculate an optimal geometric transformation. Also, the results confirm the reliability of our approach and the preprocessing used (image resizing) does not alter the quality of the mosaic.

Since the methods based on registration suffer at the level of time consumed during the matching phase the main, our approach, however, reduces the computation time without affecting the quality of results by applying the phases of matching and search for the best inliers (by RANSAC) to the miniatures of images. The process results in a considerable reduction of the processing time. Below, we present a comparison of the number of inlier matches detected, the time consumed in matching phase and finally the memory used as well as the overall duration of the process.

Figure 10 shows the number of matched points detected by our method and method (Brown & Lowe, 2007). The reduction varies between 75.96 and 95.07% of detected points. This reduction is due to the process of image resizing which reduces the number of pixels constituting the image. Naturally, the number of inlier matches will be reduced as well.
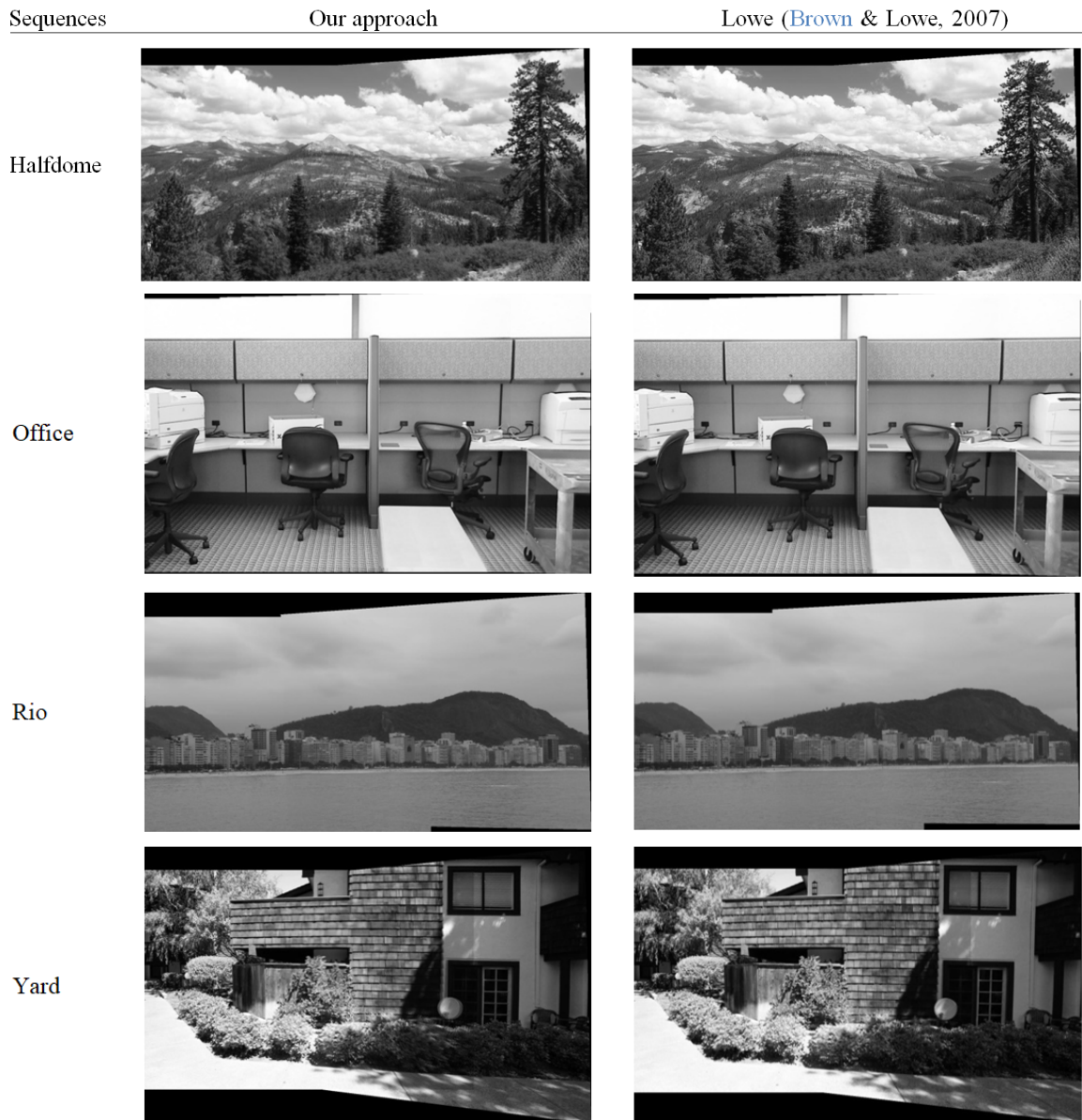
Figure 11 shows the time consumed during the matching phase of the two methods. The reduction varies between 85.76 and 90.89% in favor of our approach. The size reduction of the processed images and the reduced number of inlier matches detected minimize the matching time.

