How unexpected events destroy our timetables

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1. Introduction

The role of unexpected events on daily timetable is investigated by means of computer simulations. We check how frequency f of such surprises influences the realization of daily scheduled tasks. The everyday tasks are divided into two groups. The first group contains tasks which may not be time-shifted (lectures, tutorials, etc.) while more time-flexible events (eating, shopping, book reading, answering e-mail, web browsing, etc.) are collected in the second group of tasks. The fraction of fixed tasks in daily timetable is a model control parameter p. A given fraction $(1-q)$ of egoists tries to avoid unexpected work, trying to pass them to their colleagues. The task passing requires some extra time for both agents involved in the task transfer.

Here we check the influence of

- the density f of unexpected tasks,
- the fraction p of fixed tasks
- and fraction q of altruists

on the system efficiency.

2. Model

The team timetable for N agents and M time units is represented as a boolean matrix $\mathbf{T}_{N\times M}$, where $T_{i,j}=1$ stands for the obligatory task and $T_{i,j}=0$ represents the movable task.

$$\mathbf{T}=\begin{pmatrix}
1&0&0&1&0&0&1&1&0&1&0&1\\
1&0&1&0&1&0&1&0&1&1&1&0\\
0&1&0&0&1&0&0&1&1&0&1&1\\
0&1&0&1&0&0&0&0&1&0&0&1\\
0&0&1&1&1&0&0&1&1&1&1&0\\
1&0&1&0&1&0&0&1&0&0&1&1\\
0&0&1&0&0&0&0&1&0&0&0&0\\
0&0&1&0&0&0&0&0&1&0&1&1\\
0&0&1&0&0&0&0&1&0&0&0&0\\
1&0&0&1&1&0&1&1&0&0&0&0\\
\multicolumn{12}{c}{\dotfill}
\end{pmatrix}$$

The $S_{i,j}=1$ values in boolean matrix $\mathbf{S}_{N\times M}$ contain information about moments (j) of occurring unexpected events and indicate an agent (i) initially responsible for taking care of this event.

$$\mathbf{S}=\begin{pmatrix}
1&1&0&0&1&0&1&0&1&1&0&1\\
0&1&0&1&1&1&1&1&1&0&0&0\\
1&0&1&0&0&1&1&0&1&0&0&0\\
1&0&1&1&0&0&1&0&0&1&1&1\\
0&0&0&0&1&1&0&1&1&1&1&1\\
1&1&1&0&0&1&0&1&0&1&1&0\\
0&1&1&1&0&1&1&0&1&1&0&1\\
0&1&1&1&1&0&0&1&0&1&1&1\\
1&1&1&1&1&0&1&1&1&1&0&0\\
1&0&0&0&0&0&1&1&1&1&1&1\\
\multicolumn{12}{c}{\dotfill}
\end{pmatrix}$$

The boolean vector

$$\mathbf{w}=\begin{pmatrix}1&0&1&1&1&1&0&1&1&0&1&1\end{pmatrix}$$

indicates the agents preferences regarding passing unexpected tasks to somebody else. $w_i=1$ means that i-th agent is an altruist, while $w_i=0$ describes an egoist.

The matrix $\mathbf{S}$ is scanned in type-writer order. Each time element $S_{i,j}=1$ is encountered the value of $D_{i,j}$ is incremented. This corresponds to

- taking care on unexpected event by an altruist ($w_i=1$) and those agent who has easily movable task ($T_{i,j}=0$)
- or passing a task to somebody else for agents with fixed task ($T_{i,j}=1$) and/or for egoists ($w_i=0$).

In the latter case the first occurrence of $T_{m,n}=T_{m,n+1}=0$ is searched in matrix $\mathbf{T}$ for $m\neq i$ and $n\geq j$. Subsequently, elements $D_{m,n}$ and $D_{m,n+1}$ are incremented. Incrementing $D_{m,n}$ corresponds to situation when the task is being received from somebody, while the second incrementation reflects the task realization. An example of $\mathbf{D}$ matrix associated with above presented matrices $\mathbf{T}$ and $\mathbf{S}$ is given below.

$$\mathbf{D}=\begin{pmatrix}
1&2&0&0&1&1&1&0&1&1&0&1\\
0&2&0&2&1&2&1&1&1&0&0&0\\
2&0&2&1&0&2&2&0&1&1&0&0\\
2&0&2&1&0&1&2&0&0&2&1&1\\
0&1&0&0&1&2&1&1&1&1&1&1\\
1&2&1&1&0&2&1&1&1&2&1&0\\
1&2&1&2&1&2&2&0&2&2&0&1\\
1&2&1&2&2&1&1&1&0&2&1&1\\
1&2&1&2&1&1&1&1&2&2&1&1\\
0&1&0&0&0&1&0&0&1&0&1&1\\
\multicolumn{12}{c}{\dotfill}
\end{pmatrix}$$

The sum of matrix $\mathbf{D}$ elements

$$\alpha=\sum_{i=1,j=1}^{N,M} D_{i,j}$$

yields quantitative information on ruined team timetables.

