Transmission, an indicator of synergy reimplemented

Matthijs den Besten*

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The code below implements Leydesdorff's T (Leydesdorff et al. (2014)) derived from Shannon's H in R (R Core Team (2012)). Leydesdorff's own implementation in another language is available at `http://www.leydesdorff.net/software/th4`.

Transmission (T) or mutual information among components is defined as the sum of each component's entropy (Shannon's H) minus the joint entropy of each pair of components plus the joint entropy of each triplet of components, etcetera.

In order to compute the transmission value of a set of variables we first need to list all combinations of these variables.

```
> list.combinations <- function(variable.names) {
+   require(utils);
+   n <- length(variable.names);
+   return(lapply(1:n, function(m) combn(variable.names, m)));
+ }
```

The joint entropy for combinations of variables is based on the number of observation in each contingency. The function joint entropy extends the function entropy Hausser and Strimmer (2013).

```
> # use default arguments of entropy function
> joint.entropy.vanilla <- function(...) {
+   require(entropy);
+   entropy(summary(factor(paste(list(...))), maxsum=Inf));
+ }
> # separately specify entropy arguments
> joint.entropy <- function(var.list, ...) {
+   require(entropy);
+   if(is.data.frame(var.list)) {
+     counts <- summary(as.factor(apply(apply(var.list, 2, as.character),
+                                       1, paste, collapse="")), maxsum=Inf);
```

*Montpellier Business School,

```
+   } else {
+     counts <- summary(as.factor(var.list), maxsum=Inf)
+   }
+   return(entropy(counts, ...));
+ }
```

The joint entropy is computed for each combination of variables in the set.

```
> apply.combn <- function(input, ...) {
+   return(lapply(list.combinations(names(input)),
+                 function(el) {
+                   apply(el, 2,
+                         function(col) {
+                           joint.entropy(input[,col], ...);
+                         })}));
+ }
```

Transmission is defined as the sum all entropies derived from an odd number of variables minus the sum of all entropies derived from an even number of variables.

```
> transmission <- function(...) {
+   entropies <- apply.combn(...);
+   return(sum(sapply(entropies, sum)*ifelse(1:length(entropies)%%2, 1, -1)));
+ }
```

Leydesdorff measures entropy in bits and presumably uses maximum likelihood.

```
> T.leydesdorff <- function(...) {
+   transmission(unit="log2", method="ML", ...);
+ }
```

References

Hausser, J. and Strimmer, K. (2013). *entropy: Entropy and Mutual Information Estimation*. R package version 1.1.8.

Leydesdorff, L., Park, H. W., and Lengyel, B. (2014). A routine for measuring synergy in university-industry-government relations: Mutual information as a triple-helix and quadruple-helix indicator. *Scientometrics*, 99(1):27–35.

R Core Team (2012). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0.