Figure 12 summarizes the overall calculation time during the mosaic process. The figures obtained are the average of 5 consecutive executions of the program. The results obtained show that our approach provides a very short time compared to method (Brown & Lowe, 2007). In numbers, time reduction, based on the data used, varies between 52,93 and 71,80 % in favor of our approach. This is due to the minimization of matching time and search of best inliers.

Figure 13 shows the use of memory by different methods and indicates that our method uses less memory compared to LOWE's technique (Brown & Lowe, 2007). This reduction varies between
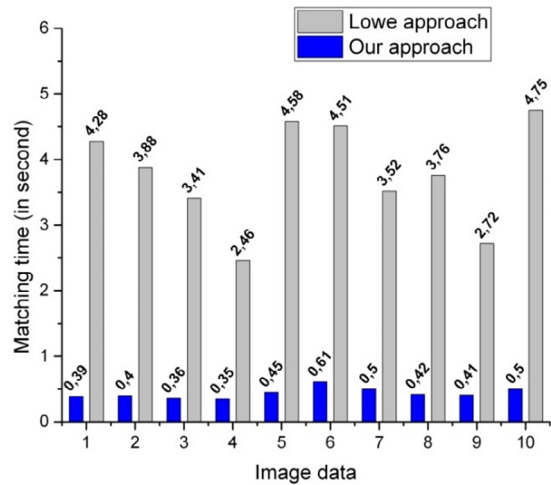
Halfdome

Office

Rio

Yard
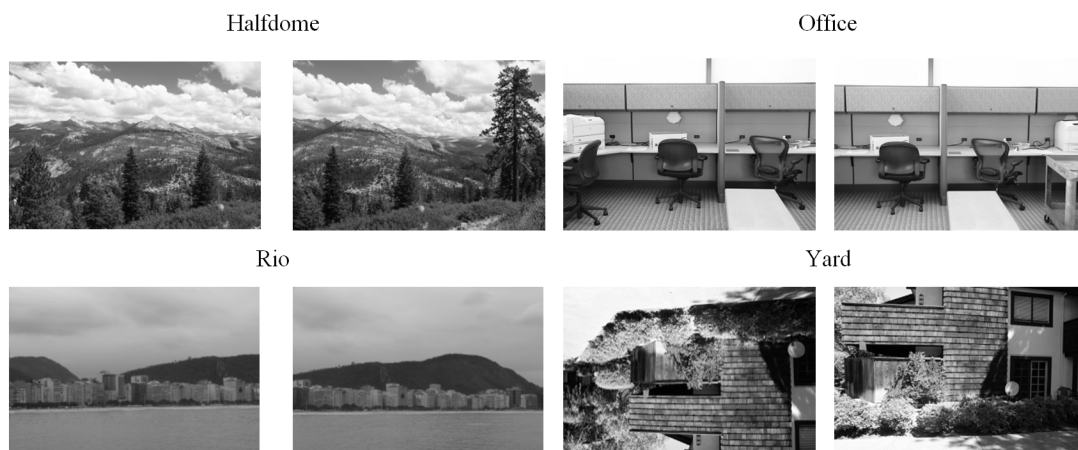
» **Figure 8:** *Four sets of sample images*

Sequences	Our approach	Lowe (Brown & Lowe, 2007)

