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# Computer based pedestrian landscape design using decision tree templates

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**Abstract**

Machine Learning algorithms can act as a valuable analytical tool in design research. In this paper, we demonstrate the application of a decision tree learning algorithm for designing pedestrian landscapes that encourage walking for health. The domain knowledge was captured using intercept surveys that queried responses to cognitive, physical and social attributes that influence pedestrian spatial analysis. Decision trees extracted from the knowledge base were used in the design of pedestrian landscapes, which were tested in a transportation simulator. The observed match between the change in the participants' response to manipulation of physical variables in the simulated world with those predicted by the decision rules indicate the appropriateness of applying decision tree rules as guidelines during the process of pedestrian landscape design and research.
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## 1. Introduction

Learning and design are cognitive processes fundamental to problem solving. Learning is the process of adaptation based on the past and current events, which improves the performance on a specific task. Design on the other hand is the process of applying the learned knowledge to seek solutions that satisfy current requirements and meet predicted future needs. This complementing aspect of learning and design raises a fundamental question. Can the complexity of the design process and the outcome be facilitated with inferences learned from related experience? In other words, how can we improve design learning and prediction using learning algorithms capable of inductively modeling human experience? This is the research question that is being investigated in this paper.

In the context of design, machine learning has been primarily used to extract symbolic knowledge from previous design data using inductive learning approaches [1], recall and reuse of specific previous design experience through case-based reasoning [2], and addressing combinatorial optimization problems in design with genetic algorithms [3]. A range of design problems from simple discrimination of feasible designs from infeasible ones [4] to complex tasks like optimizing architectural floor plans [3], completing partial room designs [5], and generating bridge designs [6,7] have already been investigated using these approaches. Readers are referred to [8 and references therein] for a thorough review of the applications of machine learning methods in design.

In this paper, we apply learning to guide generation of site-specific use-specific pedestrian landscape design. To understand how this might be done, let us consider the example of designing pedestrian landscapes based on the motive for taking the walk: commuting or health purposes. Depending on their motive, people may evaluate the environment using different set of features and decision rules. In our case study in Texas, a person walking for health may choose a route because of the presence of water features like fountain, lake, pond etc. in the vicinity of the path or by the amount of trees along the path, and may use the presence of these features to determine whether the path is suitable. A commuter on the other hand might use features like the weather condition, the traffic and the width of the walk for his evaluation of the quality of the walking route. A possible role for machine learning becomes extraction of symbolic structures (decision trees in this case) from a grass roots knowledge base of landscape evaluations made by the people walking for these two distinct walking purposes. The extracted rules can then be formulated as use-specific design principles for recovering/designing better pedestrian

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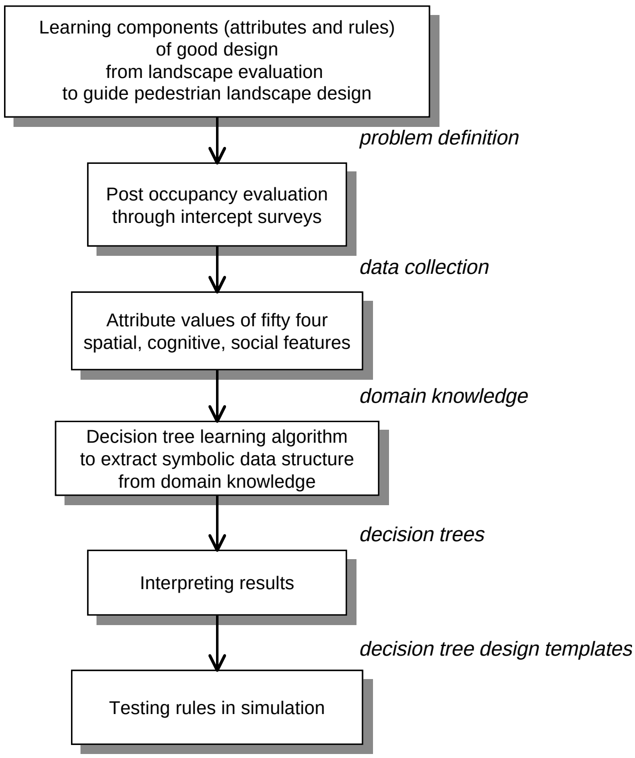


Fig. 1. Process flowchart indicating various phases involved in applying learning to guide pedestrian landscape design.

landscapes that are intended to encourage walking for both commuters as well as for people walking for health.

