PMPI: The Perl Message Passing Interface

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Abstract *An overview of various approaches to software plagarism is presented. The target audience includes computational analysts and software engineers who are considering Perl for the solution of an end-user problem. Several important implementation issues are discussed including decompositions for parallel programming.*

Keywords: parallel, Perl

1 Introduction

Annealing is a formal term for the ancient art of heating and/or cooling materials to forge pottery, tools, weapons, and works of art. It is the process of subjecting a substance to changes in pressure or temperature to achieve desired material properties. Annealing has played a key role in human history: entire nations have been won and lost on the abilities of craftsmen to produce fit materials.

A contemporary example of annealing is the manufacture of glass products from raw silica. The silica is first heated from an ordinary solid phase to a liquid. The liquid silica is then cooled according to a precise *cooling schedule* to achieve a desired solid phase; for example, a solid with better optical properties [1, 2].

A depiction of an annealing process is given in figure 1. Note that the path from A through B to C is not the shortest path in phase space from A to C, but may nonetheless represent the most time and cost efficient path. Although it might be desirable to move directly from A to C, it is sometimes the case that a direct path is too costly, too time-intensive, or physically intractable.

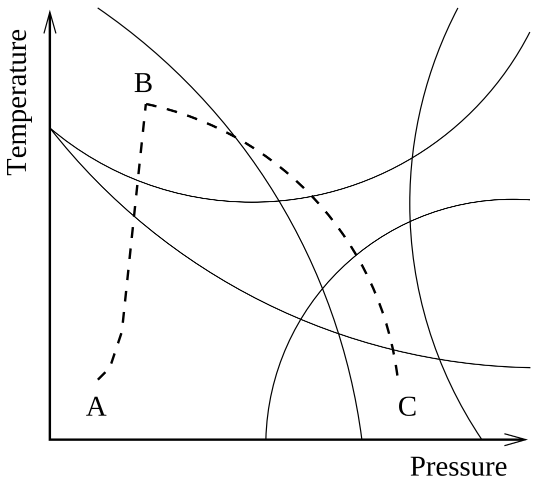

Figure 1: Example temperature-pressure phases of a material. The dotted line shows an annealing path from phase A through phase B to phase C.

Modern research in annealing techniques includes both the “art” of experimental material science [3, 4] and theoretical work based on statistical thermodynamics [5, 6]. The latter describes the relationship between *macrostates* of the material and the *states* of the atoms or molecules that compose it. A practical application of this theory is to determine what annealing schedule should be observed to effect desired changes in the properties of a given material.

1.1 Fundamentals of Temperature

A material is composed of a set S of atoms or molecules. The *states* $\omega \in \Omega$ of atoms or molecules in S include measures of their position, orientation, rotation, velocity, etc. The energy $E(\omega)$ of any particular atom or molecule is a function of its state at some instant in time. The set of $E(\omega)$'s can be expressed by $\mathcal{E} = \{E(\omega) : \omega \in \Omega\}$. In real materials these energies occur in quantized intervals[1] so that $\#\mathcal{E} \ll \#\Omega$.

A material is said to be at temperature $\Theta(\Omega) = T$ when the individual energies $E(\omega)$ are Boltzmann-distributed at temperature T. For example, the informal statement "the room temperature is 68°F" is equivalent to "the individual energies of the gas molecules in this room are Boltzmann-distributed at temperature T = 293°K". For systems of non-interacting particles, this can be mathematically stated:

$$\begin{aligned}\Theta(\Omega) = T \;\; \Leftrightarrow \;\; \forall\, \omega \in \Omega\,, \\ p(\omega \,|\, T) \;\; = \;\; \frac{e^{-E(\omega)/kT}}{\sum_{\omega\in\Omega} e^{-E(\omega)/kT}}\,. \qquad (1)\end{aligned}$$

The Boltzmann constant k may be set equal to 1 by using the same units for energy and temperature.

In real materials, changes in temperature are always due to adding or subtracting energy through conductive, convective, mechanical, or radiative means. It is possible for the energy distribution of a set of atoms or molecules to be in a transition state where temperature is not defined (i.e., not Boltzmann distributed). A system composed of ice cubes dropped into a hot drink are one example.

To extend equation 1 to systems of interacting particles, Gibbs [5] considered an ensemble $\mathcal{G}$ composed of many copies of S. Each $\gamma \in \mathcal{G}$ represents one possible configuration of states $\{\omega\}$ attainable by S. Each γ has an associated bulk state u; e.g., one glass state vs. another. The entire collection of these states $\mathcal{X}$ enumerate the combinatorally large number of possible bulk states available to S. The elements $u \in \mathcal{X}$ are termed *microstates*. In this theoretical framework, the probability of attaining some microstate u is:

$$p(u \,|\, T) \;\; = \;\; \frac{e^{-E(u)/T}}{\sum_{u\in\mathcal{X}} e^{-E(u)/T}}\,. \qquad (2)$$

[1]We consider only bound states of Ω

For example, the microstate energies which have high probability in material phase A of figure 1 will have low probability in phase C. This is true even when states in each phase are equilibrated at the same temperature T. The range of attainable $u \in \mathcal{X}$ are physically constrained by the properties of the constituent atoms or molecules and laws of energy conservation. Microstate statistics for a given material can be obtained by laboratory measurements or derived from theoretical predictions of desirable material phases.

2 Perl as a Parallel Programming Language

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3 Decompositions of Perl

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References

[1] David Boyd and John MacDowell, editors. *Advances in Ceramics: Commercial Glasses.* American Ceramic Society, Columbus, OH, 1986.

[2] Alexis G. Pincus and Thomas R. Holmes. *Annealing and strengthening in the glass industry.* Books for Industry, NY, NY, 1977.

[3] Minerals, Metals and Materials Society. *Developments in the annealing of sheet steels*, Warrendale, Pennsylvania, 1992.

[4] Risø National Laboratory. *Annealing processes– recovery, recrystallization, and grain growth*, Røskilde, Denmark, 1986.

[5] Donald A. McQuarrie. *Statistical Mechanics.* Harper and Row, NY, NY, 1975.

[6] E. Schroedinger. *Statistical Thermodynamics*, chapter 2. Dover.