3. Results

In Fig. 1 the fraction α of ruined timetables as a function of the number of unexpected events f is presented. When fixed tasks are absent ($p=0$) this fraction is just equal to frequency of surprises f. With increasing the fraction of fixed tasks $p>0$ the number of additional agents' actions associated with the task passing also increases. The latter leads to avalanches of task passing acts.

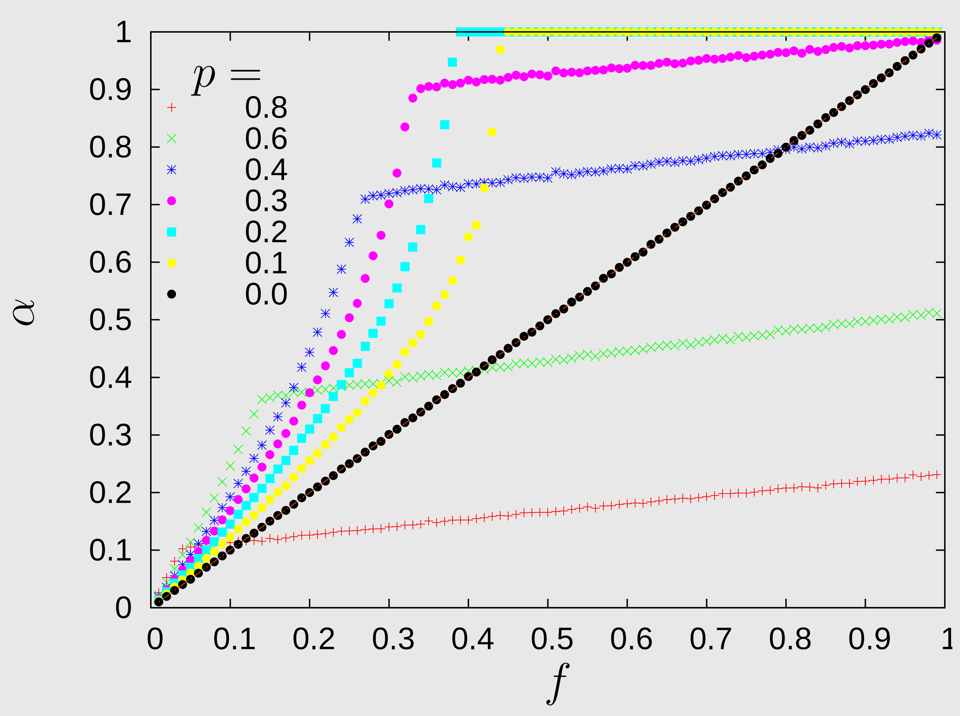

Figure 1: Fraction α of ruined timetables for $q=1$ and various fractions p of fixed tasks in daily timetable. $N=12$, $M=2000$, $N_{\text{run}}=10$.

The similar effect may be observed when fraction $(1-q)$ of egoists increases. In Fig. 2 the influence of parameter q on fraction α of ruined timetables is presented.

For high enough values of the fraction of fixed tasks p the system is not able to serve all unexpected events. In Fig. 3 the fraction β of served events vs. number of unexpected events is presented. Only for small number ($p<0.2$) of fixed tasks in agents' timetables the agents are able to serve all the unexpected events, i.e. $\beta(f)\equiv 1$.