From the above example, we can identify the following six steps for applying machine learning (ML) techniques in design [1]: (i) formulation of the learning problem in a particular design context, (ii) preparing the inputs, (iii) developing a representation for the input information, (iv) selecting a learning algorithm, (v) selecting operational parameters, and, (vi) analyzing results. Fig. 1 shows a flowchart of this process with an additional simulation testing stage used in this study.

## 2. Pedestrian landscape knowledge base

The pedestrian landscape knowledge base was set up by disaggregating and evaluating the parts and synthesis of common roadside pedestrian environments. The underlying assumption is that the pedestrian environment can be considered as a combination of several attributes or features that represent some intrinsic property of the environment. In theory, manipulation of the attributes will affect human behavior and perception of the space. Researchers have demonstrated that certain landscape dimensions can be used successfully to prepare an evaluation, and measurement of the aesthetic impact [9]. The use of physical environmental attributes for predicting public perceptions has already been demonstrated [10]. People's perception and response to common elements captures the necessary information about the environment [11]. A landmark study in the field of urban design of the physical attributes and dimensions of pedestrian intensive environments and the attributes of great streets are provided in Ref. [12]. A detailed discussion of the pedestrian environmental attributes consideration is presented in Ref. [13].

We extracted a list of 50 cognitive, physical and social attributes related to walking environments from literature review of health, transportation, engineering and planning domains to generate a grass roots survey for on-site data collection. A target attribute that captured the *overall evaluation* of the landscape as either 'good for walking' or 'not good for walking' was included in the survey to identify the predisposition of the person being interviewed for the particular walking site.

Table 1 shows the complete list of the attributes that were used in this study. Fifty-four intercept surveys conducted at six different locations in College Station, Texas queried responses to the identified attributes and captured the grass roots domain knowledge. Each attribute was measured using scales of specific choices, although margin notes and general comments were welcomed. The data from the surveys were arranged in the UCI machine learning repository format to input the domain knowledge to the learning algorithm.

## 3. Decision tree learning

The prominent machine learning algorithms can be roughly categorized as instance-based learners like nearest neighbors, symbolic learners like ID3 decision trees, statistical learners like naive Bayes classifiers, connectionist approaches like back-propagation network, or ensemble learning that combines many of these strategies. A study on the role of machine learning for well defined design problems and their limitations when applied to real world tasks has been discussed in Ref. [1].

The learning model required for our task must fulfill the following requirements: (i) must be easy to understand as it is a tool for non-AI researchers, (ii) a symbolic model, as a quantitative assessment methods for measuring scenic impacts of landscapes is complex [9], (iii) non-parametric and deterministic model (iv) must have a feature selection scheme to identify the most important features and arrange them in the order of importance. This final requirement is important because all possible categories of features were added for evaluating the landscape, therefore, the learner must not be a passive component, i.e. must not just use all the information provided to come up with the hypothesis model but select information for developing a consistent hypothesis. The ID3 decision tree was selected for performing this task as it satisfies these primary requirements.

### *3.1. PED-Learner*

The decision tree learning algorithm performs inductive inference and produces a set of if-then decision-making rules [14]. The ID3 decision tree algorithm [15] builds a bottom-up hierarchical model of the concept with the most relevant feature as the root and less relevant features at the upper levels (near the leaves) of the decision tree. Here, each branch of the tree corresponds to one decision-making rule. ID3 tries to develop hypotheses that consistently explain the training examples.

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