Halfdome

Office

Rio

Yard

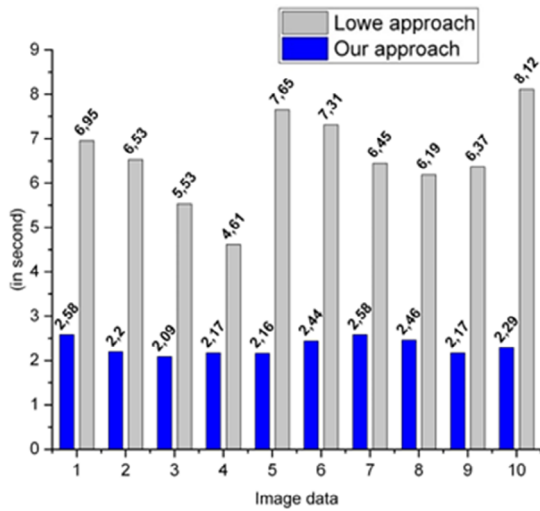» **Figure 9:** *Results of the mosaic obtained by the two methods*
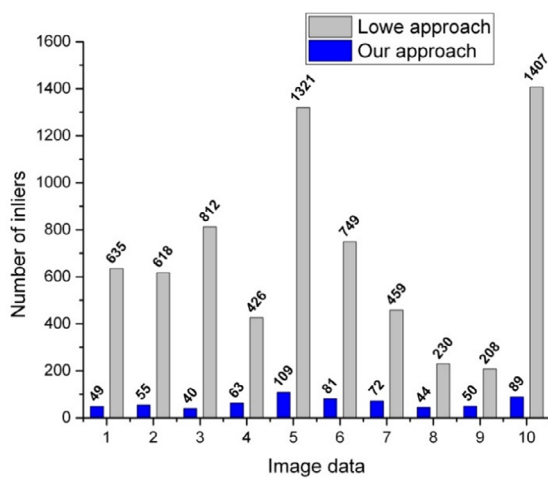
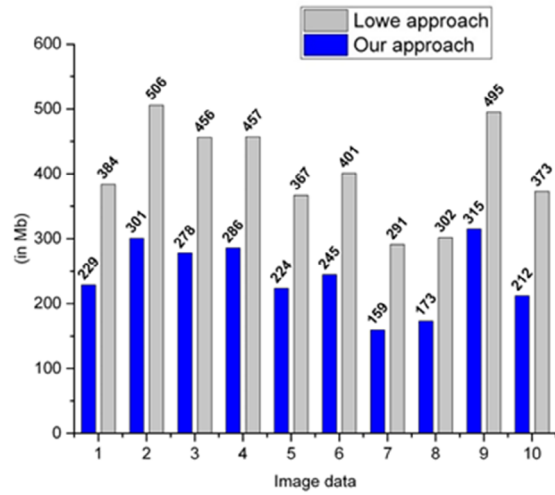» **Figure 10:** *Number of inlier matches*

» **Figure 11:** *Matching calculation time of both approaches*

» **Figure 12:** *Total calculation time of both approaches*

» **Figure 13:** *Total used memory of both approaches*

25.28 and 30.51%. These results confirm the previous ones and prove that our method is faster than Lowe's, and even consumes less resources.

Panorama

The panorama is an aspect of the mosaic which assembles more than two images in a surface (flat (Kamali et al, 2011), spherical, (Lovegrove & Davison, 2010), cylindrical (Wu, Wang & Wang, 2005) …).

We will test the performance of our approach compared to method (Wang et al, 2016) using the cylindrical projection which can reach up to 360°. The test is performed on Adobe System database (Brandt, 2010) (two sequences of images) and two real image sequences. To avoid errors that may occur during panorama creation, especially between images that suffer from a reduced overlapping area, we have opted to

use a scale value of 0.5 (50% of full size). Figure 14 shows the characteristics of sequences used (name, size and number of images) and the results obtained.

The results obtained are satisfactory and almost identical to the results of Wang method (Wang et al, 2016). This confirms the results obtained previously.

Still, the results obtained in the sequences Mountain and Mountain 2 present some anomalies in terms of consistency in colors intensity (the sequences have suffered at the time of acquisition). Therefore, a post-treatment multi band blinding (Allène, Pons & Keriven, 2008) is employed to minimize the visibility of seams between images, vignetting and enhance the rendering. Figure 15 shows the result of the sequence Mountain 2 post processed.

a. Our approach
b. Wang Approach (Wang et al, 2016)

