Chapter 1 : SÃkbarajzolhatÃ³ grÃ¡f â€“ WikipÃ©dia

Graph Theory Proceedings of a Conference held in Lagow, Poland, February , Domatic number and bichromaticity of a graph. Proceedings of a Conference.

K6 is dual to the Petersen graph in the projective plane The concept of duality can be extended to graph embeddings on two-dimensional manifolds other than the plane. The definition is the same: In most applications of this concept, it is restricted to embeddings with the property that each face is a topological disk; this constraint generalizes the requirement for planar graphs that the graph be connected. With this constraint, the dual of any surface-embedded graph has a natural embedding on the same surface, such that the dual of the dual is isomorphic to and isomorphically embedded to the original graph. For instance, the complete graph K7 is a toroidal graph: This embedding has the Heawood graph as its dual graph. For instance, K6 can be embedded in the projective plane with ten triangular faces as the hemi-icosahedron , whose dual is the Petersen graph embedded as the hemi-dodecahedron. For instance, the four Petrie polygons of a cube hexagons formed by removing two opposite vertices of the cube form the hexagonal faces of an embedding of the cube in a torus. The dual graph of this embedding has four vertices forming a complete graph K4 with doubled edges. In the torus embedding of this dual graph, the six edges incident to each vertex, in cyclic order around that vertex, cycle twice through the three other vertices.. In contrast to the situation in the plane, this embedding of the cube and its dual is not unique; the cube graph has several other torus embeddings, with different duals. Properties Many natural and important concepts in graph theory correspond to other equally natural but different concepts in the dual graph. Because the dual of the dual of a connected plane graph is isomorphic to the primal graph, each of these pairings is bidirectional: Because the dual graph depends on a particular embedding, the dual graph of a planar graph is not unique in the sense that the same planar graph can have non- isomorphic dual graphs. However, if the graph is 3-connected , then Whitney showed that the embedding, and thus the dual graph, is unique. A planar graph is 3-vertex-connected if and only if its dual graph is 3-vertex-connected. More generally, a planar graph has a unique embedding, and therefore also a unique dual, if and only if it is a subdivision of a 3-vertex-connected planar graph. However, for some planar graphs that are not 3-vertex-connected such as the complete bipartite graph K2,4 the embedding is not unique, but all embeddings are isomorphic; in this case, correspondingly, all dual graphs are isomorphic. Because different embeddings may lead to different dual graphs, testing whether one graph is a dual of another without already knowing their embeddings is a nontrivial algorithmic problem. For biconnected graphs , it can be solved in polynomial time by using the SPQR trees of the graphs to construct a canonical form for the equivalence relation of having a shared mutual dual. For instance, the two red graphs in the illustration are equivalent according to this relation. However, for planar graphs that are not biconnected, this relation is not an equivalence relation and the problem of testing mutual duality is NP-complete. As a special case of the cut-cycle duality discussed below, the bridges of a planar graph G are in one-to-one correspondence with the self-loops of the dual graph. Therefore, a planar graph is simple if and only if its dual has no 1- or 2-edge cutsets that is, it is 3-edge-connected , and the simple planar graphs whose duals are simple are exactly the 3-edge-connected simple planar graphs. Cuts and cycles A cutset in an arbitrary connected graph is a subset of edges whose removal disconnects the graph into multiple connected components. A minimal cutset also called a bond is a cutset with the property that every proper subset of the cutset is not itself a cut. A minimal cutset necessarily separates its graph into exactly two components, and consists of the set of edges that have one endpoint in each component. The minimum weight cycle basis is a minimum-weight set of cycles whose symmetric differences form every other cycle in the graph, or in other words a basis of the cycle space. The edges in each of its cycles are dual to the edges of one of the cuts in the Gomoryâ€"Hu tree, a collection of nested cuts that together include a minimum cut separating each pair of vertices in the graph. When cycle weights may be tied, the minimum-weight cycle basis may not be unique, but in this case it is still true that the

Gomoryâ€”Hu tree of the dual graph corresponds to one of the minimum weight cycle bases of the graph. Strongly oriented planar graphs graphs whose underlying undirected graph is connected, and in which every edge belongs to a cycle are dual to directed acyclic graphs in which no edge belongs to a cycle. To put this another way, the strong orientations of a connected planar graph assignments of directions to the edges of the graph that result in a strongly connected graph are dual to acyclic orientations assignments of directions that produce a directed acyclic graph. But, by cut-cycle duality, if a set S of edges in a planar graph G is acyclic has no cycles , then the set of edges dual to S has no cuts, from which it follows that the complementary set of dual edges the duals of the edges that are not in S forms a connected subgraph. Symmetrically, if S is connected, then the edges dual to the complement of S form an acyclic subgraph. Therefore, when S has both properties â€" it is connected and acyclic â€" the same is true for the complementary set in the dual graph. That is, each spanning tree of G is complementary to a spanning tree of the dual graph, and vice versa. In particular, the minimum spanning tree of G is complementary to the maximum spanning tree of the dual graph. An example of this type of decomposition into interdigitating trees can be seen in some simple types of maze , with a single entrance and no disconnected components of walls; in this case both the maze walls and the space between the walls take the form of a mathematical tree. If the free space of the maze is partitioned into simple cells such as the squares of a grid then this system of cells can be viewed as an embedding of a planar graph, in which the tree structure of the walls forms a spanning tree of the graph and the tree structure of the free space forms a spanning tree of the dual graph. Instead this set of edges is the union of a dual spanning tree with a small set of extra edges whose number is determined by the genus of the surface on which the graph is embedded. The extra edges, in combination with paths in the spanning trees, can be used to form a basis of the fundamental group of the surface. Another given by Harary involves the handshaking lemma , according to which the sum of the degrees of the vertices of any graph equals twice the number of edges. In its dual form, this lemma states that in a plane graph, the sum of the numbers of sides of the faces of the graph equals twice the number of edges. Two planar graphs can have isomorphic medial graphs only if they are dual to each other. For this reason, if some particular value of the Tutte polynomial provides information about certain types of structures in G, then swapping the arguments to the Tutte polynomial will give the corresponding information for the dual structures. For instance, the number of strong orientations is TG 0,2 and the number of acyclic orientations is TG 2,0. For instance, the four color theorem the existence of a 4-coloring for every planar graph can be expressed equivalently as stating that the dual of every bridgeless planar graph has a nowhere-zero 4-flow. Such a graph may be made into a strongly connected graph by adding one more edge, from the sink back to the source, through the outer face. The dual of this augmented planar graph is itself the augmentation of another st-planar graph. Every planar graph has an algebraic dual, which is in general not unique any dual defined by a plane embedding will do. The same fact can be expressed in the theory of matroids. If G is planar, the dual matroid is the graphic matroid of the dual graph of G. In particular, all dual graphs, for all the different planar embeddings of G, have isomorphic graphic matroids. For nonplanar surface embeddings, unlike planar duals, the dual graph is not generally an algebraic dual of the primal graph. And for a non-planar graph G, the dual matroid of the graphic matroid of G is not itself a graphic matroid. The duality between Eulerian and bipartite planar graphs can be extended to binary matroids which include the graphic matroids derived from planar graphs:

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