Digital DNA Molecules

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Abstract:
An approach based on programmable self-assembly of DNA oligonucleotides was used to create digital DNA molecules representing binary datastructures. Utilizing plasmids as a kind of computer memory, the digital molecules could be isolated, amplified and read out using common genetic techniques. Programmability allowed several applications to be realized in vitro such as a fast physical random number generator and digital DNA "barcodes".

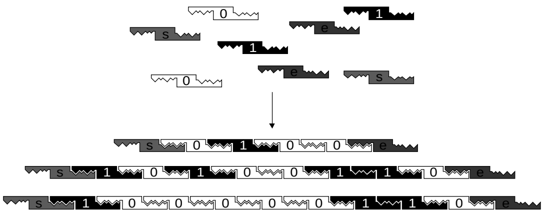


Fig. 1: Generation of random DNA bitchains using the grammar $G_{rand} = (\Sigma, V, R, S)$ with terminal alphabet Σ:= {0, 1, s, e}, set of variables V:={A}, start symbol S and rule set R:={S:=sA, A->0A, A->1A, A->e}.
Output: Binary strings of the form s{0|1}e

Programmable self-assembly

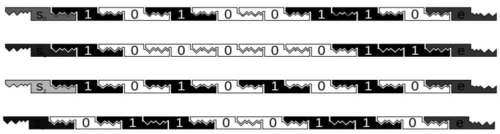


Fig. 2: Generation of 32-bit numbers using the grammar G_{32} with terminal alphabet Σ:= {0, 1, e, s_0, s_1, s_2, s_3}, set of variables V:={S_0, ..., S_8}, start symbol S and rule set R:={S:=S_0, S_0->0S_1, S_0->1S_1, ..., S_7->0S_8, S_7->1S_8, S_8->e}
Output: strings of the form s_0{0|1}e, s_1{0|1}e, s_2{0|1}e, s_3{0|1}e

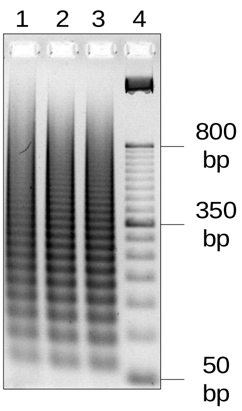


Fig. 3: DNA molecules resulting from self-assembly shown in Fig. 1

Readout: Digital DNA Typing

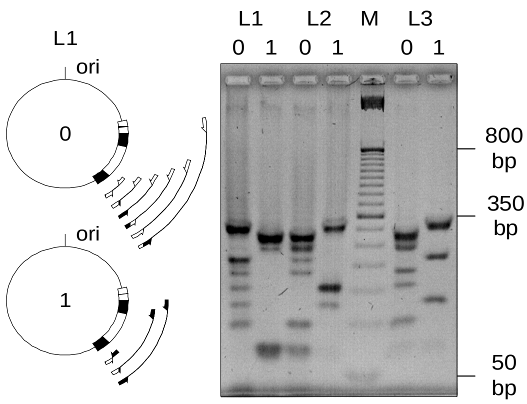
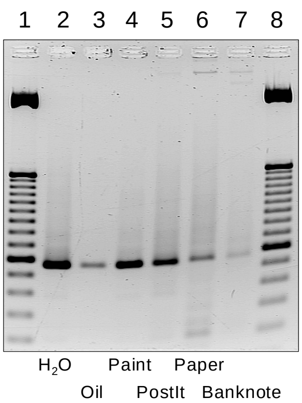


Fig. 4: Readout by PCR results in complementary ladder patterns after gel-electrophoresis. Shown are the numbers L1: $100000110_{bin} = 262_{dec}$
L2: $001100001_{bin} = 97_{dec}$
L3: $101001001_{bin} = 329_{dec}$

Labelling: DNA Barcodes

Fig. 5: Labelling of some materials with digital DNA molecules. DNA molecules could be recovered from the tested materials



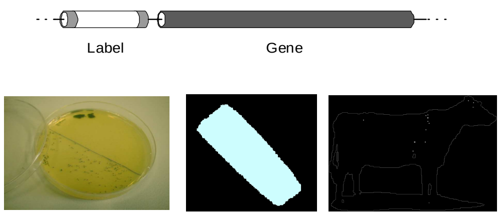


Fig. 6: Labelling of organisms.