Fabricating Wooden Circuit Boards by Laser Beam Machining

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ABSTRACT

Laser cutting machines are commonly used in wood processing to cut and engrave wood. In this paper, we propose a method and workflow for producing various sensors and electrical circuits by partially carbonizing the wood surface with a laser cutting machine. Similar to wiring on a conventional printed circuit board (PCB), the carbonized part functions as a conductive electrical path. Several methods for creating small-scale graphene by using a raster-scanning laser beam have been proposed; however, raster-scanning requires a substantial amount of time to create a large circuit using carbon. This paper extends the method with a defocused vector-scanning CW laser beam and reduces the time and cost required for fabrication. The proposed method uses an affordable CW laser cutter to fabricate an electrical circuit including touch sensors, damage sensors, and load sensors on wood boards. The circuit can be easily connected to a common one-board microcontroller using metal screws and nails typically used in DIY woodworking.

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**.

KEYWORDS

Laser Beam Machining; Digital Fabrication.

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1 INTRODUCTION

Wood has been used to produce various everyday touchable objects, such as furniture and signboards. To create such objects, the use of laser cutters has become popular among professionals and DIY enthusiasts. A laser cutter uses a laser beam to process wood, but no other processing methods except cutting and engraving have been widely explored. We propose a method and workflow for creating various sensors and electrical circuits directly on wood surfaces by partially carbonizing the wood with a CW laser cutting machine. Similar to a conventional printed circuit board (PCB), the carbonized part functions as a conductive electrical path. Various methods for creating sensors on a wood surface by applying another conductive material onto the surface have been proposed [2, 4]. However, they cover the wood surface with an inorganic material, which can adversely affect the texture of the wood. Our method forms conductive carbon paths on the wood surface and uses them as wiring while maintaining the warmth of the wood.

Several methods for creating small-scale graphene by using a raster-scanning laser beam have been proposed [1, 3]. One of these uses a raster-scanning femtosecond (fs) laser and creates electronic circuits and sensors, which is not suitable for personal fabrication than a constant-wave (CW) laser. Moreover, raster-scanning requires a substantial amount of time to create a large-sized circuit. We extend these method with a vector-scanning CW laser beam. Our method applies a defocused CW laser beam repeatedly (8 to 15 times) to create conductive electrical paths and improves the time required for fabrication. Besides electronic circuits, we implemented various types of sensors including touch sensors, damage sensors, and load sensors. These sensor circuits can be easily connected to a standard one-board microcontroller using metal screws and nails that are commonly used in DIY woodworking. By using our technique, we can integrate sensors and wiring patterns, which are essential for the construction of interactive devices, into wooden objects naturally while preserving the warmth of wood.

2 FABRICATION METHOD

Here, we describe the workflow of our fabrication method. We use VD7050-60W (COMMAX Co., Ltd.) laser cutter and set the power to 30~50 % (=18~30 W) and the speed to 25~30 % (=381~457 mm/s).

2.1 Step 1: Digital design

The user starts by designing the desired circuit using a common 2D graphics editor or CAD. Figure 1 (a) shows a design example of a wall board that contains several touch switches and a slider. Since the proposed method uses a vector-scanning laser beam, all circuit paths are composed of lines. Larger contact points such as touch switches or connectors to a conventional PCB are prepared using comb-shaped lines. The optimal spacing of the comb-shaped carbon path depends on the distance at which the cutting table is

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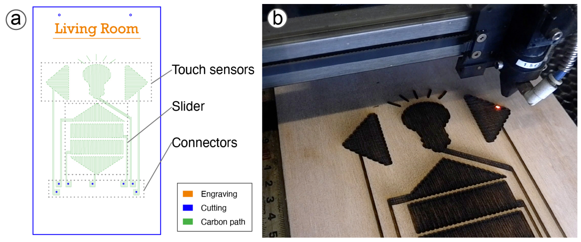

Figure 1: (a) A design example of touch switches and a slider on a wall board. (b) A defocused laser beam generates the carbon paths to create the circuit.

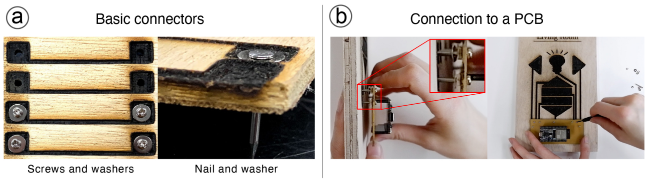

Figure 2: (a) Holes that were drilled by standard laser cutting and connection using screws and washers. Nails and washers can also be used. (b) The connection of a PCB with a microcontroller to a carbon path.

lowered for defocusing, which is 1 mm when the distance is 5 mm below the focal point and 1.25 mm when it is 6 mm below.