| Sequence name : Hotel | Image size : 1024 x 768px | Number of images : 8 |

» **Figure 14 (part 1):** *Results of panoramic images obtained by our approach (a) and Wang Approach (b)*
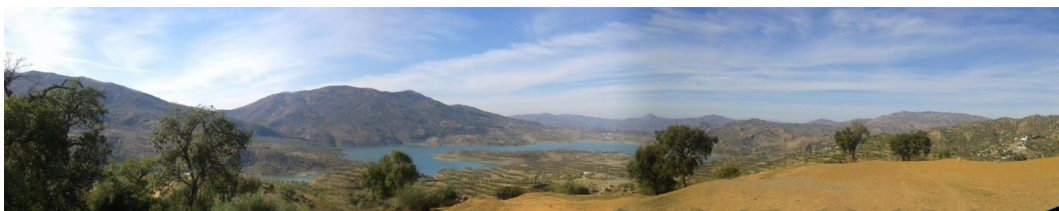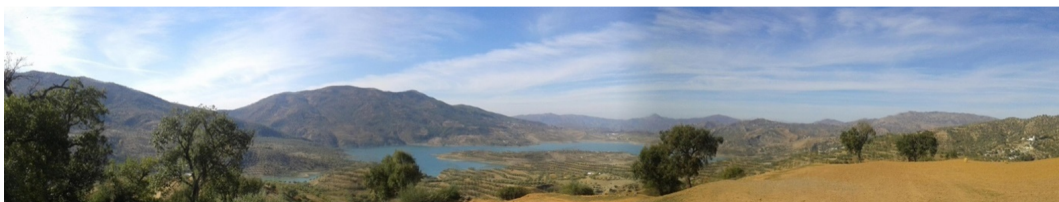
(a)

(b)

Sequence name : Goldengate   Image size : 600 x 900px   Number of images : 6

(a)
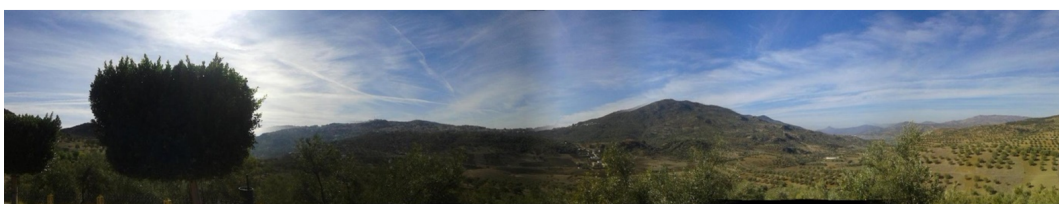
(b)

Sequence name : Mountain   Image size : 800 x 1200px   Number of images : 13

(a)

(b)

Sequence name : Mountain 2   Image size : 600 x 920px   Number of images : 12

» **Figure 14 (part 2):** *Results of panoramic images obtained by our approach (a) and Wang Approach (b)*

» **Figure 15:** *Post-processed panorama for sample Mountain 2*

Figure 16 represents the time of generating the panoramas in both methods. Our method provides a calculation time reduced on all of the sequences used. The reduction varies between 52.21 and 72.39% (following the sequence used). So our method preserves the quality of the mosaic and minimizes considerably the calculation time.
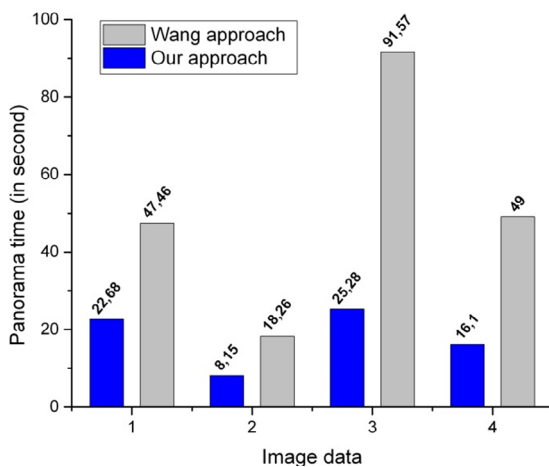
» **Figure 16:** *Total calculation time of both approaches*

Our approach provides a reduced calculation time compared to existing methods (Brown & Lowe, 2007) in case of two images and (Wang et al, 2016) in the case of panorama. This is due to the use of the miniatures of images during the phases of matching and the search for the best inliers, which reduces the execution time. Note that, the scale value S used depends essentially on the image size, the size of the overlap area between the images and the number of inliers that may exist. In the case where we use a very low value of S, the number of inliers may decrease at a rate that does not detect the best inliers reliable for estimating transformation H. To overcome this problem, it is preferable to avoid the use of the input images with a very low overlap area.

Conclusion

In this article, we have proposed an improvement of the methods of image mosaic based on registration, namely SIFT, Harris, Fast and SURF being the most popular ones in the field. The purpose of this contribution is to propose a time efficient reconstruction method that triumphs existing approaches, without having to

compromise the quality of mosaic. The results obtained show that our method was able to preserve the quality of the reconstruction despite the reduction of the calculation time by up to 71% and the memory by around 30%. This reduction allows mosaic methods based on registration to invade other computer vision areas requiring real-time processing. The use of this method should be of great benefit for low memory devices. Experimental results on synthetic and real data show the performance and effectiveness of our approach.

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