DEVELOPMENT OF METHODS TO ASSESS THERMOFORMED TACTILE DIAGRAMS

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Development of Methods to Assess Thermoformed Tactile Diagrams

By

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Dedicated to

My Father *'Kolar Eranna Sadashivaiah'*

CERTIFICATE

This is to certify that the thesis entitled **Development of methods to assess thermoformed tactile diagrams,** being submitted by Mr Ganesh S for the award of the degree of Doctor of Philosophy to the Department of Design, Indian Institute of Technology Delhi, is a record of bonafide work done by him under my supervision and guidance. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any other degree or diploma.

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Abstract

In this information-driven era, the use of pictorial forms of communication has become widely popular but at the same time making the world increasingly inaccessible to the people with visual impairment and blindness. The lack of accessibility of pictorial information limits the education and employment opportunities of the visually challenged. Access to pictures and diagrams maps such as educational materials, manuals, safety instructions, building layouts, data visualization etc is needed for the visually challenged people for inclusion and independent living.

Tactile diagrams are embossed outline drawings which are specially designed for individuals with visual impairment and blindness to communicate pictorial information through touch. One of the common processes used to prepare these diagrams in polymeric materials is by vacuum thermoforming. Though these diagrams have been in use for many decades, assessing the effectiveness of these diagrams in terms of materials and manufacturability, and its effect on user experience is largely unaddressed. Apart from perceptibility, the diagrams produced are also expected to meet affordability, manufacturability, and biocompatibility. Apart from cognitive aspects of users which is not the subject of this thesis, the perceptibility of these diagrams depends on many factors, which include the type of material used and its properties, sheet thickness, shape, size and texture of tactile features; surface roughness and friction characteristics of the sheet; and the behavior of the sheet to haptic interaction with the user. These aspects have been studied in the current thesis through laboratory experiments, user studies and computer simulations. The specific assessment methodologies developed and discussed in this work include:

- Assessment of material of tactile diagram, in terms of composition and properties before and after thermoforming.
- Assessment of tribological parameters such as surface roughness and friction of tactile diagram sheets.
- Design and development of a methodology for assessment of geometric features of tactile diagram
- Design and development of methodology and a system to assess haptic interaction of users with sheet.
- Assessment of manufacturing realizability and prediction of defects in the thermoforming process through computer simulation.

It is assumed that when the tactile diagrams are produced in large numbers and shop-floor settings, these assessment methodologies proposed, developed and demonstrated in this work will be useful for designers and manufacturers to come up with tactile diagrams that serve the intended purpose effectively by making optimum choices regarding material, manufacturability and user experience.

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सारांश

इस सूचना-प्रधान युग में चित्रात्मक संप्रेषण के रूपों का उपयोग व्यापक रूप से लोकप्रिय हो गया है, लेकिन साथ ही यह दुनिया को दृष्टिबाधित और नेत्रहीन लोगों के लिए तेजी से अप्रवेशनीय भी बना रहा है। चित्रात्मक जानकारी की पहुंच की कमी दृष्टिबाधित लोगों की शिक्षा और रोजगार के अवसरों को सीमित कर देती है। दृष्टिबाधित लोगों के समावेश और स्वतंत्र जीवन के लिए शैक्षणिक सामग्री, मैनुअल, सुरक्षा निर्देश, भवन के नक्शे, डेटा विज़ुअलाइज़ेशन आदि जैसे चित्रों और आरेखों की पहुंच आवश्यक है।

टैक्टाइल डायग्राम उभरे हुए रेखाचित्र होते हैं जो विशेष रूप से दृष्टिबाधित और नेत्रहीन व्यक्तियों के लिए स्पर्श के माध्यम से चित्रात्मक जानकारी संप्रेषित करने हेतु डिज़ाइन किए जाते हैं। इन डायग्रामों को पॉलीमर सामग्री में तैयार करने की एक सामान्य प्रक्रिया वैक्यूम थर्मोफॉर्मिंग है। हालांकि ये डायग्राम कई दशकों से उपयोग में हैं, लेकिन सामग्री और विनिर्माण क्षमता के संदर्भ में इनकी प्रभावशीलता तथा उपयोगकर्ता अनुभव पर इनके प्रभाव का मूल्यांकन अब तक बड़े पैमाने पर नहीं किया गया है। इन डायग्रामों को स्पर्शनीयता के साथ-साथ सुलभता, निर्माण-योग्यता और जैव-संगतता (बायोकम्पैटिबिलिटी) को भी पूरा करना होता है।