2.2 Step 2: Carbonization using a laser

Once the user is satisfied with the design, it is exported to a laser cutter. Conventional laser engraving using a focused raster-scanning beam generates gaps between scan lines that impair the conductivity of the carbon. In contrast, using standard laser cutting with a focused vector-scanning beam, the wood is burned and cut entirely and does not generate a sufficient amount of carbon for use as circuit wiring. To produce a sufficient amount of carbon, moderate heat must be applied repeatedly. To provide sufficient heat, we use a defocusing technique that is similar to that used in a previous study [1] , namely, we move the cutting table down from the focal point (see Figure 1 (b)). We used lauan plywood as the wood to generate the carbon path and identified the most suitable distance as 5~6 mm below the focal point. We also set the power parameter lower and the speed parameter higher than those that were used for standard cutting, and we repeatedly run the laser back and forth over the region instead. This generates a sufficient amount of carbon with high electric conductivity. In our setting, 8~15 times is suitable for the number of repeated laser runs.

2.3 Step 3: Connecting parts

In the final step, we connect electric parts or PCBs to the carbon circuit using common screws and nails. A standard laser cutting mode or a drilling machine can be used to produce a hole in the center of the terminal part of the carbon path, through which a screw or nail is inserted. To increase the area of connection between the carbon area and the screw, washers and nuts are attached to the screw (see Figure 2). In the current setup, we use mainly M2 screws and nuts, along with washers with a diameter of 6 mm.

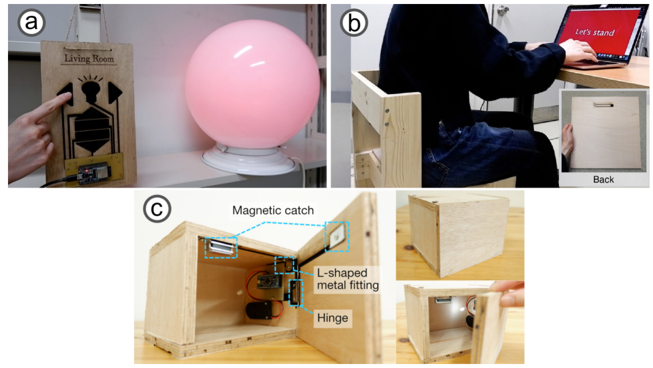

Figure 3: (a) A light control board with touch switches. (b) Interactive chair that detects prolonged sitting. (c) A wooden storage box with a door-sensor light.

3 APPLICATIONS

The proposed method can realize touch sensing via the same mechanism as a conventional capacitive touch sensor. Figure 3 (a) shows a wall board for controlling a room light (whole board size: 25.5 cm × 15.5 cm). Using this board, a user can turn an RGB lamp on/off with a bulb-shaped touch switch, change its color with an arrow-shaped touch switch, and control its brightness with an up-and-down slider. We used the Capacitive Sensing Library of Arduino for the prototype implementation.

Our method can directly embed a load sensor on the wood surface. Figure 3 (b) shows an interactive chair embedded with the carbon path on the seat surface that prevents prolonged and static sitting that has various negative health effects. When a user sits on this chair, the seat is distorted, and the resistance of the carbon path increases. By reading the change in resistance value, it is possible to detect whether the user is sitting or not. It promotes posture change (e.g., standing or half-sitting posture) by notifying the user via an application on a laptop PC when it detects prolonged sitting.

A variety of metal woodworking components commonly used in DIY projects, such as screws, nails, hinges, and catches, can be used as connectors for carbon paths. We implemented a wooden storage box using a magnetic catch, a hinge, and L-shaped metal fittings as connectors (Figure 3 (c)). These three components are attached to the joints in the box. Carbon paths on different board surfaces connect through these components to create a closed circuit. This eliminates cumbersome wiring cables inside the box. When the user opens this box, the magnetic catches are separated from each other, and they are electrically disconnected. We implemented an application that automatically turns on a LED installed in the box when the door is opened by detecting this electrical disconnection.

4 CONCLUSION AND FUTURE WORK

We proposed a method for fabricating circuits with carbon on wood surfaces using a defocused vector-scanning CW laser beam, which is applicable to DIY woodworking. Our future work is to develop a software design tool that supports the creation of carbon paths. Moreover, we will make our method accessible to future researchers by providing design guidelines based on exploring the applicability of other woods, possible treatments for wood such as fire retardants, and investigating further optimal values for laser parameters.

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