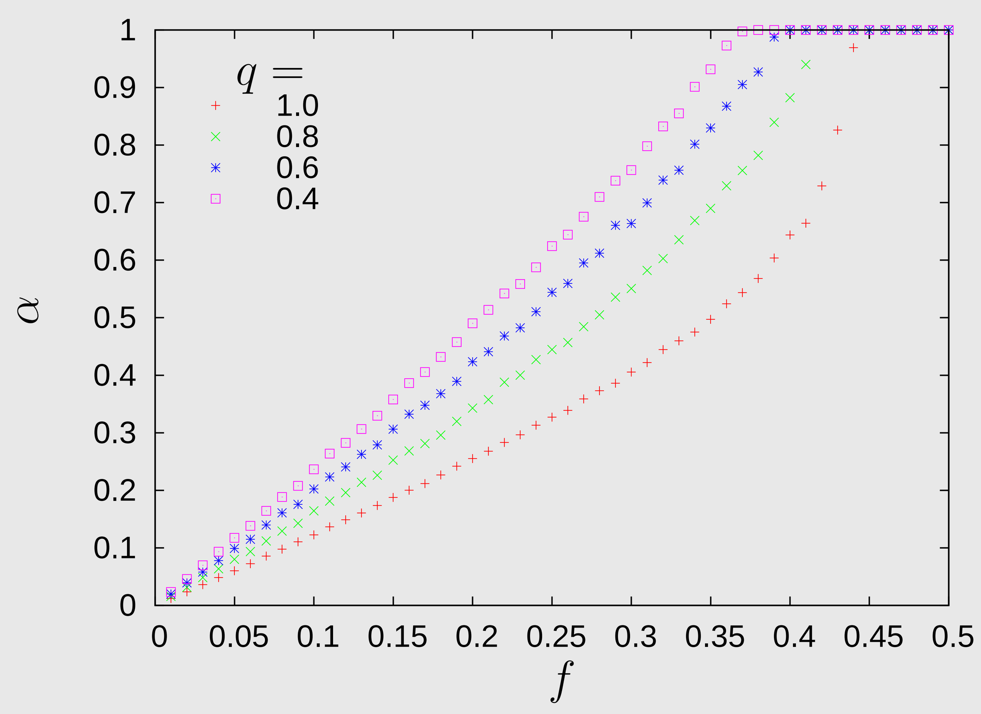

Figure 2: Fraction α of ruined timetables for $p=0.1$ and various fractions q of persons passing their tasks to their colleagues. $N=12$, $M=2000$, $N_{\text{run}}=100$.

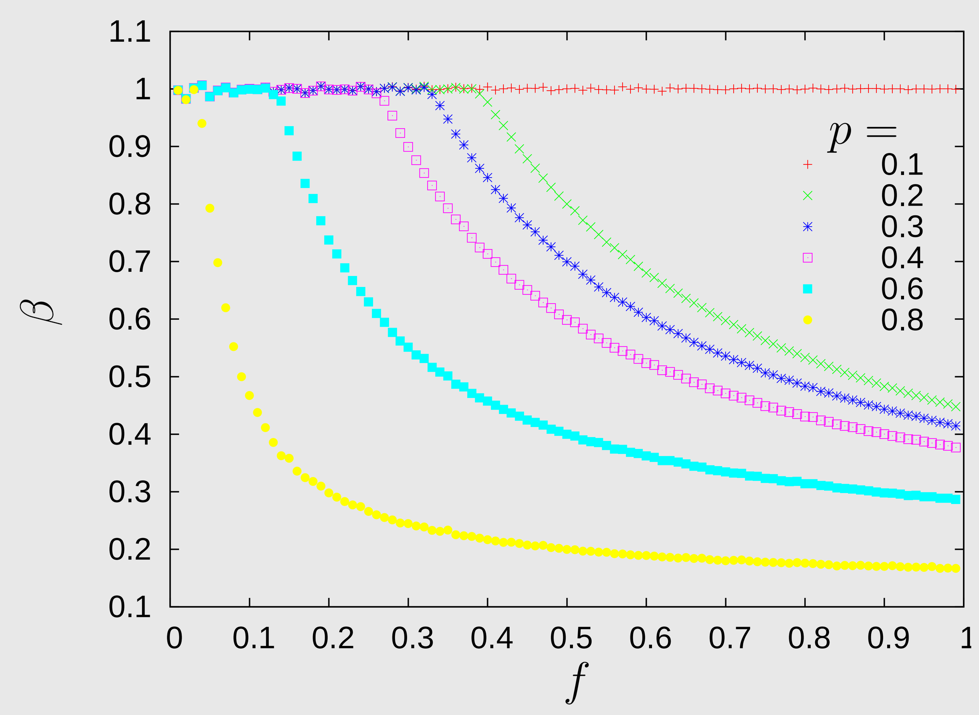

Figure 3: Fraction β of served unexpected events for $q=1$ and various fractions p of fixed tasks in daily timetable. $N=12$, $M=2000$, $N_{\text{run}}=10$.

4. Discussion

As shown in Fig. 2, for $p>0$ there are two different regimes of the fraction of ruined timetables. Up to a given (p-dependent) amount of unexpected tasks, α increases nonlinearly with f. Above some threshold, the increase becomes a linear and less abrupt one. This means that in the second regime it is not possible to find any agent able to receive a task, i.e. anybody who has a free cell now and in the subsequent time moment.

We notice also that, as shown in Fig. 3, the plot related to the largest number of altruists accelerates more quickly near the saturation than other plots. It seems that this acceleration is due to the fact that when f is large enough, even the altruists are forced to pass incoming tasks to other agents. As they avoided this selfish action as long as they could, the process of ruining the timetables is more abrupt, than in other cases.

Summarizing, the consequences of selfish actions combined with the presence of fixed tasks leads to an abrupt destruction of the timetables of all agents. The effect bears a close resemblance to a continuous phase transition, known in statistical physics.

References

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