हालाँकि इस शोध का विषय उपयोगकर्ताओं के संज्ञानात्मक पहलुओं (कॉग्निटिव एस्पेक्ट्स) को शामिल नहीं करता, लेकिन इन डायग्रामों की स्पर्शनीयता कई कारकों पर निर्भर करती है, जैसे कि प्रयुक्त सामग्री का प्रकार और उसकी भौतिक विशेषताएँ, शीट की मोटाई, स्पर्शात्मक विशेषताओं का आकार, बनावट और आकृति; शीट की सतह की खुरदुरापन और घर्षण विशेषताएँ; और उपयोगकर्ता के साथ स्पर्शात्मक संपर्क के प्रति शीट की प्रतिक्रिया। इन सभी पहलुओं का अध्ययन इस शोध में प्रयोगशाला परीक्षणों, उपयोगकर्ता अध्ययनों और कंप्यूटर सिमुलेशन के माध्यम से किया गया है। इस कार्य में विकसित और चर्चा की गई विशिष्ट मूल्यांकन पद्धतियाँ निम्नलिखित हैं:

- थर्मोफॉर्मिंग से पहले और बाद में टैक्टाइल डायग्राम की सामग्री की संरचना और भौतिक गुणों के आधार पर मूल्यांकन।
- टैक्टाइल डायग्राम शीट्स की सतह की खुरदरापन और घर्षण जैसे ट्राइबोलॉजिकल मापदंडों का मूल्यांकन।
- टैक्टाइल डायग्राम की ज्यामितीय विशेषताओं के मूल्यांकन के लिए पद्धति का डिज़ाइन और विकास।
- उपयोगकर्ताओं की शीट के साथ हैप्टिक इंटरैक्शन (स्पर्श संपर्क) का मूल्यांकन करने के लिए पद्धति और प्रणाली का डिज़ाइन और विकास।

• कंप्यूटर सिमुलेशन के माध्यम से थर्मोफॉर्मिंग प्रक्रिया में निर्माण व्यवहार्यता और दोषों की भविष्यवाणी का मूल्यांकन।

यह अनुमान लगाया गया है कि जब टैक्टाइल डायग्राम बड़े पैमाने पर और शॉप-फ्लोर सेटिंग्स में तैयार किए जाएंगे, तब इस शोध में प्रस्तावित, विकसित और प्रदर्शित की गई मूल्यांकन पद्धतियाँ डिज़ाइनरों और निर्माताओं के लिए उपयोगी सिद्ध होंगी। ये पद्धतियाँ उन्हें सामग्री, निर्माण-योग्यता और उपयोगकर्ता अनुभव के संदर्भ में उपयुक्त विकल्प चुनने में मदद करेंगी, जिससे वे अपने लक्षित उद्देश्य की पूर्ति करने वाले प्रभावी टैक्टाइल डायग्राम तैयार कर सकें।

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G. Abbreviations

TD	Tactile Diagram
TG	Tactile Graphic
FTIR	Fourier-transform infrared spectroscopy
TGA	Thermogravimetric analysis
DSC	Differential Scanning Calorimetry
UV	Ultraviolet
FDM	Fused Deposition Modeling
PVC	Polyvinyl chloride
PP	Polypropylene
LDPE	Low density polyethylene
VI	Visual Impairment
WHO	World Health Organization
TH	Thermoforming
STEM	Science, technology, engineering, and mathematics
ABS	Acrylonitrile butadiene styrene
PMMA	Poly methyl methacrylate
HDPE	High-density polyethylene
PET	Polyethylene terephthalate
COFx	Coefficient of friction
SMD	Geometrical surface roughness
MMD	Mean deviation of MIU
MIU	Coefficient of surface friction
PS	Polystyrene
JND	Just-noticeable difference
MRDT	Maximum rate of decomposition temperature
FR	Final residue
ANOVA	Analysis of variance
T-TEST	Student’s T-test
PDMS	Polydimethylsiloxane

KES	kawabata evaluation system
Bvt	Before vacuum forming
Avf_M1/ M2 / M3	After vacuum forming using mold 1/ mold 2 / mold 3
TIE	Transport of intensity equation
FTM	Fourier transform method
CRF	Central Research Facility
NRF	Nanoscale Research facility